Vision Sciences Society

15th Annual Meeting, May 15-20, 2015

TradeWinds Island Resorts, St. Pete Beach, Florida

Abstracts

Contents

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Sessions Overview

Abstract Numbering System

Each abstract is assigned a unique 4 or 6 digit number based on when and where it is to be presented. The format of the abstract numbering is DT.RN (where D is the Day, T is the Time, R is the Room and N is the presentation Number).

First Digit - Day	Second Digit - Time	Third Digit - Room	Fourth-Sixth Digits - Number
2 Saturday	1 Early AM talk session	1 Talk Room 1	1, 2, 3... For talks
3 Sunday	2 Late AM talk session	2 Talk Room 2	001, 002... For posters
4 Monday	3 AM poster session	3 Banyan Breezeway	
5 Tuesday	4 Early PM talk session	4 Pavilion	
6 Wednesday	5 Late PM talk session		
	6 PM poster session		

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

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

Member-Initiated Symposia

Schedule Overview

Friday, May 15, 12:00 - 2:00 pm

S1, Talk Room 1-2: **Attention! Features? Objects? How features, objects, and categories control visual selective attention.**

S2, Pavilion: **Measuring and Interpreting Oscillations in Perception and Behavior**

Friday, May 15, 2:30 - 4:30 pm

S3, Talk Room 1-2: **Neurally informed theories on visual working memory**

S4, Pavilion: **How to break the cortical face perception network**

Friday, May 15, 5:00 - 7:00 pm

S5, Talk Room 1-2: **Linking behavior to different measures of cortical activity**

S6, Pavilion: **How learning changes the brain**

S1 - Attention! Features? Objects? How features, objects, and categories control visual selective attention.

Time/Room: Friday, May 15, 2015, 12:00 - 2:00 pm, Talk Room 1-2

Organizer(s): Rebecca Nako; Birkbeck, University of London

Presenters: Kia Nobre, Stefan Treue, Martin Eimer, Daniel Baldauf, Greg Zelinsky, Johannes Fahrenfort

The cognitive and neural processes of visual selective attention have been investigated intensively for more than a century. Traditionally, most of this research has focused on spatially selective processing in vision, to the extent that "visual attention" and "spatial attention" are sometimes regarded as near synonymous. However, more recent investigations have demonstrated that non-spatial attributes of visual objects play a critical role in the top-down control of visual attention. We now know that feature-based attention, object-based attention, and category-based attention all affect how attention is allocated to specific objects in visual selection tasks. However, the functional and neural basis of these different types of non-spatial visual attention, and the ways in which they interact with each other and with space-based attention are still poorly understood. The aim of this symposium is to provide new and integrated perspectives on feature-, object-, and category-based visual attention. It brings together a group of leading researchers who have all made recent important contributions to these topics, with very different methodological approaches (single-unit electrophysiology, fMRI, EEG, MEG, and computational modelling). The symposium will start with an integrative overview of current views on spatial versus non-spatial attentional control. This is followed by two presentations on the neural basis and time course of feature-based and object-based attention, which address closely related questions with monkey single cell recordings and human electrophysiology. The second part of the symposium will focus on top-down control mechanisms of object-based attention (with fMRI and MEG) and category-based attention (using modelling methods from computer vision to predict attentional performance). The final presentation re-assesses the links between selective attention, feature integration, and object categorization, and will challenge the widely held view that feature integration requires attention. Much recent work in visual attention is characterized by extending its perspective beyond purely space-based models, and this symposium aims to provide a timely state-of-the-art assessment of this "new look" on visual attention. Attention research is conducted with a wide range of different methodological approaches. Our symposium celebrates this methodological diversity, and will demonstrate how these different methods converge and complement each other when they highlight different aspects (such as the time course, the neural implementation, and the functional organization) of visual attention and its top-down control. This symposium brings together the research and perspectives of three highly respected researchers in the field of visual attention (Kia Nobre, Stefan Treue, and Martin Eimer), who have literally written the (Oxford Hand) book on Attention, yet have never attended VSS before, and three researchers whose recent work has had great impact on the field, and who have attracted large audiences at VSS previously, but have not had the opportunity to present in a cohesive symposium with this array of speakers. The methodological breadth of this symposium, and the fact that it will integrate new perspectives and current views on attentional control, makes it ideal for a broad and very large VSS audience, including students, postdocs, and senior scientists with different specialist research interests.

Multiple sources of attentional biases on visual processing

Speaker: Kia Nobre; University of Oxford

Attention refers to the set of mechanisms that tune psychological and neural processing in order to identify and select the relevant events against competing distractions. This type of definition casts attention as function rather than as representation or as state. This presentation will examine the various possible "sources" of biases that can prepare perceptual mechanisms to improve interactions with the environment. Whereas many studies in the literature have probed how biases can facilitate neural processing according to receptive-field properties of neurons, it is clear that it is possible to anticipate stimulus properties that may not be easily mapped onto receptive fields. Space-based, feature-based, object-based, category-based, and temporal attention can all affect visual information processing in systematic and adaptive ways. In addition to such goal-related factors, there may also be other possible potent modulators of ongoing information processing, such as long-term memories and motivational factors associated with anticipated events.

Features and objects in the physiology of attention

Speaker: Stefan Treue; University of Göttingen

Recording from single neurons in the visual cortex of rhesus monkeys trained to perform complex attention tasks has been a highly successful approach to investigate the influence of spatial and feature-based attention on sensory information processing. For object-based attention this has been much more difficult. The presentation will explain this difference and give examples of studies of the neural correlate of object-based attention. Because object-based attention is characterized by the spread of attention across multiple features of a given object the presentation will also address studies of feature-based attention involving more than one feature. The latter will demonstrate that feature-based attentional modulation in extrastriate cortex seems to be restricted to those features for which a given neuron is genuinely, rather than accidentally, tuned. The data show a system of attentional modulation that combines spatial, feature-based and object-based attention and that seems designed to create an integrated saliency map where the perceptual strength of a given stimulus represents the combination of its sensory strength with the behavioral relevance the system attributes to it.

The time course of feature-based and object-based control of visual attention

Speaker: Martin Eimer; Birkbeck, University of London

Many models of attentional control in vision assume that the allocation of attention is initially guided by independent representations of task-relevant visual features, and that the integration of these features into bound objects occurs at a later stage that follows their feature-based selection. This presentation will report results from recent event-related brain potential (ERP) experiments that measured on-line electrophysiological markers of attentional object selection to dissociate feature-based and object-based stages of selective attention in real time. These studies demonstrate the existence of an early stage of attentional object selection that is controlled by local feature-specific signals. During this stage, attention is allocated in parallel and independently to visual objects with target-matching features, irrespective of whether another target-matching object is simultaneously present elsewhere. From around 250 ms after stimulus onset, information is integrated across feature dimensions, and attentional processing becomes object-based. This transition from feature-based to object-based attentional control can be found not only in tasks where target objects are defined by a combination of simple features (such as colour and form), but also when one of the two target attributes is defined at the categorical level (letter versus digit). Overall, the results of these studies demonstrate that feature-based and object-based stages of attentional selectivity in vision can be dissociated in real time.

Top-down biasing signals of non-spatial, object-based attention

Speaker: Daniel Baldauf; Massachusetts Institute of Technology

In order to understand the neural mechanisms that control non-spatial attention, such as feature-based, object-based, or modality-based attention we use signal processing tools in temporally high-resolving MEG signals to identify the inter-areal communication, through which large-scale attentional networks orchestrate the enhanced neural processing of attended non-spatial properties. In particular, we investigate interactions by means of synchronous, coherent oscillations of neuronal activity. Applying those methods allowed us identifying a fronto-temporal network that biases neural processing on a high, object-class level of neuronal representation. In particular, an area in the inferior part of frontal cortex, the inferior-frontal junction (IFJ), seems to be a key source of non-spatial attention signals. For example, when attending to one of two spatially overlapping objects that can not be separated in space, IFJ engages in coherent, high-frequent oscillations with the respective neuronal ensembles in IT cortex that represent the respectively attended object-class. A detailed analysis of the phase relationships in these coupled oscillations reveals a predominant top-down directionality, as IFJ seems to be the driver of those coherent interactions. We propose that the selective synchronization with different object representations in IT cortex allows IFJ to route top-down information about the attended object-class and to flexibly set up perceptual biases. Our results also suggest that attention networks in frontal cortex may be subdivided in dorsal and ventral subnets providing spatial and non-spatial attention biases, respectively.

Combining behavioral and computational tools to study mid-level vision in a complex world

Speaker: Greg Zelinsky; Stony Brook University

As vision science marches steadily into the real world, a gap has opened between theories built on data from simple stimuli and theories needed to explain more naturalistic behaviors. Can “old” theories be modified to remain relevant, or are new theories needed, tailored to these new questions? It will be argued that existing theories are still valuable, but they must be bolstered by new computational tools if they are to bear the weight of real-world contexts. Three lines of research will be discussed that attempts to bridge this theoretical divide. The first is categorical search—the search for a target that can be any member of an object category. Whereas the largely artificial task of searching for a specific target can be modeled using relatively simple appearance-based features, modeling more realistic categorical search tasks will require methods and features adapted from computer vision. Second, we can no longer simply assume to know the objects occupying our visual world—techniques must be developed to segment these objects from complex backgrounds. It will be argued that one key step in this process is the creation of proto-objects, a mid-level visual representation between features and objects. The role of image segmentation techniques in constructing proto-objects will be discussed. Lastly, the real world creates untold opportunities for prediction. Using Kalman filters, it will be shown how motion prediction might explain performance in multiple-object tracking tasks. Rather than tearing down our theoretical houses, we should first consider remodeling them using new computational tools.

Neural markers of perceptual integration without attention

Speaker: Johannes Fahrenfort; Vrije Universiteit, Amsterdam

A number of studies have shown that object detection and object categorisation can occur outside consciousness, and are largely mediated by feedforward connections in the brain. Conscious object perception on the other hand, requires a process of neuronal integration mediated by recurrent connections. The question I will address in this talk, is to what extent this process of integration requires attention. Traditionally, recurrent processing has been associated with top down attention and control. However, going against a long tradition in which attention is thought to cause feature integration, a number of studies suggest that feature integration also takes place without attention. This would imply that neuronal integration does not require attentional control. In a recent EEG experiment, we tested whether neural markers of feature integration occur without attention. Employing a 2 by 2 factorial design of masking and the attentional blink, we show that behaviourally, both masking and attention affect the degree to which subjects are able to report on integrated percepts (i.e. illusory surface perception in a Kanizsa figure). However, when using a multivariate classifier on the EEG, one can decode the presence of integrated percepts equally well for blinked and non-blinked trials, whereas masking selectively abolishes the ability to decode integrated percepts (but not features). This study uncovers a fundamental difference in the way attention and masking impact cortical processing. Together, these data suggest that feature integration does not require attention, whereas it is abolished by masking.

S2 - Measuring and Interpreting Oscillations in Perception and Behavior

Time/Room: Friday, May 15, 2015, 12:00 - 2:00 pm, Pavilion

Organizer(s): Jan Drewes and David Melcher; Center for Mind/Brain Sciences (CIMeC), University of Trento, Rovereto, Italy

Presenters: Huan Luo, Ian C. Fiebelkorn, Ayelet N. Landau, Jan Drewes, Rufin VanRullen

The majority of studies in vision science treat variability across trials as noise. However, there is a long-standing idea that oscillations in attention and other brain mechanisms lead to regular oscillations in perceptual and behavioral performance (Walsh, 1952; Callaway & Yeager, 1960; Harter, 1967). The idea of oscillations in perception and behavior has recently received renewed interest (Busch et al, 2009; Drewes & VanRullen, 2009; Van Rullen et al, 2011; Landau & Fries, 2012; Fiebelkorn et al, 2013; Song et al, 2014). In light of this increased interest in the study of oscillations and their manifestations in perception and behavior, we wish to bring together a diverse group of researchers to present novel results and methods aimed at the measurement, understanding and interpretation of these oscillatory effects.

Behavioral oscillations: hidden temporal dynamics in visual attention

Speaker: Huan Luo; Institute of Biophysics, Chinese Academy of Sciences

Neuronal oscillations are widely known to contribute to various aspects of cognition, but most associated evidence is based upon post-hoc relationships between recorded brain dynamics and behavior. It remains largely unknown whether brain oscillations causally mediate behavior and can be directly manifested in behavioral performances. Interestingly, several recent psychophysical studies, by employing a time-resolved measurement, revealed rhythmic fluctuations (Landau & Fries, 2012; Fiebelkorn et al., 2013) and even neurophysiologically relevant spectrotemporal dynamics (Song et al., 2014) directly in behavior. In this talk, I will present our recent studies in which we examined fine temporal dynamics of behavioral performances in various classical visual paradigms. Together, the results suggest that behavioral data, instead of being sluggish and unable to reflect underlying neuronal dynamics, actually contain rich temporal structures (i.e., ‘behavioral oscillations’, Song et al., 2014), in a somewhat neurophysiology relevant manner. I propose that these new ‘behavioral oscillations’ findings, in combination with well-established neuronal oscillation work, speak to an oscillation-based temporal organization mechanism in visual attention.

Rhythmic sampling at both cued and uncued locations

Speaker: Ian C. Fiebelkorn; Neurophysiology of Attention and Perception Laboratory, Princeton University

The brain directs its limited processing resources through various selection mechanisms, broadly referred to as attention. Spatial selection, one such mechanism, is sometimes likened to a spotlight, continuously highlighting regions of the visual scene for preferential processing. Evidence suggests that the operation of this spotlight is linked, at least in part, to neural oscillations. In fact, rhythmic fluctuations attributable to spatial selection have been directly observed in behavior. When spatial selection is fixed at a single target location, visual-target detection oscillates at 8 Hz. When spatial selection is split between two equally likely target locations, visual-target detection at each location instead oscillates at 4 Hz, with peaks in detection alternating between the two locations. Landau and Fries (2012) proposed that these oscillatory patterns at 8 and 4 Hz are attributable to the same neural source, either sampling a single location or alternately sampling two locations. We recently observed both patterns during an experimental task that utilized three potential target locations. A cue (80% valid) indicated the location where a visual target was most likely to occur. As predicted, visual-target detection at the cued location oscillated at 8 Hz, suggesting that participants successfully deployed spatial selection. Yet visual-target detection at each of two uncued locations oscillated at 4 Hz, with peaks in detection alternating between the uncued locations. I will argue that these behavioral data, rather than reflecting a single neural source, support the existence of two attentional spotlights that concurrently sample the visual scene: one fixed spotlight that samples the most relevant location, and a second moving spotlight that rhythmically monitors less relevant locations. We have now replicated these behavioral findings in two monkeys, demonstrating that rhythmic sampling is consistent across primate species. We will next use electrophysiological recordings to investigate the neural sources underlying these behavioral oscillations.

Distributed attention is implemented through theta-rhythmic gamma modulation

Speaker: Ayelet N. Landau; Ernst Strüngmann Institute (ESI) for Neuroscience in Cooperation with Max Planck Society and Hebrew University, Jerusalem

When subjects monitor a single spatial location, target detection depends on the pre-target phase of an ~8 Hz brain rhythm. When multiple locations are monitored, performance decrements suggest a division of the 8 Hz rhythm over the number of locations. This suggests that different locations are sequentially sampled. Indeed, when subjects monitor two locations, performance benefits alternate at a 4 Hz rhythm. These performance alternations followed a reset of attention to one location. Although resets are common and important events for attention, it is unknown, whether in the absence of resets, ongoing attention operates rhythmically. Here, we examined whether spatially specific attentional sampling can be revealed by ongoing pre-target brain rhythms. Specifically, visually induced gamma-band activity plays a role in spatial attention and therefore, we hypothesized that performance can be predicted by a theta-rhythmic gamma modulation. Brain rhythms were assessed with MEG, while subjects monitored bilateral grating stimuli for a unilateral target. The corresponding contralateral gamma-band responses were subtracted from each other to isolate spatially-selective, target-related fluctuations. The resulting lateralized-gamma activity (LGA) showed opposite 4 Hz phases prior to detected versus missed targets. The 4 Hz phase of pre-target LGA accounted for a 14% modulation in performance. These findings suggest that spatial attention is an ongoing theta-rhythmic sampling process, with each sampling cycle implemented through gamma-band synchrony. This extends previous findings by demonstrating that in the case of distributed attention, gamma-band synchrony is shaped by the slower sampling rhythm that governs performance benefits.

Oscillations in behavioral performance for rapidly presented natural scenes

Speaker: Jan Drewes; Center for Mind/Brain Sciences (CIMeC), University of Trento, Rovereto, Italy

Authors: Weina Zhu[1], David Melcher[2]; [1]Kunming Institute of Zoology, Chinese Academy of Sciences, Kunming, China, [2]Center for Mind/Brain Sciences (CIMeC), University of Trento, Rovereto, Italy

Humans are capable of rapidly extracting object and scene category information from visual scenes, raising the question of how the visual system achieves this high speed performance. Recently, several studies have demonstrated oscillatory effects in the behavioral outcome of low-level visual tasks, hinting at a possibly cyclic nature of visual processing. Here we present evidence that these oscillatory effects may also be manifest in a more complex target discrimination task using natural scenes as stimuli. In our experiment, a stream of neutral images (containing neither vehicles nor animals) was rapidly presented centrally at 20 ms/image. Embedded in this image stream were one or two presentations of a target image randomly selected from two categories (vehicles and animals) and subjects were asked to decide the target image category. On trials with two presentations, the ISI was varied systematically from 0 to 600ms. At a varying time prior to the first target presentation, the screen background was flashed with the intent of creating a phase reset in the visual system. When sorting trials by the temporal distance between flash and first target presentation, a strong oscillation in behavioral performance emerged, peaking at 10Hz, consistent with previous studies showing an oscillation in detection threshold. On trials with two targets, longer ISIs between the led to reduced detection performance, implying a temporal integration window for object category discrimination. However, the 'animal' trials additionally exhibited a significant oscillatory component at around 5Hz. These findings suggest that there are alternating optimal and non-optimal time periods for which stimulus repetition and integration can improve visual recognition, perhaps due to recurrent processing in complex visual scene perception."

Perceptual cycles

Speaker: Rufin VanRullen; Université de Toulouse; UPS; Centre de Recherche Cerveau et Cognition; Toulouse, France and CNRS; CerCo; France

Various pieces of experimental evidence using both psychophysical and physiological (EEG) measurements have lead us (and others) to conclude that at least certain aspects of visual perception and attention are intrinsically rhythmic. For example, in a variety of perceptual and attentional tasks, the trial-by-trial outcome was found to depend on the precise phase of pre-stimulus EEG oscillations in specific frequency bands (between 7 and 15Hz). This suggests that there are "good" and "bad" phases for perception and attention; in other words, perception and attention proceed as a succession of cycles. These cycles are normally invisible, but in specific situations they can be directly experienced as an illusory flicker superimposed on the static scene. The brain oscillations that drive these perceptual cycles are not strictly spontaneous, but can also be modulated by visual stimulation. Therefore, by manipulating the structure of the stimulation sequence (e.g. white noise), it is possible to control the instantaneous phase of the relevant perceptual rhythm, and thereby ensure that a given target will be perceived (if presented at the proper phase) or will go unnoticed (at the opposite phase). Better, by taking into account individual differences in oscillatory responses, we can even tailor specific stimulus sequences with an embedded target that can only be perceived by one observer, but not another – a form of "neuro-encryption".

S3 - Neurally informed theories on visual working memory

Time/Room: Friday, May 15, 2015, 2:30 - 4:30 pm, Talk Room 1-2

Organizer(s): Ilja G. Sligte; University of Amsterdam

Presenters: Christian N.L. Olivers, Mark G. Stokes, Ilja G. Sligte, Fiona McNab, Pieter R. Roelfsema, Thomas B. Christophel

THEORETICAL IMPASSE How much information can people maintain in working memory and how precise is information in working memory represented? These important questions have produced a fierce tug-of-war between camps of scholars trying to explain capacity limits in working memory in terms of slots or resources. However, that academic debate has nothing to do with how the brain enables working memory. This symposium centers on two central questions that are neurally inspired: Are all working memory representations created equally (working memory states), and how does the neural architecture shape working memory content? WORKING MEMORY STATES Visual working memory has a strict capacity limit of 3-4 items. But do all working memory representations have equal status? Some information might be represented vividly in the center of mind (foreground processes), while other information readily available, but more in the back of the mind (background processes) and yet other information needs an effortful redirection of attention before it is available for report (fragile processes). Christian OLIVERS will provide evidence that when one item is held in working memory, it initially guides attention on a visual search task (as foreground process), but it shifts to the background within a few seconds and is then unable to guide attention. Mark STOKES will show that working memory items are initially actively maintained as persistent activity in monkey prefrontal cortex. However, neural activity soon goes back to baseline, but the information is still represented in the background, presumably in newly configured synaptic weights. Ilja SLIGTE will present evidence that fragile items, that they are normally not available for report, are swapped with background information in working memory when attention is redirected during memory retention. WORKING MEMORY CONTENT Fiona MCNAB will show that the fidelity of working memory representations is impaired when visual information is presented too close together. Apparently, the receptive field size of visual neurons plays a crucial role in constraining the quality of working memory. Pieter ROELFSEMA will present monkey V1 data showing that the contents of working memory are actively maintained in different layers of primary visual cortex by means of top-down projections. Importantly, visual masks transiently erase working memory contents in V1, only to resurface again, presumably through top-down reactivation. Thomas CHRISTOPHEL will show that working memory content can be represented at many different levels in the neural hierarchy, depending on the characteristics of the memoranda. However, the lateral prefrontal cortex cares only about cognitive control, not about working memory content. TARGET AUDIENCE The symposium aims to shift the current debate on working memory to the question how the brain structures and organizes working memory content. We believe this symposium will be interested to students, postdocs, and faculty. The contents and methods will be useful to a large VSS audience: anyone studying working memory or attention, and anyone with interests in multivariate pattern analyses and multilayer electrophysiological recordings. The symposium could benefit them by suggesting new theoretical frameworks to think about data, as well as new experimental methods and paradigms.

On the role of working memory in visual attention

Speaker: Christian N.L. Olivers; VU University Amsterdam

Current cognitive and neural models of visual attention emphasize the role of working memory in biasing attention to task-relevant input. According to these models, the mnemonic maintenance of visual representations automatically creates an attentional template that prioritizes corresponding stimuli for selection. However, the past decade has provided evidence that visual working memory per se is not sufficient, nor necessary for guiding attention. I give a brief review of the field and of behavioral evidence from our lab, using paradigms that combine a memory task with a visual search task. This evidence suggests that for working memory representations to bias visual attention they require a special active template (or 'foreground') status - in line with models of working memory that assume an internal focus of attention (Oberauer & Hein, 2012). This while more passive 'accessory' or 'background' memories do not bias attention. Moreover, our most recent behavioral, eye tracking and EEG experiments indicate that task-relevant representations are actively maintained in working memory for only the first one or two trials, after which the memory representation appears to adopt a less active background status (interpreted as a shift to long term memory; Carlisle, Arita, Pardo, & Woodman, 2011). Intriguingly though, this shift from working memory occurs regardless of whether the memory is being used for attentional guidance or not, thus pointing towards a potential dissociation between active (foreground) vs. passive (background) on the one hand, and biasing attention vs. not biasing attention on the other.

Dynamic Coding for Working Memory in Prefrontal Cortex

Speaker: Mark G. Stokes; University of Oxford

It is often assumed that maintenance in visual working memory is directly supported by persistent activation of the corresponding neural representation. However, the empirical evidence is also quite mixed - persistent delay activity is not always associated with successful memory performance. We propose an alternative to standard 'persistent activity' models: working memory can be maintained via 'activity silent' neural states, such as temporary changes in effective connectivity. Within this dynamic coding framework, working memory is manifest in a temporary shift in the response profile of a neural circuit. Although such changes in connectivity may be difficult to detect using standard recording approaches, hidden states can be inferred indirectly from changes in network behavior. Here we describe a series of novel multivariate analyses that track population-level dynamics in monkey prefrontal cortex during working memory encoding, maintenance and retrieval. The presentation of a memory item triggers a complex trajectory through activity state space during the initial encoding period that strongly differentiates between memory items. Mean activity levels return to baseline during the maintenance period, however spontaneous spiking patterns continue to reflect the contents of working memory. Finally, the presentation of a memory probe triggers a state-dependent response profile that can be read out for successful memory performance. These characteristics of dynamic coding are consistent with activity-driven changes in underlying connectivity, such as short-term synaptic plasticity and/or network coherence. We consider how such a coding scheme for visual working memory could generalize to other forms of context-dependent behavior.

Multiple levels in visual short-term memory

Speaker: Ilja G. Sligte; University of Amsterdam

Authors: Dirk van Moorselaar[1], Christian Olivers[1], Victor A.F. Lamme[2], Kimron L. Shapiro[3]; [1]VU University Amsterdam; [2]University of Amsterdam, [3]University of Birmingham

As we go up the visual hierarchy, receptive field size becomes larger, tuning characteristics become more complex, and the lifetime of neural responses increases. As a logical consequence, one would predict increasingly strict capacity limits, loss of visual detail, and longer representational lifetime for representations that depend on higher visual brain regions. Thus, the neural system acts as a low-pass filter limiting capacity, yet increasing lifetime at the same. In this talk, we will provide evidence that the characteristics of visual sensory memory cohere to this principle: our brief and super-capacity iconic memory depends on neural excitability in primary and secondary visual cortex, while our seconds-lasting and high-capacity fragile memory depends on neural activation in higher visual areas. In that sense, iconic memory and fragile memory are just like low-order and high-order forms of visual sensory memory. In addition, we will show that when information from sensory memory is made available for report, it replaces virtually all information that is currently stored in visual working memory, except for one item that remains untouched. Based on the fact that replaced working memory content can be pulled back for report, we argue that there are at least three fundamentally discernable levels in visual short-term memory; 1) foreground processes that form the center of mind, 2) background processes that are readily available for report, but can easily be swapped with 3) fragile, sensory memory representation that passively decay when there is no top-down amplification available.

Competitive interactions affect working memory precision

Speaker: Fiona McNab; University of Birmingham

Authors: Jumana Ahmad[1], Anna C. Nobre[2], Kimron L. Shapiro[1]; [1]University of Birmingham, [2]University of Oxford

Competition between visually presented stimuli is associated with reduced neural firing, longer reaction time and reduced BOLD response. It is not known whether the effects of competition extend to working memory (WM), nor whether competition represents a common limiting-factor, compromising both WM performance in the absence of distraction, as well as effective distractor exclusion. Here we measured WM precision for an item placed with small or large spatial separation from another item to be remembered, or from a distractor. In both cases, WM precision was significantly reduced for small relative to large spatial separation. This indicates that the effects of competition extend to WM precision, and identifies competition as a potential common mechanism affecting WM regardless of whether the two items being encoded are both to be remembered, or whether one is a distractor. Such a mechanism is a potential basis for the association identified between distractor exclusion and WM in the absence of distraction.

The role of the different layers of primary visual cortex in working memory

Speaker: Pieter R. Roelfsema; Netherlands Institute for Neuroscience

Authors: Matthew W. Self, Timo van Kerkoerle; Netherlands Institute for Neuroscience

Imaging studies have revealed a neuronal correlate of working memory in primary visual cortex (Harrison & Tong, Nature, 2009). However, it is unknown if working memories influence spiking activity in the primary visual cortex. To address this question, we recorded neuronal activity in the primary visual cortex of monkeys trained to perform attentional and working memory tasks with a probe that records activity in all the cortical layers. We found a consistent working memory trace in the spiking activity in the superficial and deep layers of monkey V1, and only a weak memory representation in input layer 4. This V1 memory trace could be disrupted with a visual mask, but it then quickly recovered. The advantage of the laminar probe is that is also gives insight into the current-source density, which reveals the putative synaptic sources of memory activity. The current-source density measurements revealed a characteristic signature of feedback processing with putative synaptic inputs in the superficial and deep layers for working memory. This signature resembles the signature of selective attention, supporting the view that top-down modulation of activity in primary visual cortex underlies both working memory and attention. Our results provide new insights into the role of early visual cortex in working memory.

Distributed Visual Working Memory Stores Revealed by Multivariate Pattern Analyses

Speaker: Thomas B. Christophel; Charité Universitätsmedizin

Authors: Chang Yan[1], Carsten Allefeld[1], John-Dylan Haynes[1,2]; [1]Charité Universitätsmedizin, [2]Humboldt Universität zu Berlin

The storage buffers retaining visual working memory contents were originally postulated to reside in prefrontal cortex. Recently, a dissenting view has evolved claiming that working memory content depends on distributed storage in sensory brain regions. We provide strong evidence for this claim in a series of fMRI experiments investigating the content-specificity of delay-period activity using multivariate pattern analyses. Representations of color and motion patterns as well as complex shapes were identified in early visual, and lateral occipital posterior parietal cortex, but also in the frontal eye fields. A meta-analysis of content-specificity within these brain areas revealed large inter-areal differences critically depending on whether the stimuli were smooth global patterns or shapes with clear edges and on whether stimuli varied across color, luminance or motion direction dimensions. In addition, we show that areas beyond early visual cortex retain information in an inherently view-independent format and that coding of a given stimulus in higher visual areas is not solely driven by the visual display originally shown. Instead, the representation changes when a subject mentally transforms what they are holding in mind (i.e. during mental rotation). Extending our findings on visual working memory, we show that verbal content (Chinese Characters memorized by native speakers of Chinese) is selectively stored in prefrontal areas, more specifically Broca's area and articulatory premotor cortex. Finally, while working memory storage seems to be represented in a distributed way, working memory control could be traced to dorsolateral prefrontal cortex regardless of what content was memorized.

S4 - How to break the cortical face perception network

Time/Room: Friday, May 15, 2015, 2:30 - 4:30 pm, Pavilion

Organizer(s): David Pitcher; NIMH

Presenters: Marlene Behrmann, Arash Afraz, Kevin Weiner, David Pitcher,

Faces are a rich source of social information that simultaneously convey an individual's identity, attentional focus, and emotional state. Primate visual systems are so efficient that processing this wealth of information seems to happen effortlessly. Yet the simplest functions, like recognizing your mother or judging her mood, require the interaction of multiple specialized brain regions distributed across cortex. Despite many years of study our understanding of the unique functions performed by each region and how these regions interact to facilitate face perception remains limited. The speakers in this symposium use novel combinations of experimental techniques to study the behavioral effects of damage and disruption in the cortical face perception network in both human and non-human primates. Our aims are to update the fundamental understanding of how faces are cortically represented and to establish common theoretical ground amongst researchers who use different experimental techniques. To achieve this we will present studies using a range of subject populations (healthy-humans, brain-damaged patients, pre-operative epileptic patients and macaques) and experimental methods (optogenetics, fMRI, microstimulation, physiology, TMS, diffusion weighted imaging and neuropsychology). We believe this symposium will be of great interest to VSS attendees for two reasons. Firstly, understanding the neural processes underlying face perception has proven to be a testing ground in which key disputes concerning anatomical specificity and computational modularity take place and which therefore generates great interest amongst all cognitive neuroscientists. Secondly, studying the face network serves as an excellent proxy for studying the whole brain as a network and we believe attendees will be eager to apply the experimental techniques discussed to address their own questions. The symposium will conclude with an open discussion between the speakers and the audience to establish common ground between those who use different experimental methods and who hold different theoretical positions.

Reverse engineering the face perception system: insights from congenital prosopagnosia

Speaker: Marlene Behrmann; Department of Psychology, Carnegie Mellon University, USA

Reverse engineering involves disassembling a complex device and analyzing its components and workings in detail with the goal of understanding how the device works in its intact state. To elucidate the neural components implicated in normal face perception, we investigate the disrupted components in individuals with congenital prosopagnosia, an apparently lifelong impairment in face processing, despite normal vision and other cognitive skills. Structural and functional MRI data reveal compromised connectivity between more posterior face-selective cortical patches and more anterior regions that respond to face stimuli. Computational descriptions of the topology of this connectivity, using measures from graph theory that permit the construction of the network at the level of the whole brain, uncover atypical organization of the face network in CP. Moreover, this network disorganization is increasingly pronounced as a function of severity of the face recognition disorder. Last, we reconstruct the face images viewed by normal and prosopagnosic observers from the neural data and demonstrate the altered underlying representations in key cortical regions in the prosopagnosic individuals. This multipronged approach uncovers in fine-grained detail the alteration in information discrimination in the prosopagnosic individuals as well as the pertubations in the neural network that gives rise to normal face perception.

The causal role of face-selective neurons in face perception

Speaker: Arash Afraz; Massachusetts Institute of Technology

Many neurons in the inferior temporal cortex (IT) of primates respond more strongly to images of faces than to images of non-face objects. Such so-called 'face neurons' are thought to be involved in face recognition behaviors such as face detection and face discrimination. While this view implies a causal role for face neurons in such behaviors, the main body of neurophysiological evidence to support it is only correlational. Here, I bring together evidence from electrical microstimulation, optogenetic and pharmacological intervention to bridge the gap between the neural spiking of IT face selective neurons and face perception.

The human face processing network is resilient after resection of specialized cortical inputs

Speaker: Kevin Weiner; Department of Psychology, Stanford University

Functional hierarchies are a prevalent feature of brain organization. In high-level visual cortex, the 'occipital face area' (OFA/IOG-faces) is thought to be the input to a specialized processing hierarchy subserving human face perception. However, evidence supporting or refuting the causal role of IOG-faces as a necessary input to the face network evades researchers because it necessitates a patient with a focal lesion of the right inferior occipital cortex, as well as functional measurements both before and after surgical removal of this region. Here, in a rare patient fulfilling both of these requirements, we show that the face network is surprisingly resilient in two ways following surgical removal of IOG-faces. First, the large-scale cortical layout and selectivity of the face network are stable after removal of IOG-faces. Second, following resection, face-selective responses in ventral temporal cortex surprisingly become more reliable in the resected hemisphere, but not in the intact hemisphere. Further investigations of the anatomical underpinnings of this resiliency using diffusion tensor imaging suggest the existence of additional white matter pathways connecting early visual cortex to downstream face-selective regions independent of IOG-faces. Thus, after resection, neural signals can still reach downstream regions via these pathways that are largely unconsidered by present neurofunctional models of face processing. Altogether, these measurements indicate that IOG-faces is not the key input to the face network. Furthermore, our results pose important constraints on hierarchical models in high-level sensory cortices and provide powerful insight into the resiliency of such networks after damage or cortical trauma.

Transient disruption in the face perception network: combining TMS and fMRI

Speaker: David Pitcher; NIMH

Faces contain structural information, for identifying individuals, as well as changeable information, that can convey emotion and direct attention. Neuroimaging studies reveal brain regions that exhibit preferential responses to invariant or changeable facial aspects but the functional connections between these regions are unknown. This issue was addressed by causally disrupting two face-selective regions with thetaburst transcranial magnetic stimulation (TBS) and measuring the effects of this disruption in local and remote face-selective regions with functional magnetic resonance imaging (fMRI). Participants were scanned, over two sessions, while viewing dynamic or static faces and objects. During these sessions, TBS was delivered over the right occipital face area (rOFA) or right posterior superior temporal sulcus (rpSTS). Disruption of the rOFA reduced the neural response to both static and dynamic faces in the downstream face-selective region in the fusiform gyrus. In contrast, the response to dynamic and static faces was doubly dissociated in the rpSTS. Namely, disruption of the rOFA reduced the response to static but not dynamic faces, while disruption of the rpSTS itself, reduced the response to dynamic but not static faces. These results suggest that dynamic and static facial aspects are processed via dissociable cortical pathways that begin in early visual cortex, a conclusion inconsistent with current models of face perception.

S5 - Linking behavior to different measures of cortical activity

Time/Room: Friday, May 15, 2015, 5:00 - 7:00 pm, Talk Room 1-2

Organizer(s): Justin Gardner[1], John Serences[2], Franco Pestilli[3]; [1]Stanford University, [2]UC San Diego, [3]Indiana University

Presenters: Justin Gardner, John Serences, Eyal Seidemann, Aniruddha Das, Farran Briggs, Geoffrey Boynton

A plethora of tools are available for visual neuroscientists to study brain activity across different spatiotemporal scales and the BRAIN initiative offers the promise of more. Pipettes and electrodes measure microscopic activity at channels, synapses and single-units. Multi-electrode arrays, calcium imaging, voltage-sensitive dyes and intrinsic imaging measure mesoscale population activity. Human cortical areas can be mapped using fMRI, ECoG and EEG. In principle, the multiplicity of technologies offers unprecedented possibilities to gain information at complementary spatiotemporal scales. Leveraging knowledge across measurement modalities and species is essential for understanding the human brain where the vast majority of what we know comes from non-invasive measurements of brain activity and behavior. Despite the potential for convergence, different methodologies also produce results that appear superficially inconsistent, leading to categorically distinct models of cortical computation subserving vision and cognition. Visual spatial attention provides an excellent case study. A great deal of behavioral work in humans has established that reaction times and discrimination thresholds can be improved with prior spatial information. Measurements of brain activity using very similar protocols have been made using metrics ranging from single-unit responses to functional imaging in both animals and humans. Despite this wealth of potentially complementary data, general consensus has yet to be achieved. Effects of attention on basic visual responses, such as contrast-response, have yielded different conclusions in and across measurements from fMRI (Buracas and Boynton, 2007; Murray, 2008; Pestilli et al, 2011), voltage sensitive dye imaging (Chen and Seidemann, 2012) and single-units and EEG (McAdams and Maunsell, 1999; Williford and Maunsell, 2006; Cohen and Maunsell 2012; Di Russo et al., 2001; Itthipuripat et al., 2014; Kim et al., 2007; Lauritzen et al., 2010; Wang and Wade, 2011). Task-related responses measured with optical imaging (Sirotin and Das, 2009; Cardoso et al., 2012) also suggest some discrepancy across measurements. These disparate results lead to different models that relate neural mechanisms of attention with behavior (e.g. Pestilli et al, 2011; Itthipuripat et al., 2014). Moreover, some attention effects like reduction in neural variance and pairwise correlations (Cohen and Maunsell, 2009; Herrero et al., 2013; Mitchell et al., 2007; 2009; Niebergall et al., 2011), as well as changes in synaptic efficacy (Briggs et al., 2013) can not even be assessed across all measurements. Rather than considering one specific measurement as privileged, providing ground truth, we propose striving for synthesis and explains the totality of evidence. Theoretic modeling (e.g. Reynolds and Heeger, 2009) provides frameworks that offer the potential for reconciling across measurements (Hara et al., 2014). This symposium is aimed at bringing together people using different spatiotemporal scales of measurements with an eye towards synthesizing disparate sources of knowledge about neural mechanisms for visual attention and their role in predicting behavior. Speakers are encouraged to present results from a perspective that allows direct comparison with other measurements, and critically evaluate whether and why there may be discrepancies. Importantly, the discrepancies observed using these different measures can either lead to very different models of basic neural mechanisms or can be used to mutually constrain models linking neural activity to behavior.

Linking brain activity to visual attentional behavior considering multiple spatial-scales of measurement

Speaker: Justin Gardner; Department of Psychology, Stanford University

Authors: Franco Pestilli; Department of Psychological and Brain Sciences, Program in Neuroscience, Indiana University

Understanding the human neural mechanisms that underly behavioral enhancement due to visual spatial attention requires synthesis of knowledge gained across many different spatial scales of measurement and species. Our lab has focused on the measurement of contrast-response and how it changes with attention in humans. Contrast is a key visual variable in that it controls visibility and measurements from single-units to optical-imaging to fMRI find general consistency in that cortical visual areas respond in monotonically increasing functions to increases in contrast. Building on this commonality across multiple spatial-scales of measurement, we have implemented computational models that predict behavioral performance enhancement from fMRI measurements of contrast-response, in which we tested various linking hypotheses, from sensory enhancement, noise reduction to efficient selection. Our analysis of the human data using fMRI suggested a prominent role for efficient selection in determining behavior. Our work is heavily informed by the physiology literature particularly because some properties of neural response, such as efficiency of synaptic transmission or correlation of activity are difficult if not impossible to determine in humans. Nonetheless, discrepancies across measurements suggests potential difficulties of interpretation of results from any single measurement modality. We will discuss our efforts to address these potential discrepancies by adapting computational models used to explain disparate effects across different single-unit studies to larger spatial-scale population measures such as fMRI.

EEG and fMRI provide different insights into the link between attention and behavior in human visual cortex

Speaker: John Serences; Neurosciences Graduate Program and Psychology Department, University of California, San Diego

Authors: Sirawaj Itthipuripat[1], Thomas Sprague1, Edward F Ester[2], Sean Deering[2]; [1]Neurosciences Graduate Program [2]Psychology Department, University of California, San Diego

A fMRI study by Pestilli et al. (2011) established a method for modeling links between attention-related changes in BOLD activation in visual cortex and changes in behavior. The study found that models based on sensory gain and noise reduction could not explain the relationship between attention-related changes in behavior and attention-related additive shifts of the BOLD contrast-response function (CRF). However, a model based on efficient post-sensory read-out successfully linked BOLD modulations and behavior. We performed a similar study but used EEG instead of fMRI as a measure of neural activity in visual cortex (Itthipuripat et al., 2014). Instead of additive shifts in the BOLD response, attention induced a temporally early multiplicative gain of visually evoked potentials over occipital electrodes, and a model based on sensory gain sufficiently linked attention-induced changes in EEG responses and behavior, without the need to incorporate efficient read-out. We also observed differences between attention-induced changes in EEG-based CRFs (multiplicative gain) and fMRI-based CRFs (additive shift) within the same group of subjects who performed an identical spatial attention task. These results suggest that attentional modulation of EEG responses interacts with the magnitude of sensory-evoked responses, whereas attentional modulation of fMRI signals is largely stimulus-independent. This raises the intriguing possibility that EEG and fMRI signals provide complementary insights into cortical information processing, and that these complementary signals may help to better constrain quantitative models that link neural activity and behavior.

Attentional modulations of sub- and supra-threshold neural population responses in primate V1

Speaker: Eyal Seidemann; Department of Psychology and Center for Perceptual Systems The University of Texas at Austin

Voltage-sensitive dye imaging (VSDI) measures local changes in pooled membrane potentials, simultaneously from dozens of square millimeters of cortex, with millisecond temporal resolution and spatial resolution sufficient to resolve cortical orientation columns. To better understand the quantitative relationship between the VSDI signal and spiking activity of a local neural population, we compared visual responses measured from V1 of behaving monkeys using VSDI and single-unit electrophysiology. We found large and systematic differences between response properties obtained with these two techniques. We then used these results to develop a simple computational model of the quantitative relationship between the average VSDI signal and local spiking activity. In this talk I will describe the model and demonstrate how it can be used to interpret top-down attentional modulations observed using VSDI in macaque V1.

Task-related Responses in Intrinsic-Signal Optical Imaging

Speaker: Aniruddha Das; Department of Neuroscience, Psychiatry, and Biomedical Engineering, Columbia University

Authors: Cardoso, M.[1,2], Lima, B.[2], Sirotin, Y.[2]; [1]Champalimaud Neuroscience Program (CNP), Lisbon, Portugal; [2]Department of Neuroscience, Columbia University, New York, NY

There is a growing appreciation of the importance of endogenous, task-related processes such as attention and arousal even at the earliest stages of sensory processing. By combining intrinsic-signal optical imaging with simultaneous electrode recordings we earlier demonstrated a particular task-related response - distinct from stimulus-evoked responses - in primary visual cortex (V1) of macaque monkeys engaged in visual tasks. The task-related response powerfully reflects behavioral correlates of the task, independent of visual stimulation; it entrains to task timing, increasing progressively in amplitude and duration with temporal anticipation; and it correlates with both task-related rewards, and performance. Notably, however, the effect of the task-related response on stimulus-evoked responses - such as the contrast response function (CRF) - remains an open question. For tasks that are stereotyped and independent of visual stimulation, the task- and stimulus-related responses are linearly separable: the task-related component can be subtracted away leaving an imaged contrast response function that is robustly linear with stimulus-evoked spiking. When the task-related response is modified - such as, by increasing the reward size - the effect is largely additive: the baseline imaging response increases, without, to first order, changing the CRF of the stimulus-evoked component. Thus the important question remains: are there other reliable measures of changes in neural activity, such as changes in signal or noise correlation, rather than local spike rate or LFP magnitude, that can better characterize the task-related response?

Attention and neuronal circuits

Speaker: Farran Briggs; Geisel School of Medicine at Dartmouth College

Visual attention has a profound impact on perception, however we currently lack a neurobiological definition of attention. In other words, we lack an understanding of the cellular and circuit mechanisms underlying attentional modulation of neuronal activity in the brain. The main objective of my research is to understand how visual spatial attention alters the way in which neurons communicate with one another. Previously, my colleagues and I demonstrated that attention enhances the efficacy of signal transmission in the geniculocortical circuit. Through this work, we suggest that the mechanisms underlying attentional modulation of neuronal activity involve enhancement of signal transmission in neuronal circuits and increasing the signal-to-noise ratio of information transmitted in these circuits. Results from my lab indicate that these mechanisms can explain attentional modulations in firing rate observed in primary visual cortical neurons. Our current research focuses on understanding the rules governing attentional modulation of different functional circuits in the visual cortex. Preliminary results suggest that attention differentially regulates the activity of neuronal circuits dependent on the types of information conveyed within those circuits. Overall, our results support a mechanistic definition of attention as a process that alters the dynamics of communication in specific neuronal circuits. I believe this circuit-level understanding of how attention alters neuronal activity is required in order to develop more targeted and effective treatments for attention deficits.

A comparison of electrophysiology and fMRI signals in area V1

Speaker: Geoffrey Boynton; University of Washington, Seattle, WA

fMRI measures in area V1 typically show remarkable consistency with what is expected from monkey electrophysiology studies. However, discrepancies between fMRI and electrophysiology appear for non-stimulus driven factors such as attention and visual awareness. I will discuss possible explanations for these discrepancies, including the role of LFP's in the hemodynamic coupling process, the effects of feedback and timing, and the overall sensitivity of the BOLD signal.

S6 - How learning changes the brain

Time/Room: Friday, May 15, 2015, 5:00 - 7:00 pm, Pavilion

Organizer(s): Chris Baker and Hans Op de Beeck; NIMH, USA; University of Leuven, Belgium

Presenters: Krishna Srihasam, Rufin Vogels, David J. Freedman, Andrew E Welchman, Aaron Seitz

The capacity for learning is a critical feature of vision. It is well established that learning is associated with changes in visual representations and the underlying neural substrate (e.g. sharper behavioral discrimination and sharper neural tuning for trained visual features such as orientation or shape). However, the brain regions involved vary from experiment to experiment, ranging from primary visual cortex to all higher levels in the visual system. One working hypothesis suggests that the hierarchical level at which neural plasticity is most prominent is related to the complexity of the stimuli and the task context, but results do not necessarily support this prediction. Further, the nature of the changes is often inconsistent between studies. In this symposium we emphasize the viewpoint that in order to understand how learning changes the brain, it is critical to consider the underlying complexity and distributed nature of the visual system. The group of speakers we have assembled will present work using a variety of different approaches from behavior to TMS to fMRI in both monkeys and humans. The consistent theme across talks will be that a fuller and better understanding of neural plasticity might be achieved by considering how learning impacts processing from neurons to circuits to regions in the context of the distributed neural architecture of vision. Individually, the speakers will highlight specific properties of the visual system that have an important role in visual learning but are often not considered in theories of learning. First, brain regions differ in their average response and selectivity even before learning, and might each have a different role in learning, making a search for THE visual learning area unrealistic. Further, simple classification schemes such as low-level areas subserve low-level learning and high-level areas high-level learning might vastly underestimate how effects of learning are distributed across hierarchical levels. In addition, the regions critical for a task might change as a function of learning. Even more in detail, different cell types have different roles in visual processing and are possibly changed in different ways through learning. Finally, computational and behavioral approaches also emphasize that learning involves multiple learning processes, and understanding their interaction is crucial. Through these examples we will showcase the complexity of the processes involved in visual learning at the behavioral, neural, and computational level. This symposium should be of broad interest to the VSS community from students to faculty, providing a multidisciplinary overview of current approaches to visual learning. Often visual learning is studied in specific limited domains and the goal of this symposium is to try to integrate findings across different levels and different scales of visual processing, taking into account the complexity of the neural system.

Novel module formation reveals underlying shape bias in primate infero-temporal cortex

Speaker: Krishna Srihasam; Department of Neurobiology, Harvard Medical School, Boston, MA

Authors: Margaret S. Livingstone; Department of Neurobiology, Harvard Medical School, Boston, MA

Primate inferotemporal cortex is divided up into domains specialized for processing specific object categories, such as faces, text, places, and body parts. These domains are in stereotyped locations in most humans and monkeys. What are the contributions of visual experience and innate programs in generating this organization? The reproducible location of different category-selective domains in humans and macaques suggests that some aspects of IT category organization must be innate. However, the existence of a visual word form area, the effects of expertise and our recent finding that novel specializations appear in IT as a consequence of intensive early training indicate that experience must also be important in the formation or refinement of category-selective domains in IT. To ask what determines the locations of such domains, we intensively trained juvenile monkeys to recognize three distinct sets of shapes: alphanumeric symbols, rectilinear shapes and cartoon faces. After training, the monkeys developed regions that were selectively responsive to each trained set. The location of each specialization was similar across monkeys, despite differences in training order. The fact that these domains consistently mapped to characteristic locations suggests that a pre-existing shape organization determines where experience will exert its effects.

Learning to discriminate simple stimuli modifies the response properties of early and late visual cortical areas

Speaker: Rufin Vogels; Laboratorium voor Neuro- en Psychofysiologie, Dpt. Neurowetenschappen, KU Leuven Campus Gasthuisberg, Belgium

Authors: Hamed Zivari Adab; Laboratorium voor Neuro- en Psychofysiologie, Dpt. Neurowetenschappen, KU Leuven Campus Gasthuisberg, Belgium

Practicing simple visual detection and discrimination tasks improves performance, a signature of adult brain plasticity. Current models of learning with simple stimuli such as gratings postulate either changes in early visual cortex or reweighting of stable early sensory responses at the decision stage. We showed that practice in orientation discrimination of noisy gratings (coarse orientation discrimination) increased the ability of single neurons of macaque visual area V4 to discriminate the trained stimuli. Then we asked whether practice in the same task also changes the response properties of later visual cortical areas. To identify candidate areas, we used fMRI to map activations to noisy gratings in the trained monkeys, revealing a region in the posterior inferior temporal (PIT) cortex. Subsequent single unit recordings showed that the PIT neurons discriminated better the trained compared with the untrained orientations, even when the animals were performing an orthogonal task. Unlike in previous single unit studies of learning in early visual cortex, more PIT neurons preferred trained compared with untrained orientations. Thus, practicing a simple discrimination of grating stimuli cannot only affect early visual cortex but also changes the response properties of late visual cortical areas. Perturbation of the activity in PIT reduced the coarse orientation discrimination performance in the trained animals, suggesting that this region is indeed part of the network underlying the performance in the task. We suggest that visual learning modifies the responses of most if not all areas that are part of the cortical network which supports the task execution.

Learning-dependent plasticity of visual encoding in inferior temporal cortex

Speaker: David J. Freedman; Department of Neurobiology, The University of Chicago

Authors: Jillian L. McKee; Department of Neurobiology, The University of Chicago

Our ability to recognize complex visual stimuli depends critically on our past experience. For example, we easily and seemingly automatically recognize visual stimuli such as familiar faces, our bicycle, or the characters on a written page. Visual form recognition depends on neuronal processing along a hierarchy of visual cortical areas which culminates in inferior temporal cortex (ITC), which contains neurons which show exquisite selectivity for complex visual stimuli. Although both passive experience and explicit training can modify or enhance visual selectivity in ITC, the mechanisms underlying this plasticity are not understood. This talk will describe studies aimed at understanding the impact of experience on visual selectivity in ITC. Monkeys were trained to perform a categorization task in which they classified images as novel or familiar. Familiar images had been repeatedly viewed over months of prior training sessions, while novel images had not been viewed prior to that session. Neurophysiological recordings from ITC and prefrontal cortex (PFC) revealed a marked impact of familiarity on neuronal responses in both areas. ITC showed greater stimulus selectivity than PFC, while PFC showed a more abstract encoding of the novel and familiar categories. We also examined familiarity-related changes in ITC encoding within individual sessions, while monkeys viewed initially novel stimuli ~50 times each. This revealed enhanced stimulus selectivity with increasing repetitions, and distinct patterns of effects among putative inhibitory and excitatory neurons. This may provide a mechanism for familiarity-related changes in ITC activity, and could help understand how ITC stimulus selectivity is shaped by learning.

Training transfer: from functional mechanisms to cortical circuits

Speaker: Andrew E Welchman; University of Cambridge, UK

Authors: Dorita F Chang; University of Cambridge, UK

While perception improves with practice, the brain is faced with a Goldilocks challenge in balancing the specificity vs. generality of learning. Learning specificity is classically established (e.g. Karni & Sagi, 1991, PNAS 88, 4966-4970), however, recent work also reveals generalisation that promotes the transfer of training effects (e.g., Xiao et al, 2008, Cur Biol, 18, 1922-26). Here I will discuss how we can understand the neural mechanisms that support these opposing drives for optimising visual processing. I will discuss work that uses perceptual judgments in visual displays where performance is limited by noise added to the stimuli (signal-in-noise tasks) or clearer displays that push observers to make fine differentiation between elements (feature difference tasks). I will review work that suggests different foci of fMRI activity during performance of these types of task (Zhang et al, 2010, J Neurosci, 14127-33), and then describe how we have used psychophysical tests of learning transfer to understand the mechanisms that support learning (Chang et al, 2013, J Neurosci, 10962-71). Finally, I will discuss recent TMS work that implicates a wide high-level network involved in generalisation of training between tasks.

Moving beyond a binary view of specificity in perceptual learning

Speaker: Aaron Seitz; Department of Psychology University of California, Riverside

A hallmark of modern perceptual learning is the nature to which learning effects are specific to the trained stimuli. Such specificity to orientation, spatial location and even eye of training (Karni and Sagi, 1991), has been used as psychophysical evidence of neural basis of learning. However, recent research shows that learning effects once thought to be specific depend on subtleties of the training procedure (Hung and Seitz, 2014) and that within even a simple training task that there are multiple aspects of the task and stimuli that are learned simultaneously (LeDantec, Melton and Seitz, 2012). Here, I present recent results my from my lab and others detailing some of the complexities of specificity and transfer and suggest that learning on any task involves a broad network of brain regions undergoing changes in representations, readout weights, decision rules, feedback processes, etc. However, importantly, that the distribution of learning across the neural system depends upon the fine details of the training procedure. I conclude with the suggestion that to advance our understanding of perceptual learning, the field must move towards understanding individual, and procedurally induced, differences in learning and how multiple neural mechanisms may together underlie behavioral learning effects.

Saturday Morning Talks

Motion Perception

Saturday, May 16, 8:15 - 9:45 am
Talk Session, Talk Room 1
Moderator: Pascal Mamassian

21.11, *8:15 am* The orientation dependence of the motion streak aftereffect reveals interactions between form and motion neurons

Matthew Tang[1] (tangm03@student.uwa.edu.au), James Dickinson[1], Troy Visser[1], David Badcock[1]; [1]School of Psychology, The University of Western Australia

The extended integration time of visual neurons leads to fast-moving objects producing the neural equivalent of an orientation cue along the axis of motion. The dominant model [Geisler, W.S. (1999). Motion streaks provide a spatial code for motion direction. Nature, 400(6739), 65–69] proposes that these 'motion streaks' resolve the inherent directional uncertainty arising from the small size of receptive fields in V1, by combining spatial orientation with motion signals in V1. This model was tested using visual aftereffects, where adapting to a static grating causes the perceived direction of a subsequently-presented fast motion stimulus to be repelled away from the adapting orientation. Using a similar adaptation method, we measured the angular dependence of this effect and found in each human observer that a much broader range of adapting orientations (mean of 38.82º instead of 21.72°) produced aftereffects than predicted by the current model of motion streaks. This suggests that motion streaks influence motion perception at a later stage than V1. We also found that varying the spatial frequency of the adaptor by approximately two octaves changed the aftereffect from repulsive to attractive for motion, but not form stimuli. Finally, manipulations of V1 excitability, using transcranial direct current stimulation, reduced the aftereffect, suggesting that the orientation cue is dependent upon V1. These results can be accounted for if the orientation information from the motion streak, gathered in V1, enters the motion system at a later stage of motion processing, most likely V5. A new computational model of motion direction is presented incorporating gain modifications of broadly-tuned motion-selective neurons, most likely in V5, by narrowly-tuned orientation-selective cells in V1, which successfully accounts for the data in the current study. These results stress that orientation places strong constraints on motion processing in a different way than the current models predict.

Acknowledgement: This work was supported by an Australian Research Council grants DP130102580 and DP110104553 to DRB and DP120102313 to TAWV.

21.12, *8:30 am* Optimal speed estimation in natural image movies predicts human performance

Johannes Burge[1] (jburge@sas.upenn.edu), Wilson Geisler[2]; [1]Department of Psychology, University of Pennsylvania, [2]Center for Perceptual Systems, University of Texas at Austin

Accurate perception of motion depends critically on accurate estimation of retinal motion speed. Here, we first analyze natural image movies to determine the optimal space-time receptive fields for encoding local motion speed in a given direction. Next, from the receptive field responses to natural stimuli, we determine the neural computations that are optimal for combining and decoding the responses into estimates of speed. The computations show how selective, invariant speed–tuned units might be constructed by the nervous system. The space-time receptive fields (which are direction-tuned but not speed-tuned) and the speed-tuned units exhibit strong similarities to neurons in cortex. Then, in a psychophysical experiment using matched naturalistic stimuli, we show that human performance closely parallels optimal performance. Indeed, a single free parameter accurately predicts the detailed shapes of a large set of psychometric functions. For each human observer, this parameter accounts for more than 95% of the variance in the discrimination data with natural stimuli. The optimal observer also provides excellent predictions of human performance with classic artificial stimuli (e.g. drifting gabors). Importantly, the optimal observer for speed estimation was not designed to match human performance. Rather, it was constructed to maximize the accuracy of speed estimates in natural image movies given the constraints of the visual system's front end. We conclude i) that many properties of speed selective neurons and human speed discrimination performance are predicted by the optimal computations, and ii) that natural stimulus variation affects optimal and human observers almost identically.

21.13, *8:45 am* Motion pareidolia: illusory perception of coherent apparent motion in random noise

Nicolas Davidenko[1] (ndaviden@ucsc.edu), Yeram Cheong[2], Jacob Smith[1]; [1]Psychology Department, UC Santa Cruz, [2]Psychology Department, UC Riverside

We report a novel class of visual illusion we term motion pareidolia, in which the sequential presentation of random textures gives rise to illusory percepts of coherent apparent motion. In 3 experiments, we presented naive observers with sequences of random pixel arrays refreshing randomly every 400ms. In Experiment 1 (n=92), these sequences began with a "real" apparent motion prime (e.g. a fixed random texture shifting up and down by 4 pixels), which degenerated into randomness across the first 12 frames. Observers were instructed to press a button when they noticed that the primed motion pattern changed or stopped. Across conditions, 74% of observers reported that the primed motion persisted for at least 3 random frames following the prime, and often for 20 or more random frames (see Supplementary materials). In Experiment 2 (n=50), we tested whether these illusory percepts could arise spontaneously. We presented observers with 6-frame sequences depicting one of 4 motion patterns (alternating: up-down or right-left; or same-direction: up-up or right-right). Across trials we varied visual noise from 0% (pure signal) to 100% (pure noise) and instructed observers to identify which of the 4 motion patterns was being depicted, or whether the display was random. Observers falsely identified motion on 41% of the pure noise trials, indicating that motion pareidolia can arise spontaneously without a direct prime. Further, observers were significantly more likely to falsely perceive alternating than same-direction motion. In Experiment 3 (n=56), we tested whether this alternating bias could result from the boundary conditions of the display region. Indeed, when the display region was ring-shaped, the alternating bias disappeared. Overall, our data demonstrate that naive observers readily perceive suggested motion patterns in random noise. To account for this phenomenon, we propose a top-down selective visual attention model that is biased to confirm expectations.

21.14, *9:00 am* Temporal evolution of motion direction judgments

Oh-Sang Kwon[1] (oskwon@cvs.rochester.edu), Ruyuan Zhang[1], Duje Tadin[1,2]; [1]Center for Visual Science & Dept. of Brain and Cognitive Sciences, University of Rochester, [2]Department of Ophthalmology, University of Rochester, Rochester, NY, USA 14627

Existing models of perceptual decision-making for moving stimuli assume a continuous accumulation of sensory signals for a given direction of motion (Smith & Ratcliff, 2004). This predicts concurrent improvements in estimating motion axis (orientation of motion direction) and motion direction over time. Here, we present a novel finding that the visual system can extract motion axis orientation before detecting motion direction. Methods and results: To estimate the temporal evolution of motion direction judgments, we asked participants to adjust an on-screen arrow to indicate perceived direction of moving stimuli varying in duration (rigid texture motion; randomly chosen direction; 99% contrast, 11° radius, 5°/s speed; stimuli presented at 360Hz). As expected, participants' responses were completely random for very brief stimulus motions (5ms) and distributed around the actual motion direction for long durations (>90ms). Interestingly, for intermediate durations (30-60ms), participants' responses exhibited a clear bimodal distribution with equal peaks in the actual motion direction and in the opposite direction. These results indicate that participants extract motion axis information before having a sense of the actual motion direction. In a related experiment, we found that for certain brief stimulus durations, subjects were 100% correct at estimating motion axis while being at chance at perceiving motion direction. Next, we ran several experiments to rule out possible contributions of spatial signals (i.e., the well-known motion streaks). Finally, we explored the contrast and size dependency of this result (5-99% contrast; 1°-11° radius). The results reveled that rapid and early coding of motion axis was mainly associated with large, high-contrast moving stimuli, stimuli associated with center-surround suppression of motion signals (Tadin et al., 2003). Conclusion: We show the visual system can extract motion axis information considerably faster than motion direction information. The specificity to large, high-contrast motion stimuli offers new clues how center-surround suppression affects motion perception.

Acknowledgement: This work is supported by R01 EY019295 to D.T.

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21.15, *9:15 am* **The temporal efficiency function of the energy-based and feature tracking motion systems** Remy Allard[1,2,3] (remy.allard@inserm.fr), Angelo Arleo[1,2,3]; [1]INSERM, U968, Paris, F-75012, France, [2]Sorbonne Universités, UPMC Univ Paris 06, UMR_S 968, Institut de la Vision, Paris, F-75012, France, [3]CNRS, UMR_7210, Paris, F-75012, France

The low-level, energy-based motion system and the high-level, feature tracking motion system have different temporal characteristics: the sensitivity function of the energy-based system is bandpass peaking around 10 Hz and the feature tracking system is lowpass with a cut-off frequency around 3 Hz. For the energy-based motion system, the greater sensitivity to middle frequencies could be due to less internal noise or more efficient processing (i.e., requiring lower signal-to-noise ratios) at these temporal frequencies. Equivalently, for the feature tracking motion system, the sensitivity drop with temporal frequency could be due to an increase in internal noise or a decrease in processing efficiency. To investigate which underlying factor is responsible for the shape of the temporal sensitivity function for each motion system, an external noise paradigm was used to decompose the sensitivity into internal equivalent noise and calculation efficiency over a wide range of temporal frequencies. To examine the processing of the energy-based system, observers were asked to discriminate the rotating direction of a sine wave grating, which provided strong local luminance drifting cues. For the feature tracking system, the same stimulus was used except that the phase of the sine wave grating was randomized at each frame so the stimulus was drift-balanced. Results showed that the greater sensitivity of energy-based processing to middle frequencies was due to less internal noise and the calculation efficiency remained relatively constant over a wide range of temporal frequencies. Conversely, the sensitivity drop of the feature tracking system with temporal frequency was due to both a reduction in the calculation efficiency and an increase in internal equivalent noise. The shape of the temporal sensitivity function therefore reveals fundamentally different properties for the two motion systems: internal noise variation for the energy-based system and both internal noise and processing efficiency for the feature tracking system.

Acknowledgement: This research was supported by ANR–Essilor SilverSight Chair

21.16, *9:30 am* **Early, local motion signals generate directional preferences in depth ordering of transparent motion** Alexander Schütz[1] (alexander.c.schuetz@psychol.uni-giessen.de), Pascal Mamassian[2]; [1]Department of Psychology, Justus-Liebig-University Giessen, Germany, [2]CNRS & Ecole Normale Supérieure, Paris, France

Superposition of two dot clouds moving in different directions results in the perception of two transparent layers with ambiguous depth order. Intriguingly, the layer moving downwards or rightwards is preferentially seen in front (Mamassian & Wallace, 2010). Here we investigated which motion properties are causing these directional biases. In four experiments, we manipulated global properties of the dot clouds or local properties of individual dots to measure their influence on depth ordering. In all experiments, observers indicated the layer they saw in front. First, we found that the location in the visual field of the apertures within which the dots were presented did not affect depth ordering. This means that the directional biases were not related to the direction of optic flow induced by a translating observer (Gibson, 1950). Second, when the individual dots and the apertures were moving in different directions, only the motion direction of the dots determined the depth ordering. Third, when the moving elements were oriented lines rather than dots, the directional biases were strongly shifted towards the direction orthogonal to the lines rather than the motion direction of the lines. Perceived motion direction was also influenced by line orientation, but less so. This means that depth order was determined before the aperture problem was fully resolved (Pack & Born, 2001). Finally, varying the duration of the stimuli, we found that the time constant of the aperture problem was much lower for depth order than for perceived motion direction. Altogether, our results indicate that depth order is determined in one shot on the basis of an early motion signal, while perceived motion direction is continuously updated. Thus, depth ordering in transparent motion appears to be a surprisingly fast process, that relies on early, local motion signals (Qian et al., 1994) and that precedes high-level motion analysis.

Acknowledgement: ACS was supported by the SFB 135.

Object Recognition

Saturday, May 16, 8:15 - 9:45 am
Talk Session, Talk Room 2
Moderator: Martin Lages

21.21, *8:15 am* **Real-world object size is automatically activated by mid-level shape features** Bria Long[1] (brialong@fas.harvard.edu), Talia Konkle[1], George Alvarez[1]; [1]Department of Psychology, Harvard University

When we recognize an object, we automatically know how big it is in the world (Konkle & Oliva, 2012). Here we asked whether this automatic activation relies on explicit recognition at the basic level category of the object, or whether it can be triggered by mid-level visual features. To explore this question, we gathered images of big and small objects (e.g. car, shoe), and then generated texture stimuli by coercing white noise to match the mid-level image statistics of the original objects (Freeman & Simoncelli, 2011). Behavioral ratings confirmed that these textures were unidentifiable at the basic-level (N=30, 2.8% SD: 4%). In Experiment 1, participants made a speeded judgment about which of two textures was visually bigger or smaller on the screen. Critically, the visual sizes of the textures were either congruent or incongruent with real-world sizes of the original images. Participants were faster at judging the visual size of the texture when it's original size was congruent (M=504 ms) vs. incongruent (M=517 ms) with it's size on the screen ($t(15)=3.79$, $p< .01$). This result suggests that these texture stimuli preserve shape features that are diagnostic of real-world size and automatically activate this association. Consistent with this interpretation, we found that a new set of observers could correctly classify these textures as big or small in the real-world at a rate slightly above chance (N=30, small objects, 63.2%, big objects: 56.4%), and that the magnitude of the Stroop effect was greater when judging textures that were more consistently associated with big or small real-world sizes ($F(1, 23)=38$, $p< 0.001$). Taken together, these results suggest that mid-level visual features are sufficient to automatically activate real-world size information.

21.22, *8:30 am* **Category Boundaries and Typicality Warp the Neural Representation Space of Real-World Object Categories** Marius Cătălin Iordan[1] (mci@stanford.edu), Michelle Greene[1], Diane Beck[2], Li Fei-Fei[1]; [1]Computer Science Department, Stanford University, [2]Psychology Department & Beckman Institute, University of Illinois, Urbana-Champaign

Categories create cognitively useful generalizations by leveraging the correlational structure of the world. Although classic cognitive studies have shown that object categories have both intrinsic hierarchical structure (entry-level effects, Rosch et al., 1976), as well as graded typicality structure (Rosch, 1973), relatively little is known about the neural underpinnings of these processes. In this study, we leverage representational similarity analysis to understand how behaviorally relevant category structure emerges in the human visual system. We performed an fMRI experiment in which participants were shown color photographs of 15 subordinate-level categories from each of two basic-level categories (dogs and cars). Typicality for each subordinate within its basic was also assessed behaviorally. We computed the neural correlation distance between all pairs of categories in early visual areas (V1, V2, V3v, hV4) and object-selective cortex (LOC). We found that as we move from low-level visual areas to object-selective regions, neural distances are compressed within object categories, and simultaneously expanded between object categories. This effect arises gradually as we move up the ventral visual stream through V1, V2, V3v, hV4, with a marked increase between hV4 and LOC. Furthermore, within each basic category in LOC, subordinate typicality influences the organization of the neural distance space: highly typical items are brought closer together, while distance between atypical exemplars grows. Again, this effect arises between hV4 and LOC, suggesting that a significant qualitative jump in the differentiation of object categories from one another as independent structures, as well as in their internal organization, occurs in object-selective areas. Our results show that as we move up the ventral visual stream, distances between neural representations of real-world objects warp to facilitate categorical distinctions. Moreover, the nature of this warping may provide evidence for a prototype-based representation that clusters highly typical subordinates together in object-selective cortex.

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21.23, *8:45 am* **Searching through the hierarchy: Modeling categorical search using class-consistent features** Justin Maxfield[1] (jmaxfieldsbu@gmail.com), Chen-Ping Yu[2], Zelinsky Gregory[1,2]; [1]Department of Psychology, Stony Brook University, [2]Department of Computer Science, Stony Brook University

This study describes how the hierarchical level at which a target is specified affects categorical search—the search for any member of an object category. Participants (n=24) searched for a text-cued target at either superordinate, basic, or subordinate levels (counterbalanced over participants). Stimuli were images of objects from ImageNet. Consistent with previous work, search was guided most strongly to categorical targets cued at the subordinate-level, but basic-level targets were verified the fastest. Our computational method first built bag-of-words histograms using SIFT and hue features extracted from 100 exemplars for each of 68 categories. To describe categorical guidance, we then quantified the feature variability within each category by finding the mean pairwise chi-squared distance between all 100 histograms. Doing this for each category, we found the highest intra-class feature variability at the subordinate level, followed by the basic and superordinate levels, the same pattern found in the behavioral time-to-target-fixation data. To describe categorization, we averaged the 100 histograms for each category, then used k-means to find those "class-consistent" features in the averaged histogram having the highest means and the lowest variability. We found the greatest number of class-consistent features at the basic level, replicating the advantage observed in verification times. Basic-level categories may therefore be verified faster because they have more consistent features to aid in the decision of category membership. Our work advances this story by quantifying these principles using features extracted directly from images. Using these same features, this work also offers an intuitively appealing explanation for differences in categorical guidance; the less variability in a target category the stronger the guidance. This simple framework shows that target guidance and verification are two behaviors that can be derived from the same features, thereby further bridging the narrowing gap between search and categorization.

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21.24, *9:00 am* **Visual interference disrupts visual and only visual knowledge** Pierce Edmiston[1] (pedmiston@wisc.edu), Gary Lupyan[1]; [1]Department of Psychology, University of Wisconsin-Madison

Visual imagery and the making of visual judgments involves activation of cortical regions that underlie visual perception (e.g., reporting that taxicabs are yellow recruits color sensitive regions of cortex, Simmons et al., 2007). Such results, however, leave open the critical question of whether perceptual representations are constitutive of visual knowledge (Barsalou, Simmons, Barbey, & Wilson, 2003; Mahon & Caramazza, 2008). We report evidence that visual interference disrupts the activation of visual and only visual knowledge. Recognizing an upright object next to a rotated picture of the same object is known to be aided by cueing; hearing word cues that match the subsequently presented pictures (e.g., hearing "alligator" prior to seeing pictures of alligators) improves performance, whereas hearing invalid cues (e.g., hearing "alligator" prior to seeing pictures of dogs) impairs it. We show that we can reduce this cueing effect by 46% by presenting a visual mask during or after the auditory word cue. The mask did not affect performance on no-cue trials, showing that the effect of the visual interference disrupts the knowledge activated by the word. In subsequent studies we show that the same type of visual interference affects knowledge probed by verbal propositions. For example, hearing the word "table" while viewing visual noise patterns made participants 1.4 times more likely to make an error in affirming the visual property that tables have flat surfaces but not the more general (and equally difficult) property that tables are furniture. These results provide a convincing resolution of a longstanding debate in cognitive psychology and neuroscience about the format of visual knowledge. Although much of our knowledge abstracts away from perceptual details, knowledge of what things look like appears to be represented in a visual format.

21.25, *9:15 am* **Words jump-start vision: a label advantage in object recognition** Bastien Boutonnet[1] (bastien.b1@gmail.com), Gary Lupyan[1]; [1]Department of Psychology, University of Wisconsin, Madison

Making sense of visual input and its structure largely depends on interplay between bottom-up signals and top-down influences from higher-level processes. Often neglected, is the fact that humans live in a world additionally structured by language where people use language to shape each other's behaviour in flexible ways. Could language play a key role visual processing? Traditionally, effects of language on perception are often assumed to be "high-level" in that, while language clearly influences reasoning, and decision-making, it does not influence low-level visual processes. Here, and in opposition with this common view, we test the prediction that words are able to provide top-down guidance at the earliest stages of visual processing. We compared whether visual processing of images of familiar animals and artefacts was enhanced after hearing their name (e.g., "dog") compared to hearing an equally familiar and unambiguous nonverbal sound (e.g., dog-bark). We predicted that words would deploy more effective categorical templates, allowing enhanced visual recognition. By recording EEGs, we were able to distinguish whether this "label-advantage" stemmed from changes to early visual processing or to later semantic decision-making. The results show that hearing a label affects visual processes within 100 ms of image presentation, and that this modulation is category-sensitive. ERPs show that the P1 was larger when people were cued by labels compared to when they were cued by equally informative nonverbal cues. More importantly, this enhancement predicted behavioural responses occurring almost 500 ms later. Hearing labels modulated single-trial P1 activity such that it distinguished between target and non-target images, showing, for the first time, that words rapidly guide early visual processing. Crucially, while cue-picture congruence modulated the N4 – known to index semantic integration– cue-types did not, confirming that both cue-types were equally informative, and that the label-advantage results from modulations of perceptual processes.

21.26, *9:30 am* **Illusory Expansion Improves Visual Acuity** Martin Lages[1] (m.lages@psy.gla.ac.uk), Stephanie Boyle[2], Rob Jenkins[3]; [1]School of Psychology, University of Glasgow, [2]Institute of Neuroscience and Psychology, University of Glasgow, [3]Department of Psychology, University of York

A Snellen-type chart is commonly used for routine eye examination. This test serves as a benchmark for visual acuity where observers read out Sloan letters of decreasing size at a recommended viewing distance. The smallest readable letter size is typically used as a measure of visual acuity. For example, vision of 20/20 and 10/10 describes the ability to resolve letters subtending 5 minutes of arc at a viewing distance of 20 (6m) and 10 feet (3m), respectively. Here we show that adaptation to a rotating spiral and the ensuing motion aftereffect (MAE) significantly alters visual acuity in observers with normal or corrected-to-normal vision. In a first group n=44 observers adapted to contracting motion and in a second group n=30 observers adapted to expanding motion before reading out a string of five letters. The results demonstrate that the expanding MAE significantly facilitated subsequent letter recognition whereas the contracting MAE impaired letter recognition. There also was an effect of crowding between letters but the absence of a significant interaction indicated that the adaptation effect was not qualified by crowding. We conclude that illusory expansion increases perceptual fields by recruiting additional feature detectors thereby enlarging the apparent size of letters. Illusory contraction on the other hand decreases perceptual fields and number of feature detectors thereby reducing the apparent size of letters. It is a special feat of the visual system that adaptation to motion can improve visual acuity - a measure that is typically associated with refractive error in the optics of the eyes rather than perceptual inference. We speculate that optimal integration (multiplexing) of information from motion and form processing is responsible for this surprising effect.

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Attention: Mechanisms and models

Saturday, May 16, 10:45 am - 12:30 pm

Talk Session, Talk Room 1

Moderator: Kristina Visscher

22.11, *10:45 am* **Visual spiking responses in V1 couple to alpha fluctuations in deep layers** Kacie Dougherty[1] (kacie.dougherty@vanderbilt.edu), Michele Cox[1,2], David Leopold[2], Alexander Maier[1,2]; [1]Department of Psychology, Vanderbilt University, [2]Laboratory of Neuropsychology, National Institute of Mental Health

Alpha-range (8-12 Hz) neural rhythms, prominent over occipital cortex, can serve as a predictor of performance on visual tasks. Specifically, visual performance and attentional selection have been shown to co-vary with the ongoing alpha cycle recorded on the scalp. Despite their impact on visual performance, little is known about the intracortical origins of alpha rhythms and how alpha cycles impact visual processing. Here, we study laminar neural activity in primate visual cortex in order to determine a mechanistic link between alpha cycles and visually evoked spiking responses. Two macaque monkeys (Macaca radiata) fixated while static grating stimuli

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were presented inside of the receptive field under study. During this time, we recorded alpha-range local field potentials and multiunit spiking activity from all layers of V1 simultaneously. We found that throughout several hundred milliseconds of visual stimulation, spiking activity in all layers was strongly decreased at the time of alpha troughs recorded in the deep, feedback-recipient cortical layers compared to the level of columnar spiking at alpha peaks. Specifically, the magnitude of population spiking activity at the time of alpha troughs was nearly half that at alpha peaks, suggesting that alpha induces pulsed inhibition of visual responses at the earliest stages of cortical processing. Lastly in order to probe the potential role of feedback afferences, we will present a comparison of intracolumnar coupling between alpha and visual spiking responses between the two attentional states.

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22.12, *11:00 am* **Neural correlates of time-resolved behavioral responses reveal theta-band oscillations in the fusiform face area and parahippocampal place area** Bingbing Guo[1] (bingbing.guo@dartmouth.edu), Jessica Goold[1], Huan Luo[2,3], Ming Meng[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College, [2]Institute of Biophysics, Chinese Academy of Sciences, [3]Department of Psychology, PKU-IDG/McGovern Institute for Brain Research, Peking University

Repeated exposure to same stimuli may lead to on one hand neuronal adaption in brain areas representing the stimuli, on the other hand visual priming effect to facilitate recognition of the stimuli. To investigate dynamic relationships between these neural and behavioral effects, we measured brain activity using fMRI when participants performed a speeded response task of detecting face/house with visual priming of the same but smaller face/house. Critically, we employed time-resolved measurements, by varying stimulus onset asynchrony (SOA) between the prime and probe in a small step of 20ms, from 200ms to 1080ms. Recent behavioral studies using a similar paradigm but different stimuli to measure time-resolved response dynamics revealed theta-band oscillations in reaction times (see Huang, Chen and Luo, VSS2015). Here we chose face/house as the stimuli to examine whether activity in the known face-selective areas (e.g., the fusiform face area, FFA) and house-selective areas (e.g., the parahippocampal place area, PPA) may correlate with the rhythmic dynamics of reaction times in detecting face/house. Our behavioral results replicated previous findings, showing theta-band oscillations in priming effects. Interestingly, fMRI multivariate pattern analysis (MVPA) results also demonstrate theta-band oscillations and out-of-phase relationship between congruent and incongruent conditions in the FFA and PPA. This is the first time of using fMRI to localize time-resolved rhythmic activity, despite the relatively sluggish temporal resolution of fMRI. Our results suggest a feasible strategy that may use fMRI to localize the neural correlates of mental and behavioral oscillations in the processing of repeatedly presented stimuli. These results also provide critical constraints for developing a neural model to understand brain mechanisms underlying behavioral oscillations.

Acknowledgement: Research supported by the National Science Foundation under Grant Number 1157121

22.13, *11:15 am* **Central vs. peripheral primary visual cortex differ in cortical thickness and functional connectivity** Kristina Visscher[1], Joseph Griffis[1], Wesley Burge[1]; [1]Neurobiology, University of Alabama, Birmingham

Central and peripheral vision have different functions. For example, we regularly attend to objects in central vision, and only occasionally attend to objects in peripheral vision. However, aside for compensating for the cortical magnification factor, neuroscientists tend to treat centrally-and peripherally-responsive cortical areas as if they were the same. We tested how centrally-representing and peripherally-representing parts of primary visual cortex (V1) differed in cortical thickness and functional connectivity. We collected T1-weighted structural MRI data and blood oxygen level dependent functional connectivity MRI data from healthy young adult participants aged 19-30 years. V1 was identified anatomically and segmented into central and peripheral portions using Freesurfer software. Our data imply that central vs. peripheral primary visual cortex have distinct patterns of cortical thickness and functional connectivity. Patterns of cortical thickness and functional connectivity echoed each other, in a way that is consistent with putative functions of central and peripheral regions. Cortex was thicker in central V1 than peripheral V1, consistent with studies showing that increased use leads to increased cortical thickness. Echoing this inhomogeneity of structure, central V1, more than peripheral V1, was functionally connected to several fronto-parietal regions that have been shown by previous studies to be involved with moment-to-moment control. This result is consistent with the idea that central vision often requires moment-to-moment control and therefore centrally-representing cortical areas have developed strong connections to control regions. Another network of regions, termed the "default mode network" has been shown in previous work to be suppressed during tasks requiring externally focused attention. Peripheral V1, more than central V1, was functionally connected to regions of the default mode network. Together, these findings suggest that the anatomy and connections of V1 differ between centrally- and peripherally- representing areas, in a way that is consistent with their function.

Acknowledgement: Dana Foundation

22.14, *11:30 am* **Refining The Resource Model: Cortical Competition Could Explain Hemifield Independence** John Clevenger[1,2] (jcleven2@illinois.edu), Diane Beck[1,2]; [1]Department of Psychology, University of Illinois at Urbana-Champaign, [2]Beckman Institute, University of Illinois at Urbana-Champaign

Recent studies have shown performance advantages in visual tasks when task-relevant stimuli are presented in different visual hemifields as opposed to a single hemifield. One way to interpret these findings is to posit that each cortical hemisphere has independent attentional resources. In contrast to this view, we suggest that competition between representations in visual cortex might explain this hemifield independence. When stimuli fall into separate hemifields, they project to different cortical hemispheres, reducing the local competitive interactions that occur when stimuli are presented in adjacent areas of a single hemisphere. To test whether local competitive interactions underlie hemifield independence, we had subjects search displays in which the target was placed such that it either shared a hemifield with non-targets or was alone in the hemifield. Set size was constant across all conditions. Critically, we also varied the overall display density (distance between objects). The resource account predicts the task should be harder when the target shares a hemifield with non-targets but predicts no difference when density is manipulated. Alternatively, the competition account predicts that sharing a hemifield should only make the task harder if the objects are close enough to strongly compete with one another (suppressing each others' representations). We found that subjects were faster to find a target when the target was alone in the hemifield than when it shared the hemifield with non-targets, but only when overall display density was high (when the target was cortically near non-targets). These data suggest that hemifield independence might be caused by a lessening of local competitive interactions in visual cortex. When stimuli are cortically distant, either by being placed in separate hemifields or by being spread out, they are less likely to suppress each other's representations in visual cortex and are thus easier to detect.

22.15, *11:45 am* **EEG alpha rhythms track the deployment of spatial attention** Joshua Foster[1] (jfoster2@uoregon.edu), David Anderson[1], John Serences[2], Edward Vogel[1], Edward Awh[1]; [1]Department of Psychology, University of Oregon, [2]Department of Psychology, University of California, San Diego

Numerous studies have demonstrated a link between spatial attention and alpha (8-13 Hz) activity measured with electroencephalography (EEG). In spatial cueing studies, a posterior alpha desynchronization is seen contralateral to the cued visual hemifield relative to the ipsilateral side (e.g., Thut, Nietzel, Brandt, Pascual-Leone, 2006). In light of recent work showing that the pattern of alpha activity across the scalp tracks the content of visual working memory (Anderson, Serences, Vogel, & Awh, 2014), we examined whether the topography of alpha activity provides precise information about the locus of spatial attention. We recorded EEG while participants performed a spatial cueing task. A central cue (87.5% valid) directed participants to one of eight placeholders arranged in a circle around fixation. After 1250 ms a search array was presented and participants were asked to identify the digit among letters. A robust spatial cueing effect confirmed that participants attended the cued location. We examined whether the distribution of EEG activity across the scalp carried information about the attended location during the cue-target interval. Using a linear classifier, we identified the frequencies between 4 and 30 Hz that allowed for above-chance decoding of the locus of attention. Activity in the alpha frequency band carried information about the cued location, beginning ~500 ms after cue onset and sustaining until onset of the search array. Using a forward encoding model of location selectivity, we were able to reconstruct location-based channel tuning function (CTFs) from the topography of alpha activity that tracked the position of attention. Consistent with the classification results, the CTF emerged ~500 ms after cue onset.

These results support the hypothesis that alpha activity plays a role in the deployment of spatial attention, and suggest that CTFs provide a time-resolved measure for tracking the deployment of covert spatial attention.

22.16, *12:00 pm* **Attentional gain control during decision-making with multiple alternatives** Sirawaj Itthipuripat[1] (itthipuripat.sirawaj@gmail.com), Kexin Cha[2], Sean Deering[2], John Serences[1,2]; [1]Neurosciences Graduate Program, UCSD, [2]Psychology Department, UCSD

The magnitude of sensory responses is enhanced when attention is directed to a relevant stimulus (i.e., sensory gain), and this gain modulation adequately accounts for attention-related behavioral improvements in simple two alternative-force-choice (2AFC) tasks (Itthipuripat et al., 2014a). However, other evidence suggests that sensory gain is not always sufficient to account for improved performance, and that attention may also influence post-sensory read-out mechanisms (Pestilli et al., 2011). Based on previous visual search studies (e.g., Palmer and Verghese, 2000), we reasoned that the number of competing items and alternative choices might be the key factor that determines how much sensory gain and efficient read-out contribute to behavioral performance. Fourteen subjects participated in 2AFC and 4AFC contrast discrimination tasks in which they reported the location that contained an incremental contrast within a target stimulus. This contrast increment target was embedded in an array of four competing stimuli flickering at different frequencies and contrasts. Subjects were cued either to the target-location (focused-attention) or all stimulus-locations (distributed-attention). Contrast discrimination thresholds were measured concurrently with electroencephalography (EEG). Steady-state visual evoked potentials (SSVEPs) were used as an index of sensory responses and late event-related potentials in occipital and frontal channels were used as indices of sustained attention and post-sensory decision processes, respectively. To our surprise, the amount of sensory gain measured by SSVEPs is comparable and sufficient to explain attention-related improvement in perceptual sensitivity in both 2 and 4AFC tasks. Similarly, sustained attention-related negative difference over occipital cortex is comparable across the two tasks. Finally, the pattern of late centrofrontal positive potentials suggests that the decision threshold in the 4AFC task is higher than that in the 2AFC task, consistent with the observed main effects of attention and task-type on decision times.

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22.17, *12:15 pm* **Neuronal signatures of covert visual attention prior to microsaccades** Chih-Yang Chen[1,2] (chen.chih-yang@cin.uni-tuebingen.de), Alla Ignashchenkova[2], Ziad Hafed[2]; [1]Graduate School of Neural and Behavioural Sciences, International Max Planck Research School, [2]Werner Reichardt Centre for Integrative Neuroscience

Neuronal modulations such as response gain enhancement and reductions in response variability are classically thought to reflect the allocation of covert visual attention to behaviorally relevant stimuli. Here we show that these neuronal signatures of attention can occur without any attentional task. In six different monkeys and two different brain areas classically implicated in covert visual attention, we found that classic neuronal signatures of attention occur if stimuli simply appear before microsaccades. We recorded 113 superior colliculus (SC) neurons of two monkeys performing simple fixation, while we presented vertical sine-wave gratings (2.2 cpd; 5-80% contrast) in the neurons' peripheral response fields (RF's). We analyzed mean visual activity 50-150 ms after grating onset and separated trials based on whether such onset happened without (baseline) or < 100 ms before microsaccades. We also analyzed 37 SC neurons from two more monkeys, and 36 frontal eye field (FEF) neurons from yet two more monkeys. For the latter four monkeys, the RF stimulus was a small spot as part of a subsequent discrimination task. In all six monkeys, we found robust pre-microsaccadic enhancement of response gain. Moreover, in the first two monkeys, we analyzed contrast sensitivity, fano factor (to assess neuronal variability), and ROC discriminability (between baseline and microsaccade trials). All analyses revealed modulations that are classic signatures of covert visual attention (e.g. reductions in fano factor and increases in ROC discriminability), but without attentional task requirements. Moreover, neurons with sustained visual responses exhibited sustained elevations in response gain and sustained reductions in fano factor, simply when stimuli appeared before microsaccades, and again without any attentional task. Our results suggest that there is an obligatory link between pre-motor processes and neuronal or behavioral (Hafed, Neuron, 2013) signatures of selective visual processing, even when such pre-motor processes are associated with seemingly "irrelevant" microsaccades.

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Color Perception

Saturday, May 16, 10:45 am - 12:30 pm
Talk Session, Talk Room 2
Moderator: Won Mok Shim

22.21, *10:45 am* **A spectral estimation method for predicting between-eye color matches in unilateral dichromats** Haomiao Jiang[1] (hjiang36@gmail.com), Joyce Farrell[1], Brian Wandell[2]; [1]Department of Electrical Engineering, Stanford University, [2]Psychology Department, Stanford University

Introduction. There are several reports describing color vision in subjects who are dichromatic in one eye and trichromatic in the other. Between-eye color matches in these unilateral dichromats have been used to model color appearance for dichromats (Brettel et al, 1997). Methods. We describe a theoretical principle that makes specific predictions about the mapping from two cone class absorptions in the dichromat eye to three cone class absorptions in the trichromatic eye. Specifically, we propose that the brain estimates a spectral power distribution consistent with the two measured cone absorption rates; we use this estimate to predict the equivalent absorption rate for the missing cone type. We examined the implications of different spectral estimation methods, which is a severely under constrained estimation problem. These include (a) a smoothness constraint, (b) non-negativity constraint, and (c) natural scene priors. We implemented these calculations in open-source software. Results. Under some assumptions (smoothness only), a single linear transformation converts the dichromatic cone absorptions to the estimate for the missing cone class. This transformation matches some, but not all, of the color matches in unilateral dichromats. Adding additional assumptions (non-negativity) results in a nonlinear relationship between the two measured cone class absorptions and the estimated absorptions for the missing cone class. This observation predicts which wavelengths of light will appear the same to the dichromatic and trichromatic eyes (isochromes). The non-negativity constraint improves the agreement between predictions and measurements in unilateral dichromats (Alpern et al, 1983). Conclusion. Establishing a quantitative map from the two cone classes in a dichromat to a missing cone class has practical value for estimating color appearance matches between dichromats and trichromats (Brettel, et al.; Vischeck). In addition, we explain how the method can be useful for implementing a color difference metric for dichromatic observers.

Acknowledgement: Simons Collaboration on Global Brain

22.22, *11:00 am* **Color representation in lateral geniculate nucleus: a human fMRI study** Sang Wook Hong[1] (shong6@fau.edu), Qing Yu[2], Won Mok Shim[2]; [1]Department of Psychology, Florida Atlantic University, [2]Psychological and Brain Sciences, Dartmouth College

Studies in non-human primate visual system show a distinction between two cardinal chromatic channels, parvocelluar (L-M) and koniocellular (S-(L+M)), in neuronal responses of the lateral geniculate nucleus (LGN). Thus, it is believed that colors which vary on both cardinal channels cannot be represented in LGN but can only be encoded at the cortical level where a major transformation of chromatic signals occurs, known as the higher-order color mechanism (Krauskopf et al., 1986). However, color representations in human LGN are largely unknown. In the current study, we investigated color representations in LGN and the primary visual cortex (V1) in human visual system using functional Magnetic Resonance Imaging (fMRI) and a forward encoding model (Brouwer & Heeger, 2009). In each experimental run, observers viewed equi-luminant concentric ring patterns, composed of one of eight colors (four colors varying on only one channel, four colors varying on both channels) and equal-energy-spectrum white, which alternated drifting in expanding and contracting directions. In V1, we found clear population-level color tuning responses which peaked at each of the viewed colors, indicating that colors of both chromatic channels and combinations of them are encoded in V1. In contrast, in LGN, distinct tuning responses were found for colors varying along the koniocellular channel, whereas tuning responses for colors varying along the parvocellular channel were indistinguishable. These large-scale population-level color tuning responses may indicate the lack of an S-OFF mechanism in LGN. In sum, our results provide evidence for a major transformation of color representation from LGN to V1 in human visual system, consistent with findings in non-human primates.

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22.23, *11:15 am* **Responses of macaque V1 neurons to color images of natural scenes** Max Snodderly[1,2] (max.snodderly@mail.utexas.edu), Hee-kyoung Ko[1,2], Christopher Carter[1,2], Baoyu Zhou[1,2]; [1]Dept of Neuroscience, Inst for Neuroscience, Ctr for Perceptual Systems, [2]University of Texas, Austin

During natural vision, we scan scenes of a world full of colors with large and small eye movements. Surprisingly, the responses of cortical neurons are seldom studied under these conditions. Most commonly, gray scale images are displayed, and eye movements are mimicked by movie sequences that assume the eye is stationary during intersaccadic intervals. The results indicate that cortical activity is very low and sparse when viewing achromatic movies. We have recorded activity of V1 neurons while a monkey viewed calibrated color images of natural scenes from the McGill database and performed eye movement tasks. Eye position was recorded at high precision with a scleral search coil so that fixational saccades, drifts, and tremor were measureable. There was a wide range of response characteristics, but many neurons were continuously active during drift periods as well as immediately after saccades. This activity would be expected to contribute to the fine detailed vision that is enabled by fixational drift. However, it poses a challenge to determine whether the drift-related activity integrates easily into the rubric of sparse coding. When saccades were performed from a blank field to a natural image or vice-versa, we were able to separate the situations where the receptive field lands on a region of a natural scene or leaves it. We are currently investigating the balance of "on" and "off" responses that accompany these abrupt changes. Many of the neurons gave quite vigorous responses to colored images that were often greater than the response to the same image converted to gray scale. This comparison offers a novel measure of the contribution of color to cortical activity and the metabolic cost of this important perceptual capacity.

Acknowledgement: NSF IOS 0843354

22.24, *11:30 am* **Area VO in human visual cortex is color selective as revealed by fMRI adaptation** Dorita Chang[1] (dorita.chang@mcgill.ca), Robert Hess[1], Kathy Mullen[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University, Canada

Introduction: We use an fMRI adaptation paradigm to investigate the selectivity of the human visual cortex to red-green (RG) and achromatic (Ach) contrast, comparing regions in early visual cortex (V1, V2) with those in the dorsal (V3d, V3a, hMT+) and ventral (V3v, V4, VO) cortex. Methods: RG and Ach adaptation and no-adaptation conditions were contrasted within a block design. Test and adapting stimuli were high contrast sine-wave counter-phasing rings (0.5cpd, 2Hz), as previously described (Chang et al, JOV, 2014, 14 (10) 983). Regions of interest (as listed above) were independently localized using standard procedures. We assume that cross-adaptation of responses to RG and achromatic stimuli indicates a common neural substrate for both, whereas a lack of cross-adaptation indicates selective neural responses within voxels. Selectivity was defined as significantly greater same-adaptation (RG on RG, or Ach on Ach) than cross-adaptation (RG on Ach, or vice versa), established by RM ANOVAs. Results: Adaptation was present in all areas except for hMT+, which showed no color adaptation. Areas V1 and V2 showed no selectivity of adaptation; specifically, both RG and Ach test stimuli were adapted as much by the cross adaptor as by the same adaptor. In the dorsal cortex, areas V3d, V3a, hMT+ showed significant selectivity for achromatic contrast. In the ventral cortex, VO showed significant selectivity for RG color contrast. Conclusion: Color-luminance responses are dominant in areas V1 and V2 with selectivity developing along the extrastriate pathways. While dorsal areas show selectivity for achromatic contrast, ventral cortex (VO) exhibits selectivity for RG color contrast. Area VO has previously been shown to be a color responsive area in human cortex. Here we show that it is also color selective, suggesting it plays a significant role in color processing.

Acknowledgement: CIHR grants (MOP-10819) to KTM and (MOP-53346) to RFH

22.25, *11:45 am* **Spectral sensitivity measurements reveal partial success in restoring missing rod function with gene therapy** Andrew Stockman[1] (a.stockman@ucl.ac.uk), Bruce Henning[1], Caterina Ripamonti[1]; [1]UCL Institute of Ophthalmology

Rod visual function can be established with some certainty by demonstrating that dark-adapted visual spectral sensitivity has the shape of the rod (scotopic) spectral sensitivity function and that this scotopic shape collapses to a cone (photopic) shape when cones, but not rods, have recovered following an intense bleach. We used these tests to assess retinal function in eight young adult and child patients with early-onset severe retinal dystrophy enrolled in phase II of a clinical gene therapy trial for RPE65 deficiency, an isomerase, the lack of which disrupts the "visual cycle" upon which rods solely depend for regenerating visual pigment after light exposure. The trial involved subretinal delivery of a recombinant adeno-associated viral vector expressing RPE65. After gene therapy, substantial improvements in 1-Hz dark-adapted flicker sensitivity were found in two of the eight patients. One patient showed up to a 1000-fold improvement in sensitivity 4 months after treatment, and the second, up to a 100-fold improvement 6 months after treatment. In both cases, the spectral sensitivity after treatment was rod-like after normal periods of dark adaptation, but remained cone-like during the cone plateau after an intense bleach. The dark-adapted spectral sensitivities of the other six patients were cone-like both before and after treatment with only minimal sensitivity changes. It is not clear why restored rod function was evident in only some patients, but the response may be limited by the extent of retinal degeneration at the locus tested.

22.26, *12:00 pm* **Contourless Color Field Induction** Christopher Tyler[1] (cwt@ski.org); [1]Smith-Kettlewell Eye Research Institute

Introduction. It is well known that color can be induced spatially as the completion of a color boundary (Pinna, 1987) and temporally as an afterimage (especially within a boundary contour; Daw, 1962). Also, figures with sparse color contours can induce local extensions of the contour boundary, as in Neon Color Spreading (Varin, 1971). These observations have invoked the concept of color induction as driven largely by color contours. Consideration that most chromatic cells in primary visual cortex are not contour selective, however, suggests that contourless color induction should be possible. Methods. Fields of sparse random dots of one color on the left side of a black field and a contrasting color on the other side are accurately fixated for 10 s, and assessed for color induction. The dots are then removed and the empty black field assessed for color induction. Results. The colored dots induce color spreading across each side of the field. Rather than being the opposite color, as predicted by the local color border hypothesis, the field color is a darker version of the color of the dots overlying the field. This induced color represents a novel form of color induction from the color of the dots alone. Removal of the dots switches the induced field color to the opponent color. The dots also have afterimages of the opponent color that may appear and disappear with microsaccadic eye movements, while the induced opponent field color remains and fades gradually over about 5s, as though it were an afterimage of the initial induced field color. The two different induced field colors form a color border much sharper than between the sets of sparse random dots. Discussion. Induced colors can form borders in the absence of contour border in the input image, inverting the standard logic of color border processing.

Acknowledgement: CDMRP 130266

22.27, *12:15 pm* **The color communication game** Delwin Lindsey[1,2] (lindsey.43@osu.edu), Angela Brown[2], David Brainard[3], Coren Apicella[3]; [1]Department of Psychology, Ohio State University, Mansfield, OH, [2]College of Optometry, Ohio State University, Columbus, OH, [3]Department of Psychology, University of Pennsylvania, Philadelphia, PA

We report a new, information theory based analysis of color naming. We compute mutual information (MI, in bits) in a simulated "game" involving a "sender" (S) who names out loud, based on his color idiolect, the colors of samples selected randomly (with replacement) from an array of N samples. A "receiver" (R) attempts to identify S's selections from her duplicate array of color samples, based only on S's color term message and her own color idiolect. MI measures how much S's messages improve R's chances of guessing S's selections correctly. Computing average MI for all pairwise permutations of informants of a language provides an estimate of shared color knowledge within the informants' culture that takes into account the number of color samples tested, the number of color terms in informants' idiolects, and the group consensus in color term deployment. The communication game reveals several interesting properties of worldwide color naming. For example, MI is quite variable among the 110 World Color Survey languages using a given number of high-frequency color terms, because the consensus for those terms is often highly variable. Moreover, 96% of the variance in WCS MI can be accounted for by informants' responses to just 23 of 330 color samples tested in the WCS, suggesting a very efficient stimulus set for other color naming studies. Additionally, many informants of Hadzane, a language spoken by nomadic Tanzanian hunter-gatherers, profess no knowledge of names for many color samples, yet have surprisingly high group MI (relative to many WCS languages), because their limited lexicon is deployed with high consensus. Finally, we show that allowing informants to use two rather than one color name generally offers little improvement in group MI. Thus, information theory provides a powerful quantitative tool for studying human communication about color.

Acknowledgement: NSF BCS-1152841 to DTL and NEI RO1 EY10016 to DHB

Saturday Morning Posters

Perceptual Learning: Lower-level processes and mechanisms

Saturday, May 16, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

23.3001 **Dynamics of blur adaptation** Alissa Winkler[1] (awinkler@alumni.uci.edu), Susana Marcos[2], Stephen Engel[3], Michael Webster[1]; [1]Dept. of Psychology, University of Nevada, Reno, [2]Instituto de Optica, CSIC, Madrid, Spain, [3]Department of Psychology, University of Minnesota

Adaptating to blurred images changes visual performance in two ways: perceived focus of images alters almost immediately, and, more gradually, visual acuity improves. Do these aftereffects reflect changes in the strength of the same controlling mechanism over different durations, or are perceived blur and visual acuity controlled by separate adaptive mechanisms? To answer this question, we tracked the magnitude of blur aftereffects over periods up to 2 hours. Observers adapted by watching a film that was blurred by filtering the log amplitude spectrum to have a steeper slope (-0.5) but the same rms contrast as each original frame. The film was a documentary portraying natural outdoor scenes and was shown in grayscale on a calibrated monitor. Test trials were interleaved with the film at 7.5 sec intervals and alternated between a single static grayscale image of a natural textured scene with varying spectral slope, or a Landolt C pattern that varied in size. A quest routine was used to track perceived blur as the image slope that appeared in focus (neither too blurred nor too sharp) and a one-up, one-down staircase tracked the acuity limit for the Landolt C target (minimum angle of resolution). Blur aftereffects were strong and built up rapidly, but asymptoted after a few minutes and thus showed little increase at longer durations. In contrast, for our conditions acuity was not affected by the adaptation and thus did not systematically vary across the session. Our results indicate that the potential emergence of long-term acuity changes with blur adaptation may not coincide with corresponding changes in perceived image focus over time. This difference in timecourses suggests that dissociable mechanisms may underly the different aftereffects.

Acknowledgement: Supported by EY-10834

23.3002 **Dichoptic de-masking learning in adult amblyopes and its mechanisms** Jun-Yun Zhang[1] (zhangjy1982@gmail.com), Cong Yu[1]; [1]Department of Psychology and Peking-Tsinghua Center for Life Sciences, Peking University

Amblyopia is characterized by poor visual acuity in the amblyopic eyes (AEs) and degraded stereoacuity. Previously we found that dichoptic de-masking training aiming at reducing the impact of interocular suppression could further boost stereoacuity, but not visual acuity, in adult amblyopes who had received extensive monocular perceptual training (Zhang et al., VSS2013). Here we further investigated whether dichoptic de-masking learning is a low- or high-level process. Eleven new adult amblyopes used AEs to practice contrast or orientation discrimination with two aligned vertical/horizontal Gabors (80% contrast). The stimuli were dichoptically masked by a band-filtered noise masker simultaneously presented in NAEs. A 1-interval 2AFC staircase procedure estimated the maximal tolerable noise contrast (TNC). Training of dichoptic de-masking for contrast discrimination (n=6) doubled maximal TNC, but maximal TNC was unchanged at an orthogonal orientation, showing orientation specificity. AEs were then exposed to the orthogonal orientation through irrelevant orientation discrimination also under dichoptic masking, which improved maximal TNC for contrast discrimination at the orthogonal orientation as much as at the trained orientation. A control experiment confirmed that improved maximal TNC for contrast discrimination did not result from de-masking training for orientation discrimination. (2) Reversely, orientation specificity in dichoptic de-masking learning for orientation discrimination (n=5) was also eliminated by exposure of the transfer orientation through contrast discrimination under dichoptic masking. (3) Training (15-hrs) improved stereoacuity by 61.3%, similar to previous 66% improvements after two-stage monocular and dichoptic training. The complete orientation transfer of dichoptic de-masking learning and the task specificity suggest that dichoptic de-masking learning is mainly a high-level process. The brain may learn to readout orientation or contrast signals from dichoptically presented noise, and this learning is rule-based to allow transfer to untrained orientations. The training may also reduce the impact of interocular suppression to improve stereoacuity.

Acknowledgement: Natural Science Foundation of China Grants 31230030 and 31470975

23.3003 **Binocular suppression learning reveals inhibitory plasticity in early vision** Mark Vergeer[1] (mark.vergeer@ppw.kuleuven.be), Johan Wagemans[1], Raymond van Ee[1]; [1]Laboratory of Experimental Psychology, KU Leuven, Belgium

In visual perceptual learning, the ability to respond to visible stimuli is improved through practice. The visual input on our retina, however, is intrinsically ambiguous, supporting a multitude of valid representations. The brain selects one out of many possible visual interpretations, which is neurally enhanced, while alternative interpretations remain perceptually suppressed. Here, we show that not only visibility can improve through training, but that suppression can also be trained. Throughout training (in total 2560 trial), an oriented grating presented to one eye was constantly suppressed by a high-contrast expanding bull's eye presented to the other eye. This suppression-trained grating was always presented to the same eye, always with the same orientation within an observer. Pre- and post training detection thresholds were measured for target gratings with the suppression-trained orientation and for gratings with the orthogonal orientation, in the trained and untrained eye, independently, using an adaptive Quest procedure. The target gratings competed with a low-contrast expanding bull's eye presented to the opposite eye. Performance showed a stronger improvement after training compared to before training for gratings presented to the eye that was dominant during training (where the bull's eye was presented), indicating eye-based learning. Most interestingly, we found a stimulus-specific effect of suppression learning, where improvement was significantly worse for detecting the trained orientation, relative to detection of the orthogonal orientation. Hereby, we show stimulus selectivity in binocular suppression, and that observers can be trained to suppress a certain stimulus. These findings are indicative of the plasticity of inhibitory networks responsible for perceptual suppression.

Acknowledgement: This research was funded by an FWO Pegasus Marie Curie Fellowship, by the Flemish government and the European Union, awarded to Mark Vergeer and by Methusalem program by the Flemish Government (METH 08/02) awarded to Johan Wagemans.

23.3004 **Regulation of the expression of the cholinergic receptors in the visual cortex following long-term enhancement of visual cortical activity by cholinergic stimulation** Marianne Groleau[1] (marianne.groleau@umontreal.ca), Mira Chamoun[1], Menakshi Bhat[1,2], Frédéric Huppé-Gourgues[1], Réjean Couture[2], Elvire Vaucher [1]; [1]Laboratoire de Neurobiologie de la Cognition Visuelle, École d'optométrie, Université de Montréal, [2]Département de physiologie moléculaire et intégrative, Université de Montréal

The muscarinic and nicotinic transmissions in the primary visual cortex (V1) are involved in the enhancement of specific visual stimuli as well as long-term modifications of the neuronal processing, in regards to perceptual learning. We investigated the involvement of the different cholinergic receptors subtypes underlying this long-term functional plasticity using RT-PCR and recording of visual evoked potentials (VEPs). Perceptual learning-like test was performed by exposing awaken rats to a visual stimulation (VS) - a sinusoidal grating (30°, 0.12cpd) - for 10min/day during 14days. This VS was provided alone or coupled to an electrical stimulation of the basal forebrain which sends cholinergic projections to V1 (HDB/VS) or paired with a cholinesterase inhibitor (donepezil, 1mg/kg injected 30min prior to visual exposure) to enhance cholinergic transmission in V1 (DONEP/VS). One week after the last training session, VEPs were recorded and the cortices encompassing V1 were collected to determine the expression level of mRNA of muscarinic (M1-5) and nicotinic (α/β) receptors sub-units by RT-PCR. VS coupled to pharmacological or electrical stimulation of the cholinergic system produced a significant enhancement of the cortical response, as shown by VEP recordings. Two weeks of VS treatment alone caused an increase of the expression of M3 and M5 mRNA suggesting an increase of their production and activity during long-term visual stimulation. In the HDB/VS group, $\alpha 3$ sub-unit was decreased suggesting its involvement in phasic cholinergic stimulation. The DONEP/VS treatment presented a decrease in the expression of M2, suggesting a down regulation of mRNA

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synthesis. This could indicate an increased cortico-cortical inhibition, as M2 receptors are located massively on the GABAergic neurons. Therefore, even with similar functional enhancement, the cholinergic receptors regulation differs between an electrical and a pharmacological treatment. These results are crucial for determining which receptors are the most involved in the pharmacological cholinergic stimulation to enhance visual perception.

Acknowledgement: CIHR (MOP-111003) and NSERC (238835-2011)

23.3005 Explaining anterograde and retrograde interference in visual perceptual learning by a limited plasticity resource model

Qingleng Tan[1] (qingleng_tan@brown.edu), Kazuhisa Shibata[1], Yuka Sasaki[1], Takeo Watanabe[1]; [1]Department of Cognitive, Linguistic and Psychological Sciences, Brown Univeristy

Visual Perceptual Learning (VPL) refers to a long-term enhancement in visual task performance as a result of visual experience (Sasaki et al., 2009). To understand the mechanism of VPL, it is crucial to examine how VPL is temporally developed. One key phenomenon is interference, which occurs when training on a first task is followed by training on a second and competing task within a one-hour interval. Disruption of VPL of the first task by training on the second task is called retrograde interference (Seitz et al., 2005, PNAS), whereas disruption of VPL of the second task by training on the first task is called anterograde interference (Yotsumoto et al., 2009, Vis Res). Interference suggests that the state of VPL is fragile immediately after training. However, there is no model that successfully explains both retrograde and anterograde interference. Here, we built a Hebbian learning model ($\Delta\omega_{ij}=\alpha^*x_i^*y_j$, where the changes of weight equal to a learning rate α times the input x_i times response y_j and α=exp(-time2/σ2), where the learning rate decays with time) in which there is a limited plasticity resource for VPL within a certain time window ($\Sigma_{i,j}\omega_{ij}\leq c$). The model indicates that successive learning competes for the limited plasticity resource. The result of simulation indicates that the model can explain recent psychophysical and brain imaging results. First, short-period training leads to retrograde interference, whereas long-period training leads to anterograde interference. Second, the concentration of glutamate divided by the concentration of GABA in the primary visual cortex, termed the E(excitatory signal)/I(inhibitory signal) ratio increased after the short-period training, whereas it decreased after the longer-period training. These results indicate the current model can explain how the two types of interference occurs and would be useful for a better understanding of time-course development of VPL.

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23.3006 The neural mechanism of stabilization of perceptual learning revealed by the concentration of excitatory and inhibitory neurotrasmitter

Kazuhisa Shibata[1] (kazuhisa_shibata@brown.edu), Maro Machizawa[1], Edward Walsh[2], Ji-Won Bang[1], Li-Hung Chang[1], Aaron Berard[1], Qingleng Tan[1], Yuka Sasaki[1], Takeo Watanabe[1]; [1]Department of Cognitive, Linguistics, & Psychological Science, Brown University, [2]Department of Neuroscience, Brown University

Visual perceptual learning (VPL) is regarded as a manifestation of experience-dependent plasticity in the visual/brain system. It has been found that VPL of a task is disrupted or interfered with by training of a new task if the interval between the two training was less than one hour (Seitz et al, PNAS, 2005). This retrograde interference effect suggests that after training is over, it takes up to one hour for VPL to be stabilized. However, another study has found that first training also interferes with VPL of second training (Yotsumoto et al, Vis Res, 2009), indicating that the mechanism of interference and its relationship with stabilization process after VPL training is more complex than it was originally thought. The purpose of the present study is to resolve the puzzle and better clarify the underlying mechanism of stabilization and interference. In the first experiment, a detection task on a different orientation was repeatedly performed in each of the first and second training. There was no interval between the two trainings. The subjects who underwent 8-block training (N=12) showed retrograde interference, whereas the subjects who underwent 16-block training (N=12) showed anterograde interference. In the second experiment, we measured the concentration of excitatory and inhibitory neurotransmitters in the early visual cortex as a function of the length of training on an orientation detection task using magnetic resonance spectroscopy. The E(xicitaotry)/I(nhibitory) ratio defined by the concentration of glutamate divided by that of GABA was significantly higher after the 8-block training than before the training (N=12), whereas it was significantly lower after the 16-block training (N=12). These results are in accord with the hypothesis that a lower E/I ratio is associated with greater resilience against being interfered with and therefore greater stability of VPL.

Acknowledgement: This work was supported by NIH grant R01 EY019466 and JSPS.

23.3007 Seeing to see: How templates enhance visual perception

Zhicheng Lin[1] (zhichenglin@gmail.com), Barbara Dosher[2], Zhong-Lin Lu[1]; [1]Department of Psychology, Ohio State University, [2]Department of Cognitive Sciences, University of California, Irvine

In order to find a target, one needs to know what the target is. The process of internalizing the target template is critical for visual perception. For example, by previewing a target object just once, this one-shot seeing has been shown to enable sustained improvement in perceiving subsequent objects, an effect known as insight (Rubin, Nakayama & Shapley, 1997) or eureka (Ahissar & Hochstein, 1997). Here, we report a new type of template enhancement effect that lasts longer than (transient) visual priming, but has a shorter lifetime than (sustained) insight/eureka. Subject performed a shape discrimination task (square vs. diamond) with two target durations: 200 ms (easy) and 16.7 ms (hard). We compared discrimination performance in mixed and single blocks. The mixed blocks consisted of 10 hard trials, 20 alternating easy and hard trials, and 10 hard trials. The single blocks consisted of 40 hard trials. The mixed and single blocks alternated with at least 15 s interval between blocks; a total of 28 blocks were run. We found that, performance was much better for the 2nd 10 hard trials than for the 1st 10 hard trials (83% vs. 69% correct), but only for the mixed blocks, demonstrating that mixing easy trials greatly enhances performance in the hard trials. In addition, this effect spilled over to enhance subsequent hard trials, with little drop in performance, resulting in comparable performance between the 2nd and 3rd 10 hard trials in the mixed blocks. However, this effect did not carry over to the single blocks, resulting in comparable performance between the 1st 10 hard trials in the mixed and single blocks. These results reveal a fast route of visual learning, whereby the visual system exploits target templates to enhance visual perception in a temporally restrictive manner. We call this template effect seeing to see.

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23.3008 An integrated reweighting theory accounts for the role of task precision in transfer of perceptual learning for similar orientation tasks

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

Specificity is one of the hallmark findings of perceptual learning. One of the factors influencing the extent of specificity is the difficulty of the training task1 or, alternatively, the precision of the transfer task2. For example, the specificity of perceptual learning is higher for more precise (±5°) than less precise (±12°) orientation discrimination transfer tasks at new reference angle and retinal locations, essentially independent of the precision of the training task2 (see also second-order3 or first-order4 motion direction tasks). Recently, an integrated reweighting theory (IRT)5 was developed to account for the degree of specificity over position. The IRT reweights evidence from both location independent and location specific representations to decision to account for transfer and specificity. Here we develop the predictions of the IRT for the effects of judgment precision on transfer2, using a visual front end of normalized spatial-frequency and orientation tuned channels and Hebbian reweighting to decision, augmented by feedback and criterion correction5. The exact details of the experiment are reprised to generate simulated model predictions. The IRT correctly predicts that the specificity depends upon the precision of the transfer task, relatively independent of the precision of the training task. In sum, when the training and the transfer tasks involve the same kinds of judgments but use stimuli that are rotationally symmetric, the degree of specificity is primarily driven by the precision of the transfer task. A more precise judgment in the transfer task is more demanding and so shows more specificity and less transfer. The IRT model can also be used to make predictions about a number of related phenomena in perceptual learning.

23.3009 Exploring timescales of adaptation mechanisms along the visual-processing hierarchy

Gaoxing Mei[1] (meigx@psych.ac.cn), Xue Dong[1], Min Bao[1]; [1]Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, Beijing, P.R. China

Recent work has indicated that adaptation is controlled by multiple mechanisms acting at different timescales, but their neural underpinnings remain largely unknown. Here we explored this issue with two psychophysical experiments. We first used a "deadaptation" procedure (Bao, Fast, Mesik, & Engel, 2013) to investigate contrast adaptation under either the binocular or monocular adaptation condition. Thresholds were measured with a spatial 4-AFC contrast detection task, tracked by a one-down-one-up staircase. The "deadaptation" duration was individually set, based upon a pilot test where 5 minutes of adaptation to high contrast was followed by 280s of deadaptation. Interestingly, the effects of adaptation failed to completely decay to the baselines under the monocular condition in 21 out of 37 subjects, but succeeded under the binocular condition in everyone. For the 16 subjects whose adaptation's effects could deadapt to the baselines, their data showed spontaneous recovery in the post-tests, demonstrating that multiple mechanisms controlled adaptation in both conditions. Critically, it took longer to deadapt to the baseline ($p < .001$) in the monocular (84s) than the binocular condition (51s). Given the larger proportion of monocular neurons activating in the binocular condition, these results suggest that longer-term mechanisms reside at the binocular processing stage. To compare the timescales of mechanisms spanning wider in the visual processing hierarchy, we modified Hancock and Pierce's (2008) paradigm to track the decay of TAE in 15 subjects after adaptation to either the compound gratings (curvature) or component gratings. An exponential function was fit to the timecourses following adaptation, which revealed slower time constant ($p < .05$) for the compound (149s) than the component (113s) adaptation condition. This indicates longer-term mechanisms in the mid-level (e.g. V4) than the early visual areas. Our findings imply that cortical mechanisms for controlling adaptation may become more sluggish along the visual processing stream.

23.3010 **Repeatedly adapting to orientation ensembles does not change contrast adaptation dynamics**

Juraj Mesik[1] (mesik002@umn.edu), Akshay Patke[1], Stephen Engel[1]; [1]Department of Psychology, University of Minnesota

Contrast adaptation adjusts sensitivity to match the statistical structure of the world. Does the visual system adapt faster to statistics with which it has prior experience? To answer this question, we repeatedly adapted subjects (n=6), over the course of 4 days, to three distinct sets of contrast statistics, and measured the growth and decay of the tilt-aftereffect. Subjects viewed 2 min sequences comprised of rapidly presented sinusoidal gratings of 12 different orientations (33 ms/grating, 85% contrast). The sequences were either uniform across orientation, or biased, with one orientation much more likely than the others (66% vs 3% probability). The biased sequences have been shown to induce contrast adaptation to the high probability orientation. "Adapter" and unbiased "test" sequences were presented simultaneously on opposite sides of fixation at 2.5 deg eccentricity. To measure the tilt-aftereffect, every 1 sec a pair of 2.5 deg, 50% contrast gratings were inserted in the sequences for 250 msec. Using a mouse, subjects adjusted the tilt of the grating in the test sequence to match its apparent orientation in the adapter sequence. The test was oriented 13, 15, or 17 deg away from the biased orientation, offsets at which robust tilt-aftereffects are observable. Every day, subjects completed 4 task runs, each containing 5 blocks that alternated between biased adapters and unbiased "baseline" adapters. The biased adapters induced a strong tilt-aftereffect (on average ~2 deg). However, we observed no change in adaptation dynamics across the 4 days. Adaptation growth and decay time constants and peak tilt-aftereffect levels did not reliably change across the 4 days ($p>0.05$). Our results suggest that the visual system cannot learn to adapt more quickly to statistical regularities in low-level visual features, at least over the timescales tested here.

23.3011 **The psychophysical mechanisms underlying the transfer of perceptual learning enabled by double training**

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Although visual perceptual learning is often location specific, learning can transfer to a new location/hemisphere if the new location/hemisphere is additionally trained with an irrelevant task (Xiao et al., 2008). Here we characterized the impact of this double training on Vernier learning and its transfer at various levels of external noise. The 2-Gabor Vernier was imbedded in five levels of white noise (rms contrast 0%□29%) and centered in a visual quadrant at 5o eccentricity. When training was at zero noise, Vernier thresholds were reduced at all noise levels at the trained location, and at high noise at the diagonal quadrant location. However, if orientation discrimination with a Gabor at zero noise was also practiced at the diagonal location, Vernier thresholds were improved at all noise levels at the same location. The pre- and post-training TvC functions were similar across trained and untrained locations. When training was at high noise, Vernier thresholds were only reduced at high noise at both trained and untrained locations. Interestingly, if Gabor orientation discrimination at zero noise was also practiced at the diagonal location, Vernier thresholds at lower noise levels were improved at both trained and untrained locations. Again the pre- and post-training TvC functions were similar across trained and untrained locations. Fitting TvC functions of Vernier learning revealed that: After double training the reduction of equivalent internal noise transferred from trained to untrained location when Vernier training was at zero noise. Double training also reduced equivalent internal noise at both trained and untrained locations when Vernier training was at high noise. These improvements at both trained and untrained locations due to training of an irrelevant task at the diagonal location suggest that equivalent internal noise reduction is realized through a high-level process.

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23.3012 **Under-stimulation at untrained orientation may explain orientation specificity in perceptual learning**

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Perceptual learning (PL) can transfer completely to an orthogonal orientation if the latter is exposed through an irrelevant task in a Training-plus-Exposure (TPE) paradigm (Zhang et al., 2010). This and additional evidence for learning transfer to new locations/hemisphere after double training (Xiao et al, 2008) suggests that PL reflects cognitive changes beyond the early visual areas. However, it is unclear why PL is orientation specific in the first place and why exposure to the transfer orientation enables learning transfer. Here we used a continuous flashing suppression paradigm to investigate the role of orientation exposure in TPE training. Foveal orientation discrimination was always trained at one orientation. In other blocks of trials flashing white noise was presented to one eye, which suppressed the awareness of an orthogonal Gabor (sometimes a letter C) presented to the other eye. In Experiment I, the observers reported the color (red/green) of a small dot centered on the flashing noise images. They were not told that an orthogonal Gabor was shown to the other eye. This bottom-up orientation exposure produced partial learning transfer to the orthogonal orientation. In Experiment II, the observers guessed whether a Gabor/C was presented, but the orthogonal Gabor was not shown. Such top-down only "orientation exposure" led to no learning transfer. In Experiment III when the orthogonal Gabor did show, learning transfer was complete with this combined bottom-up and top-down orientation exposure. These results indicate that bottom-up orientation exposure is required for learning transfer, and that orientation specificity may result from under-stimulation of untrained orientations, possibly because these orientations are unstimulated or even suppressed during training. Although top-down influence itself has no impact on learning transfer, it can boost the effect of bottom-up exposure, so that high-level learning can functionally connect to new orientation inputs for complete learning transfer.

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23.3013 **Expectation and the tilt aftereffect**

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Exposure to oriented stimuli leads to a bias in the perceived orientation of subsequently viewed stimuli (tilt aftereffect, TAE). This is traditionally attributed to sensory adaptation, and viewed as a stimulus-driven process, independent of stimulus predictability. Here, we tested whether the magnitude of the TAE is modulated by expectations, and specifically, whether TAE depends on the congruency of adapted and expected orientations. Observers were presented at fixation with successive pairs of oriented Gabor patches (s=0.6°, l=0.3°). Each Gabor was presented for 50ms with 600ms interval between pair members (pairs were separated by 1-1.5secs). Gabor pairs were arranged in blocks, forming two experimental conditions with orientation either expected or not expected. For all blocks, the orientation of the first Gabor in each pair was randomized (±20° relative to vertical). In the 'expected' condition, the orientation of the second Gabor correlated, either positively or negatively, in different sessions, with that of the first Gabor. In the 'not-expected' condition, the orientation of the second Gabor was independent of the first Gabor (randomized ±20°). Intermixed test trials (33%) were used to measure the shift in subjects' perceived vertical, with the second pair member serving as a target, oriented around the vertical, permitting a measurement of the TAE produced by the presentation of the first Gabor member. Presentation of the oriented Gabors led to a tilt aftereffect, which was modulated by the expected orientation. The aftereffect was significantly higher (N=5; $p< 0.01$, pairwise t-test) in the positively correlated blocks (1.6°±0.2SE) than in the corresponding 'not expected' blocks (1.0°±0.3SE). In the negatively correlated blocks (N=2), the aftereffect was lower (0.6°±1.1SE) than in the corresponding 'not expected' blocks (1.0°±0.7SE). These findings indicate a role

of expectation in generating the perceptual tilt aftereffect and are in line with predictive coding models of perception. Acknowledgement: BRF/ISF.

23.3014 Transcranial Random Noise Stimulation Enhances Visual Learning In Healthy Adults

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Recent psychophysical studies have demonstrated that visuo-perceptual functions can improve over multiple training sessions, both in healthy adults (Sagi, 2011) and in hemianopic stroke patients (Das et al., 2014). To date, rehabilitative therapies for hemianopic patients have shown significant improvements only after many weeks of daily training. Recent studies using transcranial direct current stimulation (tDCS) have shown enhancement of visual performance in normal subjects. Notably, when current is applied in a random noise mode (tRNS), effects are seen earlier and are longer lasting. Here, we asked whether tDCS or tRNS can be used to boost visual perceptual learning of global direction discrimination, thus providing a proof-of-concept for the potential use of this approach in pathological populations. We tested 40 healthy, visually-intact subjects, aged 19-26 who were randomly assigned to 4 training groups: “anodal tDCS”, high frequency “hf-tRNS”, “sham” and “no-stimulation”. All subjects were trained to discriminate the left or right global motion direction of random-dot stimuli for 10 days (one session/day). Before and after training, we measured the subjects’ direction range and motion signal thresholds. Brain stimulation was delivered concurrently with the training task. For the active stimulation conditions, anodal tDCS was delivered over the occipital pole, while for hf-tRNS and sham, electrodes were positioned bilaterally over the left and right occipital poles. On average, all subjects improved over the two-weeks training period. However, the hf-tRNS group attained a direction range threshold of 162.88° (subtracting day10 from day1), while the “tDCS”, “sham” and “no stimulation” subjects attained a threshold of 53.57°, 126.6° and 88°, respectively. Paired sampled t-tests indicated a significant effect of hf-tRNS on performance relative to the other groups (p = .03). These results indicate that hf-tRNS may be a more effective intervention to boost visual perceptual learning than tDCS or no stimulation during visual training.

23.3015 Criterion Learning in an Orientation-discrimination Task

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Humans often make decisions based on uncertain sensory information. Signal detection theory describes detection and discrimination decisions as a comparison of stimulus “strength” to a fixed decision criterion. How is the criterion set? We examine how observers learn to set a decision criterion in an orientation-discrimination task. To investigate mechanisms underlying trial-by-trial criterion placement, we compared two tasks. (1) The typical covert-criterion task: Observers make binary discrimination decisions and the underlying criterion is unobservable. (2) A novel overt-criterion task: Observers explicitly set the decision criterion. In each task, stimuli were ellipses with principle orientations drawn from two categories: Gaussian distributions with different means and equal variance. In the covert-criterion task, observers categorized an ellipse. In the overt-criterion task, observers adjusted the orientation of a line on every trial, which served as the discrimination criterion for the subsequently presented ellipse. Feedback was provided at the end of every trial and the observer’s goal was to maximize the number of correct categorizations. The category means were constant throughout each block but changed across blocks. Observers had to relearn the categories for each block. We compared observer performance to the ideal Bayesian model and several suboptimal models (moving average, exponential moving average, reinforcement learning, and limited memory) that varied in both computational and memory demands. While observers were able to learn the optimal criterion over many trials, we found that, in both tasks, observers used suboptimal learning rules. A model in which the recent history of past samples determines a belief about category means (the exponential moving average rule) fit the data best for most observers and on average. We also investigate an analogous task in which category means change slowly over time (a random walk). Our results reveal dynamic adjustment of discrimination criterion, even after prolonged training.

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Perception and Action: Complex interactions

Saturday, May 16, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

23.3016 Action Videogame Play Improves Visual Motor Control

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Can action videogame play improve visual motor control? If yes, can it be used in training complex visual motor skills such as driving? Here we took a control-theoretic approach and tested non-video-game players with a typical compensatory manual control task. After playing a driving (Experiment 1) or a first-person shooter (FPS) action videogame (Experiment 2) for only five hours, participants improved significantly in both the control precision (measured as the RMS error) and response amplitude (gain) for their performance on the manual control task. No enhancement on participants’ contrast sensitivity function was observed. We fit the performance data to an extensively validated Crossover Model to further understand how action gaming affects the perceptual system that processes visual information and the neuromuscular system that executes the control command. Our model-driven analysis revealed that playing either a driving or an FPS game improved the perceptual sensitivity to input visual information for online motor control; that playing the FPS game also facilitated anticipating input errors to generate control ahead of time but hurt the stability of the neuromuscular system. In contrast, no effect on the control performance was observed for participants who played a non-action videogame. We then examined whether the improvement in the performance on the manual control task can transfer to daily visual motor control tasks such as driving. We found that lane-keeping performance significantly improved for participants who completed a 40-min training session of the manual control task while no such improvement was observed for participants without training. In summary, the present study provides the first empirical evidence for a causal link between action gaming (for as short as five hours playing) and enhancement in visual motor control. The findings have practical implications for developing training tools to improve performance on daily visual motor control tasks such as driving.

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23.3017 Unconscious perception of an opponent’s goal

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Humans are experts at reading others’ actions. They effortlessly navigate a crowded street or reach for a handshake without grabbing an elbow. This suggests real-time, efficient processing of others’ movements and the ability to predict intended future movements. We designed a competitive reaching task where two subjects faced each other separated by a plexiglass screen. Fingertip positions were recorded with magnetic sensors. One subject (Attacker) was instructed via headphones to tap one of two targets on the screen and the other subject (Blocker) was told to try to reach the same target as quickly as possible. Reaction times, measured as the difference in initial finger movement (finger launch) of Attacker and Blocker were fast (~150ms): much faster than reaction times to a moving dot projected on the screen (~250ms). This suggests Blockers use preparatory actions of Attackers to predict their goal before finger launch. Next, we videotaped an Attacker and projected the video onto the transparent screen. Blockers’ reaction times to the videos matched those to a real Attacker. In half the blocks we cut the preparatory information from the video. Blockers were ~120ms slower responding to cut videos, suggesting preparatory information is predictive ~120ms before finger launch. Finally we played the videos from the start to various times relative to finger launch and asked subjects to report the Attacker’s goal with button presses. Surprisingly when videos were cut at ~120ms before finger launch subjects’ accuracy was ~70%: significantly lower than the accuracy of arm movements in response to full videos (~98%). This suggests that in the arm movement task subjects utilize implicit information that is not consciously accessible in the button press task. Taken together, these results suggest participants in a competitive interaction have implicit or unconscious knowledge of the intentions of their partner before movement begins.

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23.3018 **How drawing shapes object representations** Judith Fan[1] (jefan@princeton.edu), Daniel Yamins[2], Nicholas Turk-Browne[1]; [1]Department of Psychology, Princeton University, [2]McGovern Institute for Brain Research, Massachusetts Institute of Technology

Drawing is a powerful tool for communicating ideas visually — a few well-placed strokes can convey the identity of a face, object, or scene. Here we examine how people learn to draw real-world objects in order to understand the more general consequences of visual production on the representation of objects in the mind. As a case study, we ask: How does practice drawing particular objects affect the way that those and other objects are represented? Participants played an online game in which they were prompted on each trial with an image (N=314) or word (N=276) that referred to a target object for them to draw. We used a high-performing, deep convolutional neural network model of ventral visual cortex to guess the identity of the drawn object in real time, providing participants immediate feedback about the quality of their drawing. Objects belonged to one of eight categories, each containing eight items. Each participant was randomly assigned two of these categories. During training, participants drew four randomly selected objects in one category (Trained) multiple times. Before and after training, participants drew the other four objects in that category (Near), as well as the objects in the second category (Far), once each. We found that drawings of Trained items were better recognized by the model after training, and that this improvement reflected decreased confusions with other items in the same category. By contrast, recognition of Near items worsened after training, which reflected increased within-category confusion. Recognition of Far items did not change significantly. These results show that visual production can reshape the representational space for objects: by differentiating trained objects and merging other objects nearby in the space. More broadly, these findings suggest that the outward expression of visual concepts can itself bring about changes to their internal representation.

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23.3019 **Motor action can make natural scenes pleasant: It's just a matter of comfort** Carlo Fantoni[1,2] (cfantoni@units.it), David Pearson[3], Luca Ianza[1], Walter Gerbino[1]; [1]University of Trieste, Department of Life Sciences, Psychology Unit "Gaetano Kanizsa", Trieste, Italy, [2]Istituto Italiano di Tecnologia, Center for Neuroscience and Cognitive Systems@UniTn, Rovereto, Italy, [3]University of Aberdeen, School of Psychology, Aberdeen, United Kingdom

Recently we have shown that performing comfortable and uncomfortable reaching acts produces dramatic changes in the perception of facial expressions consistent with motor action induced mood congruency. More anger is needed to perceive neutrality in a happy-to-anger morph continuum (Fantoni & Gerbino, 2014), and a lower absolute threshold for the detection of happiness is required after performing a sequence of comfortable than uncomfortable reaches (Fantoni, Cavallero & Gerbino, 2014). Here we asked whether such influences generalize across the entire affect domain or whether they are specific for faces. In two experiments considering the biphasic representation of motor actions, we tested whether performing comfortable vs. uncomfortable motor actions might change the way in which the valence and the arousal components of natural scenes influence our affective choice. In order to induce comfort/discomfort, we used our Motor Action Mood-Induction Procedure (MAMIP). This included two successive visually guided reaching blocks each involving a sequence of reaches with the depth extent randomly selected in the 0.65-to-0.75 (Comfortable) or the 0.90-to-1.00 (Uncomfortable) arm length range. After each block participants performed a sequential image selection task on a randomized set of 27 IAPS natural scenes varying in valence and arousal. The likelihood of affective selection was well described by a combination of sigmoid functions of valence and arousal: per cent selection monotonically increased with valence, with the rate of increase decreasing as arousal grew larger. Importantly, we found a mood-congruent effect following MAMIP. Action comfort enhanced the quality of observer's global experience, with perceived scene neutrality after comfortable reaches requiring less valence and arousal than after uncomfortable reaches. Relative to inaction (Experiment 2), action enhanced scene attractiveness with an increment of selection choices in Experiment 1. We conclude that influences by action-induced mood are general and not restricted to the domain of facial expression.

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23.3020 **Nonconscious Emotional Information Boosts Categorically Unrelated Concurrent Visual Decisions** Galang Lufityanto[1] (g.lufityanto@unsw.edu.au), Joel Pearson[1]; [1]The University of New South Wales, Australia

Can categorically different sources of unconscious information be utilised to aid in concurrent perceptual decisions? Here, we employ a novel empirical paradigm that utilises a noisy visual decision task and the concurrent presentation of suppressed emotional images. Using continuous flash suppression we rendered both positive and fearful images nonconscious. Participants had to decide the direction of random dot motion stimuli presented simultaneously with the suppressed emotional images. The binary emotional valence of the images (positive or negative) was concordant with the direction of the motion in the decision stimulus (right or left) across 6 levels of dots motion coherence. We found that that suppressed emotional images boosted decision accuracy, sped up reaction times, and increase reports of confidence for brief presentation of stimuli (i.e. 400 ms) relative to a spatial phase-scrambled version of the same images. However, accuracy was no higher when the decisional stimulus was paired with different categories of non-emotional images. To test the contingency between emotional and sensory information, we reversed the association between emotional valence (positive and negative emotion) and dot motion direction on the third block of trials. When the association was reversed the difference in accuracy between the intact emotional images and their phase-scrambled version disappeared. A consistent contingency between emotional valence and dot direction is seemingly required for individuals to utilize unconscious emotional information in the otherwise unrelated decision task. Next, we measured skin conductance while participants performed the emotionally boosted decision task. We found a differential skin conductance response to suppressed normal images compared to the phase-scrambled control images. More importantly, the electrodermal activity declined with increasing dots motion coherence suggesting an interaction with decisional difficultly. Together these data suggest a possible new experimental paradigm to investigate the dynamics of processes and experiences often described as intuition.

23.3021 **Perceptual Distortions of Distances on a Hill Depend on Interoceptive Awareness** Nathan Tenhundfeld[1] (nlt4au@rams.colostate.edu), Jessica Witt[1]; [1]Department of Cognitive Psychology, College of Natural Sciences, Colorado State University

Research has shown that distances on a hill appear further than they do on the flat ground (Stefanucci, et al., 2005). It is theorized that this perceptual distortion is a function of energetic demands associated with traversing the hill, compared to the flat ground. A big question concerns the nature of information about action and how it is then integrated with visual information. One theory is that information about action is detected on-line from proprioceptive and interoceptive receptors (Witt & Riley, 2014). If perceivers depend on interoception to provide cues about our internal states as they relate to the environment, those who show greater sensitivity to interoceptive information might also show a greater effect of the hill on perceived distances. Here, we tested that idea by assessing individuals' ability to detect their own heart rate, which is a standard measure of interceptive awareness. Participants verbally estimated the distance to cones placed on the hill and on the flat ground, followed by a heart rate estimation task. The effect of hill versus flat on perceived distance was significantly modulated by heart rate detection ability, $F(1,49) = 4.45$, $p = .04$. The best heart-rate estimators (top two-thirds) revealed a significant effect of terrain (hill vs flat) on perceived distance, $F(1, 34) = 17.52$, $p < .001$. The bottom third, however, did not, $F(1, 15) = 0.52$, $p > .48$. These results indicate that for individuals with greater interoceptive awareness, perceived distance is affected by the hill, while for those with worse interoceptive awareness, perceived distance is not. Stated another way, those who are more in tune with their internal states appear be more affected by anticipated energetic expenditures. This suggests that the perceptual distortions related to energetics are likely due to the ability to sense internal responses to the anticipation of action.

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23.3022 **Metacognitive ability of confidence sharing modulates optimization of collective perceptual decision** Peiyuan Zhang[1,2] (an.inspired.idea@gmail.com), Chang-Bing Huang[1]; [1]Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, Beijing, China, [2]Department of Psychology, Peking University, Beijing, China

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Much is known about how metacognition modulates individual performance in perceptual decision. Yet to be determined is how metacognitive ability modulates the performance of collective perceptual decision. In the first experiment (Exp 1), we adopted a contrast discrimination task and examined the relationship between collective (dyad) and individual sensitivities in 12 groups (12 groups*2 subjects/group). Individual decisions were shared after each participant made choice without consulting each other; If participants disagreed, they discussed the matter until they reached a joint decision. We found that although collective perceptual sensitivity can be generally explained by a weighted confidence sharing model (WCS) that assumes individuals communicate genuinely their level of confidence (i.e. uncertainty) and two heads are Bayes-optimally integrated (Bahrami, et al., 2010), there is evident discrepancy between WCS model prediction and empirical collective sensitivity in many groups. Aiming to test whether metacognitive ability contributed to this collective failure, eleven groups were asked to report their level of confidence via confidence rating after joined decision was made (Exp 2; 11 groups*2 subjects/group). Metacognitive ability was quantified by the interrelationship of the confidence rating and the accuracy of visual judgments using the type-II receiver operating characteristic (ROC) curve (Fleming, et al., 2010). The result showed that the discrepancy between the empirical and predicted collective sensitivity negatively correlated with group metacogntive ability (r=-.703, p=0.016); the higher the metacognitive ability, the less the discrepancy. In experiment 3, we confirmed the findings in the case of triad decision (8 groups*3 subjects/group): discrepancy between empirical performance and the WCS model prediction negatively correlated with group metacognitive ability (r=-.749, p=0.018). To conclude, our results implied that metacognitive ability of understanding and communicating visual uncertainty modulates optimization of collective perceptual decision.

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23.3023 **Motor-evoked potentials reveal a motor-cortical readout of evidence accumulation for sensorimotor decisions**

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Many everyday activities, such as driving and sports, require us to engage in time-pressured sensorimotor decision making in response to visual cues. The computational principle of continuous evidence accumulation is the dominant account underlying models of speeded decision making, but the nature and locus of the decision variable that triggers action is debated. Traditionally, cognitive stages such as perception, stimulus-response translation, and the generation of motor plans, have been considered to occur in series. However, this idea is challenged by neurophysiological work in animals, suggesting that cognitive operations are distributed across sensorimotor cortex. Here, we investigate whether a decision variable can be observed in the primary motor cortex (M1) of humans. Participants categorised faces as male or female, with task difficulty manipulated using natural or morphed stimuli. Transcranial magnetic stimulation, applied at random across the reaction-time interval, produced motor-evoked potentials (MEPs) in two hand muscles that were the major contributors when generating the correct and incorrect pinch/grip movements. MEP magnitudes reveal covert action preparation, even when no action is produced. Smoothing MEPs using a Gaussian kernel allowed us to recover a continuous time-varying MEP average, comparable to an EEG component, which permitted precise localisation of the time at which the motor plan for the responding muscle began to dominate over the non-responding action. This moment was calculated in both stimulus-locked and response-locked analyses, and was found to occur at the same time with stimulus locking, but earlier with response locking, when ambiguous stimuli made the decision more challenging. This pattern is consistent with M1 providing a continuous readout of evidence accumulation. We predicted the evidence accumulation profile from a drift diffusion model, using only behavioural data, and found a good qualitative match to the observed neurometric MEP profiles.

23.3024 **Encoding attentional-states during visuomotor adaptation**

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We recently showed that visuomotor adaptation acquired under attentional distraction is better recalled under a similar level of distraction compared to no distraction. This paradoxical effect suggests that attentional state (e.g., divided or undivided) is encoded as an internal context during visuomotor learning, and should be reinstated for successful recall (Song & Bédard, in press). To investigate if there is a critical temporal window for encoding attentional state in visuomotor memory, we manipulated whether participants performed the secondary attention-demanding task concurrently in the early or late phase of visuomotor learning. Recall performance was enhanced when the attentional states between recall and the early phase of visuomotor learning were consistent. However, it reverted to untrained levels when tested under the attentional state of the late phase learning. This suggests that attentional state is primarily encoded during the early phase of learning before motor errors decrease and reach an asymptote. Furthermore, we demonstrate that when divided and undivided attentional states were mixed during visuomotor adaptation, only divided attention was encoded as an internal cue for memory retrieval. Therefore, a single attentional state appears to be primarily integrated with visuomotor memory while motor error reduction is in progress during learning.

23.3025 **Canonical Viewpoints for Videos of Assembly Tasks**

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Canonical-views for static objects are defined as preferred-views that provide richer spatial information and richer cognitive processing (Palmer, Rosch, & Chase, 1981; Blanz, Tarr, & Bülthoff, 1999; Ghose & Liu, 2013). For simple dynamic scenes consisting of three moving balls on a flat surface, canonical-views provide richer information about temporal changes in the spatial relationships (Garsoffky, Huff, & Schwan, 2007; Garsoffky, Schwan, & Huff, 2009). In this research we ask (1) if there is a single canonical-view for an entire movie depicting an assembly task, and (2) if the canonical-view depends on a specific assembly-step or action-type. The stimuli consisted of three complex assembly tasks taken from a technical construction toolkit. Each scenario was recorded from 5 different viewpoints, namely, self, opposite-to-self, left, right and top. The mean assembly time per scenario was 4 min and 14 sec. The actor in the video was right-handed. There were 66 assembly-steps with 7 action-types. Procedure: A pair of video clips showing the same step appeared successively at two different positions on the screen. After the first showing, the videos were played back in a loop until the participant responded. The task was to choose the "better-view" for learning the assembly-step. Data from 20 participants show that canonical-view varies to some extent from assembly-step to assembly-step. The self and the opposite-to-self views were most-preferred 74% of the time. Left and right views were least-preferred 76% of the time. That is, views along the median plane were rated as "better" for learning than frontal and top plane for every action-type. An "unambiguity measure" was calculated for each assembly-step as mean frequency of (most minus least) preferred-views. Higher unambiguity values mean that the best perspective is unambiguously preferred. The median views are unambiguously preferred over other views suggesting these are canonical-views of actions.

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23.3026 **Motor planning and control: Humans interact faster with a human than a robot avatar**

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How do we control our bodily movements when socially interacting with others? Research on online motor control provides evidence that task relevant visual information is used for guiding corrective movements of ongoing motor actions. In social interactions observers have been shown to use their own motor system for predicting the outcome of another person's action (direct matching hypothesis) and it has been suggested that this information is used for the online control of their social interactions such as when giving someone a high five. Because only human but not non-human (e.g. robot) movements can be simulated within the observer's motor system, the human-likeness of the interaction partner should affect both the planning and online control of movement execution. We examined this hypothesis by investigating the effect of human-likeness of the interaction partner on motor planning and online motor control during natural social interactions. To this end, we employed a novel virtual reality paradigm in which participants naturally interacted with a life-sized virtual avatar. While 14 participants interacted with a human avatar, another 14 participants interacted with a robot avatar. All participants were instructed to give a high-five to the avatar. To test for online motor control we randomly perturbed the avatar's hand trajectories during participants' motor execution. Importantly, human and robot looking avatars were executing identical movements. We used optical tracking to track participants' hand positions. The analysis of hand trajectories showed that participants were faster in carrying out the high-five movements with humans than with robots suggesting that the human-likeness of the interaction partner indeed affected motor planning. However, there was little evidence for a substantial effect of the human-likeness on online motor control. Taken together the results indicate that the human-likeness of the interaction partner influences motor planning but not online motor control.

Visual Search: Eye movements and memory

Saturday, May 16, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

23.3027 Feedback about gaze position improves saccade efficiency

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When searching for an unknown number of noisy targets in a limited time, looking at uncertain locations is more efficient than looking at locations with a high probability of the target. Previously, we showed that immediate saccadic feedback that revealed the true identity of a noisy stimulus was effective in improving saccade efficiency (Verghese, Ghahghaei, 2013). However, the stimuli in that task were not limited by visibility, and the feedback artificially removed any ambiguity about the identity of the stimulus as soon as a saccade landed at that location. Here we examine if the increase in visibility upon naturally foveating a target combined with simple knowledge about eye position will encourage a strategy to fixate informative locations. Observers actively searched a brief display (900 ms) with six Gabor patches in noise, located 3 degrees from fixation to locate an unknown number of horizontal targets, among vertical distractors. The contrast of the Gabors was high or low such that the orientation of the high-contrast Gabor was perfectly discriminable at 3 degrees, but that of the low-contrast Gabor only upon foveation. Thus, saccades to low-contrast rather than high-contrast locations were more informative. In separate blocks participants received either (i) no gaze feedback, (ii) delayed gaze feedback at the end of the trial, or (iii) immediate gaze feedback after each saccade in the trial. Feedback was provided by changing the color of the ring that surrounded each location. In the absence of feedback, participants differed in the proportion of saccades to informative locations, with a greater proportion for more experienced participants. Both immediate and delayed feedback increased the proportion of informative saccades for four out of five participants. Furthermore, gaze feedback increased the latency of the first saccade and reduced the number of reflexive saccades to salient locations, making saccades more informative.

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23.3028 Visual Search for Transparent Overlapping Objects in Depth: Overlap Impairs Performance, but Depth does not benefit Performance

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During everyday visual search tasks, such as searching for keys in a cluttered room, it is commonplace for objects to overlap one another and occur at different levels of depth. This situation stands in contrast to standard search tasks in which objects are presented on a single depth plane and do not overlap with one another. We previously examined how overlap and depth influence search performance by asking participants to search displays containing overlapping opaque polygons presented on different depth planes to one another. We found that overlap impaired search performance (increased RTs, decreased accuracy), and the presence of depth in the highly-overlapping displays decreased RTs. Here, we extend this previous work to examine search in displays containing transparent overlapping coloured polygons, again assessing whether the presence of depth aids performance, and whether overlap impairs performance. In such displays, overlap results in combinations of colours that alter the colour (but not the shape) of objects. We found that, with transparent displays, response accuracy was high – higher than our previous study where participants searched overlapping opaque objects. However, this increase in accuracy came at the cost of increased RTs. Finally, the presence of depth information in the displays had no effect on accuracy or speed. Overall, in displays containing opaque objects, response accuracy is negatively affected by overlap because the opaque nature of the objects removes information regarding object identities. However, in displays containing transparent objects, accuracy is negatively affected by overlap to a lesser extent, while response times are negatively affected to a greater extent. This is because information regarding object identity is available in transparent displays, but it requires more time to disambiguate each object's identity from that of other objects. The delay occurs because the transparency of overlapping objects changes and obfuscates the colour of the objects.

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23.3029 Scene context reduces distractor set-size effects during search

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Scene context guides eye movements and facilitates search performance (Torralba et al., 2006; Chen & Zelinsky, 2006; Eckstein et al., 2006). Here, we assess how scene context modulates the effect of number of distractors on eye movements and search performance with real scenes. Methods: Observers (64) were presented with 24 grayscale images plus 96 fillers (22.53 deg. x 15.03 deg.) sampled from a dataset of 1224 desk images from multiple viewpoints and varying number of distractor objects. Half the images contained the target (computer mouse). When present, the target appeared in context in 60 % of the images (next to a monitor/keyboard) and out of context in the remaining 40 % (e.g., mouse over monitor). Observers searched for the target from an initial fixation at the edge of the images that was equidistant from mouse in context and out of context locations. Eye position was monitored and the display was randomly terminated after: 1, 2, 3 saccades or a 2 seconds time limit. At the end of each trial, participants performed a 10-scale confidence rating, expressing their certainty of finding the target. Results: Context significantly increased target detection accuracy ($p < 0.05$) and reduced time to first foveate the target (in context: 900 ms vs. out of context: 1400 ms) across multiple distractors, as well as fixation distance to the target. For the 2 second displays, the detrimental effect of distractors on accuracy (set-size effect) diminished when the target was in context. The temporal dynamics of performance varied across conditions. Additional saccades led to large increases in hit rate for the out of context targets and small for the in context targets. Conclusions: Scene context diminishes the detrimental effect of distractors on search performance in real scenes and alters the temporal dynamics of accuracy increments with subsequent saccades.

23.3030 Memory in visual search is task-dependent in both 2D and 3D environments

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Previous studies have indicated the effect of memory for both context and targets on search in 2D images of naturalistic scenes. However, recent results in 3D immersive environments failed to show much effect of context (Li et al., JOV, 2014). To examine whether this reflects differences between 2D vs. 3D environments, we ran a 2D experiment designed to parallel our previous 3D virtual reality environment. Subjects viewed 2D snapshots taken from the two rooms in the 3D immersive environment and then searched those images for a series of targets. The number of fixations required to locate the targets improved rapidly and was similar in both 2D and 3D environments. Interestingly, most of the improvement reflects learning to choose the correct room to look for a given target. Once in the correct room, search is very rapid and objects were located within 3-5 fixations in either environment. Previous exposure (one minute) to the context did not facilitate subsequent search. This was true for both 2D and 3D. In addition, there was little or no effect of experience with the environment on subsequent search for contextual objects in the scene. Even after 24 search trials, the number of fixations required to locate contextual objects in the room was close to values found with no experience. Incidental fixations made during previous trials also do

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not seem to benefit search much (though a small effect is detectable). Thus, search in both 2D and 3D environments is very comparable, and the primary effect of experience on search depends on task relevance (i.e., previously searched objects are easily remembered but not otherwise). We speculate that the effects of context either require much more extensive experience, or else a pre-exposure that immediately precedes the search episode.

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23.3031 **Modeling search guidance: Three parameters for characterizing performance in different types of visual search.** Tamaryn Menneer[1] (t.menneer@soton.ac.uk), Kyle Cave[2], Michael Stroud[3], Elina Kaplan[2], Nick Donnelly[1]; [1]University of Southampton, UK, [2]University of Massachusetts, Amherst, [3]Merrimack College

The accuracy of search guidance is reflected in the probability of fixating distractors within a search display as a function of their similarity to the target (e.g., Stroud et al., JEP:HPP, 2012). Strong search guidance produces high fixation rates to distractors that match the target on a given dimension (e.g., color), and low fixation rates to distractors that do not match the target. When guidance is absent, fixation rates are equal across all distractors, regardless of similarity to target. We modeled fixation rates across different levels of target similarity using a sigmoid function. Three parameters are necessary and sufficient to fit the function across a range of color-search tasks: single-target search, dual-target search, search plus a working-memory task, and search plus shape discrimination (modeled data: Stroud et al., ACP, 2011; Stroud et al., VSS, 2011; Stroud et al., JEP:HPP, 2012; Menneer et al., BPS, 2014). These parameters are as follows. (1) Unguided fixation rate (u): Even in guided search, participants exhibit a baseline fixation rate to distractors that are maximally different to the target. u defines the ratio of unguided fixations to guided fixations. (2) Selectivity (s): Participants with high selectivity (e.g., for target-similar colors) exhibit a guidance curve that drops off steeply for distractors less similar to the target, while low selectivity produces a shallow drop-off. (3) Target region (t): Some tasks produce high fixation rates to the target color only, but others produce high fixations rates to a range of colors similar to the target color. t allows adjustment of the region in color space that receives high fixation rates, and determines the level of dissimilarity at which the fixation rate begins to drop off steeply. The estimates for these three parameters demonstrate how guidance changes across different types of search.

23.3032 **Dual-Target Cost in Visual Search for Multiple Unfamiliar Faces** Natalie Mestry[1] (Natalie.Mestry@soton.ac.uk), Tamaryn Menneer[1], Hayward Godwin[1], Kyle Cave[2], Nick Donnelly[1]; [1]Psychology, University of Southampton, UK, [2]Psychology, University of Massachusetts Amherst, MA, USA

Visual search is slower and less accurate when trying to find more than one target object, referred to as the dual-target cost, and reduced attentional guidance has been shown to be the cause (e.g. Menneer et al., 2012). Studies in the eye-witness domain have shown the presence of two target faces reduces accuracy of identifying a single target face in both memory and matching paradigms (Megreya & Burton, 2006; Bindemann et al., 2012; Megreya & Bindemann, 2012). Here we examine behavioural performance and eye movements when searching for one versus two unfamiliar faces. Specifically, we were interested to see whether there was a dual-target cost and, if observed, whether the cause is the same for faces as for objects. Across two experiments, we varied the visual similarity of distractors to target faces using morphing. In both experiments, the similarity of distractors to targets was graded. In Experiment 1 distractors were morphed with only one of the targets and in Experiment 2 some distractors were morphs of both targets. In both experiments there was evidence of a dual-target cost: dual-target search took longer and was less accurate than single-target search. On target-absent trials, the participants searched exhaustively in both single and dual-target conditions, highlighting the difficulty of the task. Searching for two targets resulted in 'shedding', wherein participants gave up searching for one of the targets. There was evidence of guidance to faces in relation to the participant's preferred target in both single and dual-target search in Experiment 2, but only single-target search in Experiment 1. Probability of fixation to distractors was proportional to the similarity of the distractor to the preferred target. Overall, results suggest effective visual search for unfamiliar faces is limited to a single face, which has profound implications for applied search tasks.

23.3033 **Eye movements reveal two search modes for the detection of targets in novel dynamically changing visual displays** Alex Muhl-Richardson[1] (amr2e13@soton.ac.uk), Hayward Godwin[1], Matthew Garner[1,2], Julie Hadwin[1], Simon Liversedge[1], Donnelly Nick[1]; [1]School of Psychology, University of Southampton, [2]Clinical and Experimental Sciences, Faculty of Medicine, University of Southampton

Standard visual search tasks present participants with objects that do not change. This contrasts with some real-world tasks where observers monitor complex displays of dynamically changing visual indicators over time for evidence of risk (e.g. warning lights turning red). In these tasks, target detection may be driven by responses to specific target onsets, or by monitoring changes to potential targets over time. In the present study, participants completed a novel dynamic visual search task. Arrays of 9x12 squares changed between 16 colours at varying rates and each trial lasted 40 seconds. Participants' task was to respond with mouse-clicks after moving a cursor to targets defined by a specific colour. Only a single target was ever present at once and target prevalence, the proportion of target-present trials, was either low (6%) or high (66%). Eye movements provided evidence for two concurrent modes of search. 46% of targets were detected in accordance with responses to specific target onsets, but other targets were detected predictively, via monitoring of distractors with likelihood to become targets. Monitoring might operate through a coarse template in which squares within two colour-steps of the target are assessed as potential targets. Hit-rate did not differ between high (84%) and low (82%) prevalence and, most often, targets were missed because they were not fixated. However, in line with recent evidence, target detection was slower when prevalence was low (2900ms) versus high (2500ms) and this was due extended verification times (time from first target fixation to response). We conclude that (1) target prevalence effects are similar in dynamic search to those in standard search; (2) prevalence influences search in dynamic displays by slowing verification; and (3) there are two distinct modes of search for targets in dynamically changing displays. Further analyses will explore the relationships between prevalence and search mode.

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23.3034 **Visual search for targets in predictable routes and matched randomized scenes** Oliver Tew[1] (ot1e13@soton.ac.uk), Hayward Godwin[1], Matthew Garner[2], Julie Hadwin[3], Simon Liversedge[1], Nick Donnelly[1]; [1]Centre for Vision and Cognition (CVC), Psychology, University of Southampton, [2]Psychology and Medicine, University of Southampton, [3]Developmental Brain-Behaviour Laboratory (DBBL), Psychology, University of Southampton

Experiments exploring visual search in familiar real-world scenes usually consider target detection in individual scenes. They rarely consider the influence of the relationship between sequences of scenes on target detection. Specifically, they do not consider how the ability to predict the form and structure of a forthcoming scene influences target detection. In this study we explored the effect of temporal order of scenes on the detection of targets placed within photographs of residential areas. In one condition the temporal order was consistent with a route being followed by the participant. In a second condition the temporal order was randomized. Targets were defined as tools, with twenty instances of tools being used. All tools fitted naturally within the context of all of the scenes and were placed in positions at which they would ordinarily occur. Forty scenes were used in each condition. Participants made target present/absent decisions by pressing a button across eight iterations of the forty scenes. Target position changed across iterations in a pseudorandom manner. Following responses in the route condition, scenes remained on the screen for one second to allow a cue to be presented indicating the position of the next scene. In the randomized condition, no cue was presented. Response latency and accuracy across conditions were recorded. Eye movements were also recorded. The results showed a learning effect across the first three blocks with improvements to the speed and accuracy of target detection, and a numerical reduction in the number of fixations. Surprisingly, we found no evidence that presenting the images in a predictable order influenced responses or eye movement measures. The results suggest that viewing scenes in a fixed temporal order, as if following a route, is of limited benefit to visual search when target position is unpredictable.

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23.3035 **Saliency-guided eye movement during free-viewing in schizophrenic patients** Masatoshi Yoshida[1,2] (myoshi@nips.ac.jp), Kenichiro Miura[3], Ryota Hashimoto[4,5], Michiko Fujimoto[4], Hidenaga Yamamori[4], Yuka Yasuda[4], Kazutaka Ohi[4], Masaki Fukunaga[6], Masatoshi Takeda[4], Tadashi Isa[1,2]; [1]Department of Developmental Physiology, National Institute for Physiological Sciences, Okazaki, Japan, [2]School of Life Science, The Graduate University for Advanced Studies, Hayama, Japan, [3]Department of Integrative Brain Science, Graduate School of Medicine, Kyoto University, Japan, [4]Department of Psychiatry, Osaka University Graduate School of Medicine, Osaka, Japan, [5]Molecular Research Center for Children's Mental Development, United Graduate School of Child Development, Osaka University, Osaka, Japan, [6]Division of Cerebral Integration, National Institute for Physiological Sciences, Okazaki, Aichi, Japan

Patients with schizophrenia show various kinds of abnormality in eye movements. Recent studies showed that such abnormalities, including the shorter scanpath during free-viewing of natural images, is able to use as an efficient biomarker for schizophrenia. Here we extended our previous work (Miura et.al. 2014 Schizophr Res) and examined whether such difference in eye movements during free-viewing arises from the way in which their attention is drawn to specific features of the visual stimuli. The age-matched subjects (41 patients and 72 healthy controls) viewed 56 natural and/or complex images including faces, scenes and so on. During 8 seconds of viewing time for each image, eye movements were recorded using an eye tracker (EyeLink 1000). We calculated the saliency map of the images for low-level features (luminance, L-M, S-Lum and orientation) based on our previous work (Yoshida et.al. 2012 Curr. Biol.). Then we evaluated the time course of the saliency value at the position of the gaze. The luminance saliency was highest for the first fixation and went down during the 8-sec viewing time in the healthy controls. This is also true for patient group but the luminance saliency was consistently higher in the patients than in the healthy controls (repeated measures ANOVA, $F_{1,111}$=5.78, P=0.017). The saliency for other features showed different time course. By combining saliency values for different features (4 models * 8 time points), we constructed a classifier in which patients and controls are distinguished with 83% accuracy. These results suggest that the abnormality in eye movements during visual exploration can be explained, at least partly, by dysregulated saliency in the patients.

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23.3036 **Active working memory tasks interfere with inefficient search but NOT with efficient search, guided by bottom-up salience.** Beatriz Gil-Gómez de Liaño[1] (bgil.gomezdelianno@uam.es), Trafton Drew[2], Daniel Rin[1], Jeremy Wolfe[3]; [1]Universidad Autónoma de Madrid, [2]University of Utah, [3]Harvard Medical School-Brigham & Women's Hospital

It is still unclear how working memory representations bias attentional selection in visual search and, specifically, how that bias affects top-down and/or bottom-up guidance in search. Researchers studying the influence of Working Memory (WM) load in visual search have found some discrepant data, sometimes showing a WM modulation (e.g. Oh & Kim, 2004) but sometimes finding lack of effects of passive working memory loads on search (e.g. Woodman, Vogel & Luck, 2001). However, recent data have shown that active working memory tasks do modulate visual search performance (Gil-Gómez de Liaño, Drew, Quirós & Wolfe, 2014). Does the effect of active WM tasks occur both for efficient and inefficient searches? We compared WM effects on a relatively inefficient search for a specific object among heterogeneous distractor objects and efficient search for a salient object among homogeneous distractors. As in Gil-Gómez de Liaño et al. (2014), we used two active WM tasks: active-span tasks and updating n-back tasks. In the first active-span task, participants had to count how many times WM items were repeated through several visual search trials. In the second task, information in WM had to be updated during the search task. The results show that active WM tasks only interfered with inefficient search tasks, not with efficient search. Moreover, inefficient searches, but not efficient ones, were sensitive to the degree of WM load: high WM loads in the active-span and updating tasks, produced higher RT x set size slopes in search (control-no load: 21 msec/item, high load-active span: 36 msec/item, high load-updating: 34 msec/item). No differences were found for slopes in efficient search (control-no load: 0.44 msec/item, high load-active span: 1.96 msec/item, high load-updating: 2.79 msec/item). The results suggest that active working memory loads specifically interfere with top-down guidance during visual search, but not under bottom-up guided search.

23.3037 **Priority of items in working memory affects attentional capture in visual search** Anna Schubö[1] (anna.schuboe@staff.uni-marburg.de), Tobias Feldmann-Wüstefeld[1]; [1]Experimental and Biological Psychology, Philipps University Marburg

Recent research has shown that visual attention can be biased towards visual features that match working memory (WM) content. Some studies have suggested that search for a target is facilitated when the target shares features with WM content and hampered when a distracting item shares features with WM content. So far, most studies have compared the impact of features maintained in WM with the impact of (neutral) WM-irrelevant features on visual search tasks. In the present study we extend previous evidence of close inter-relations of WM and attention by introducing negative WM priority. To that end, a WM task was combined with a visual search task. Observers had to memorize a number of items (supposedly inducing high WM priority) while ignoring other, simultaneously presented items (supposedly inducing negative WM priority). Results showed that memorized items had only little impact on attention deployment in a visual search task when WM load was high. Ignored items, however, modulated attention deployment: search targets received less attention when they shared features with ignored items but more attention when distractors shared features with ignored items, as indicated by RTs and N2pc amplitudes. These results suggest that items which need not be encoded into WM nevertheless affect subsequent attentional control processes. We interpret these findings as WM maintenance and attention control mechanisms being closely intertwined, and assume that high, low or even negative priorities can spill over from one task to the other.

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23.3038 **Contextual cuing for targets in the rear** Satoshi Shioiri[1,2] (shioiri@riec.tohoku.ac.jp), Masayuki Kobayashi[2], Kazumichi Matsumiya[1,2], Ichiro Kuriki[1,2]; [1]Research Institute of Electrical Communication, Tohoku University , [2]Graduate School of Information Sciences

[Purpose] Spatial layouts can be obtained implicitly as has been shown by contextual cuing effect (CCE). We investigated contextual cuing effect for spatial layout around us including the layouts in the rear. That is, we examined whether a learned spatial layout in a front display cues the target in a rare display, using the visual search in the stimulus presented on the displays surrounding the participant (360° visual field). [Experiment] We investigate implicit learning of spatial layouts using a CCE experiment. The CCE is a learning effect of spatial layout in visual search displays. Visual search performance increases by repeating visual search in the same layouts, without noticing the repetitions. We investigated the CCE for layouts presented in a 360° display and examined whether spatial layouts in front influence the detection of targets in the rear (CCE for target outside the visual field). Analyzing the reaction time for target detection separately for the time required to reach the display with the target and the time required to detect the target within the display, the CCE for the location of the target display would be isolated from the CCE for the target location within the display. [Results] We found CCEs for the location of target displays in the rear in addition for the target location within the display. Target detection of repeated layouts were shorter than that of new layouts independently of the location of target display and a part of the shortening was for reaction time to reach the target display. This suggests that the visual system can learn implicitly association between the layout in front and the target location in the rear. [Discussion] Our results suggest that the visual system learns spatial layout implicitly around oneself including the information in the rear.

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23.3039 **Phonological Interference in Visual Search: Object Names are Automatically Activated in Non-Linguistic Tasks** Stephen Walenchok[1] (swalench@asu.edu), Michael Hout[2], Stephen Goldinger[1]; [1]Arizona State University, [2]New Mexico State University

During visual search, it is well known that items sharing visual similarity with the target create interference (e.g., searching for a baseball among softballs vs. a baseball among bats). Although such a task is inherently visual, might linguistic similarity between target and background items' names also create interference? We conducted several experiments in which people searched for either one or three potential targets, among a background of distractors that either shared a phonological overlap with the target(s) (e.g., "beast" and "beanstalk") or had no overlap (e.g., "beast" and "glasses"). Experiment 1 involved standard oculomotor search, Experiment 2 pre-

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sented a serial search task in which participants manually rejected distractors (or confirmed the target), and Experiment 3 again presented oculomotor search, while also tracking eye movements. We varied whether targets were initially specified by visual icons or verbally as names. We predicted that when searching for a single item, people could easily maintain a visual representation of the target in memory, resulting in minimal activation of linguistic information. When searching for multiple items, however, visual memory demands are high. In order to minimize these demands, people might use less taxing verbal codes as a memory aid during search (i.e., rehearsing target names). If so, these verbal codes may increase the potential for linguistic interference when target and distractor names share phonological overlap. All three experiments revealed effects of phonological interference, but only under high target load, and primarily when targets were specified verbally. In Experiment 4, we tested whether concurrent articulatory suppression during search might minimize verbal memory strategies and eliminate such effects of phonological interference. Phonological competition effects remained robust, however, indicating that distractor names are automatically activated under high cognitive demands and that verbal strategies are not the sole source of phonological interference in search.

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23.3040 **Synesthesia induced colors do not bias attention in the same manner as physical colors do** Thomas Sørensen[1,2] (thomasalrik@gmail.com), Árni Ásgeirsson[1,3]; [1]Cognitive Neuroscience Research Unit, CFIN, MindLab, Aarhus University, [2]Centre for Cognitive Neuroscience, Aalborg University, [3]Center for Visual Cognition, University of Copenhagen

Grapheme-color synesthesia affects visual cognition in significant ways. The congruence or incongruence of physical stimuli with synesthetic color affects how quickly and accurately synesthetes respond to stimuli, and the induced color experience may help them memorize achromatic material and performance in visual search, much like physical stimulus features. It has been demonstrated that the content of visual memory can guide attention (e.g. Carlisle & Woodman, 2011). This effect can be measured in the response time costs or benefits related to the presence of memorized color in a visual search display. Retaining color information in memory biases attention towards that specific color in visual search, apparent by response time costs when a matching distractor is present, but a benefit when the target matches the retained color. We investigated whether a synesthetic color is automatically represented in visual memory of observers with color-grapheme synesthesia, and consequently biases attention towards the synesthesia congruent stimuli. A group of synesthetes performed a memory task combined with a visual search for colored Landolt squares to explore this question. Each trial started with the presentation of an achromatic letter, followed by a visual search display. There were three types of search trials; 1) where the target color matched the color associated with the memorized letter, 2) where a distractor color matched the letter, and 3) where the associated color was absent from display. Finally, participants responded to memory probe to ensure that the letter was memorized. We found no significant differences in response times dependent on synesthetically induced colors. However, there were clear costs and benefits of having physical colors in visual memory. This suggests that - unlike physical color - synesthetic colors are not automatically represented in visual memory.

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23.3041 **Is visual working memory modulated by prior knowledge about probability? An ERP study** Tomoya Kawashima[1] (tkawashima@stu.kobe-u.ac.jp), Eriko Matsumoto[1]; [1]Graduate School of Intercultural Studies, Kobe University

Prominent theories of visual attention claim that the contents of visual working memory (VWM) can guide attention during visual search. This is supported by numerous experimental observations showing that information held in VWM automatically captures attention (e.g., Soto et al., 2008, Trends Cong Sci). Recently, Carlisle & Woodman (2011, Acta Psychol) reported that the effects of attentional capture varied according to prior instructions about the probability of memory-match trials, which suggests that strategic use of the contents held in VWM may alter visual search performance. However, it remains unclear how these instructions influence the contents stored in VWM. In the present study, we used contralateral delay activity (CDA) as an electrophysiological index of VWM load. The task was to conduct visual search while holding an item in VWM. There were three within-subjects conditions, across which we pre-informed participants about the probability (20%, 50%, or 80%) of memory-match trials. We hypothesized that VWM would be more loaded with more probability of memory-match trials. We found that RT costs (invalid minus neutral trials) in the 80% condition were larger than in the 20% and 50% conditions, but there were no between-condition differences in RT benefits (valid minus neutral trials). These results indicate that prior knowledge about probability affected RT costs only. Unexpectedly, CDA was only obtained in 50% condition. These results imply that knowledge about biased-probability (20% and 80%) leads to a decrease in the demands to attend to or hold to-be-memorized item. In conclusion, the present ERPs findings, combined with the RT results, suggest that changes in RT costs across conditions by instruction may not depend on VWM activity as measured by CDA.

Eye Movements: Consequences

Saturday, May 16, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

23.3042 **Illusory reversal of temporal order around the time of visual disruptions** Douglas McLelland[1] (mclelland@cerco.ups-tlse.fr), Louisa Lavergne[2], Eckart Zimmermann[3], Patrick Cavanagh[4], Rufin VanRullen[1]; [1]Centre de Recherche Cerveau et Cognition, CNRS UMR 5549, Universite Paul Sabatier, Toulouse, [2]Laboratoire Vision Action Cognition, Institut de Psychologie, Universite Paris Descartes, Paris, [3]Cognitive Neuroscience, Institute of Neuroscience and Medicine (INM-3), Research Centre Jülich, Germany, [4]Laboratoire Psychologie de la Perception, Centre Attention Vision, CNRS UMR 8242, Universite Paris Descartes, Paris

How does the brain maintain a stable, continuous perceptual experience in the face of large visual disruptions such as those frequently occurring during blinks and eye movements? Saccadic remapping, a predictive shift in neuronal receptive fields around the time of saccades, has been proposed as an essential neuronal mechanism. In turn, saccadic remapping has been linked to a set of perisaccadic illusions, whereby stimuli flashed briefly around the time of a saccade are mislocalized in space and time. In a recent study, Zimmermann et al. (J Neurophysiol 2014) broadly reproduced similar spatial and temporal mislocalization patterns when the saccade was replaced by a full-field masking interruption. Rather than saccadic compensation alone, such illusions must be due to a more general updating process linking targets of interest across visual interruptions. In this study, we focus more fully on temporal consequences of visual disruptions. Two vertical bars were presented at varying stimulus-onset asynchronies (SOA: -20 to 160 ms in 10 ms increments, furthest vs nearest stimulus), and a full field mask presented at one of three intervals relative to the near stimulus (50, 100 and 150 ms), along with an unmasked condition. Subjects (N=8) maintained fixation throughout the trial, and reported the order in which the two bars appeared. When the second stimulus was presented close to the time of the mask, subjects often reported (30 to 40% of trials on average) that it appeared before the first stimulus, even when the SOA was as large as 150 ms. In a second experiment in which subjects (N=6) also reported response confidence, we obtained similar results analysing only 'confident' responses, indicative of an actual perceptual reversal rather than increased perceptual uncertainty. We offer a speculative explanation in terms of sequential processing of discrete events, and link this to recent results on neuronal oscillations.

Acknowledgement: ERC Consolidator Grant P-CYCLES (614244) , FET SPACECOG grant (600785)

23.3043 **A computational model of the perisaccadic updating of spatial attention** Michael Teichmann[1] (michael.teichmann@informatik.tu-chemnitz.de), Julia Schuster[1], Fred Hamker[1]; [1]Department of Computer Science, Chemnitz University of Technology

During natural vision, scene perception depends on accurate targeting of attention, anticipation of the physical consequences of motor actions, and the ability to continuously integrate visual inputs with stored representations. For example, when there is an impending eye movement, the visual system anticipates where the target will be next and, for this, attention updates to the new location. Recently, two different types of perisaccadic spatial attention shifts were discovered. One study shows that attention lingers after saccade at the (irrelevant) retinotopic position, that is, the focus of attention shifts with the eyes and updates not before the eyes land to its original position (Golomb et al., 2008, J Neurosci.; Golomb et al., 2010, J Vis.). Another study shows that shortly before saccade onset, spatial attention is remapped to a position opposite to the saccade direction, thus, anticipating the eye movement (Rolfs et al., 2011, Nat Neurosci.). Recently, we proposed a model of perisaccadic perception based on predictive remapping and corollary discharge signals to explain several phenomena of vision (Ziesche & Hamker, 2011, J Neurosci.; Ziesche & Hamker, 2014, Front. Comput. Neurosci.). The model allows for the simulation of stimulus position across eye movements by using a discrete eye position signal and a corollary discharge. We extended the model with an additional feedback loop and a tonic spatial attention signal and show that the observations made by Golomb et al. and Rolfs et al. are not contradictory and emerge through the model dynamics. The former is explained by the proprioceptive eye position signal and the latter by the corollary discharge signal. Interestingly, both eye-related signals are core ingredients of the model and are required to explain data from mislocalization and displacement detection experiments. Thus, our model provides a comprehensive framework to discuss multiple experimental observations that occur around saccades.

23.3044 **Testing for inhibition of return with purely vertical cues: implications for models of covert visual attention**

Xiaoguang Tian[1,2] (txgxp@hotmail.com), Ziad Hafed[1]; [1]Werner Reichardt Centre for Integrative Neuroscience, Tuebingen University, [2]Graduate School of Neural & Behavioural Sciences, Tuebingen

When a peripheral cue is presented, subsequently presented targets at the cued location first experience facilitated reaction times (RT's) relative to other locations (a phenomenon classically termed "attentional capture"). Later, a large RT cost occurs (a phenomenon termed "inhibition of return", IOR). We recently suggested that both attentional capture and IOR are a simple consequence of saccadic system rhythmicity (Tian & Hafed, VSS, 2014). In our simple model, saccades are repetitively generated, including during fixation when they become microsaccades, and they oscillate in direction. When cues appear (typically in a lateralized manner), they "reset" saccadic system phase (Hafed & Ignashchenkova, J. Neurosci., 2013), and whether attentional capture or IOR occurs simply depends on the phase of cue-reset saccadic oscillations at which subsequent targets appear. Here, we aimed to understand one possible source of such oscillations; we hypothesized that purely vertical cues would have weaker impact than horizontal ones because vertical stimuli activate lateralized visuomotor structures (e.g. superior colliculus) in a simultaneous, bilateral manner. We ran two monkeys in a classic Posner cueing paradigm. In each trial, a cue/target (1 deg diameter white circle) appeared at 5 deg eccentricity, either horizontally or vertically. Cue-to-target onset asynchrony (CTOA) was random (between 32 ms and 1532 ms), and the post-cue target could appear either in the "same" or "opposite" cued location. We collected >4000 trials per monkey. We observed strong IOR with purely horizontal cues, as expected. However, with purely vertical cues, IOR was eliminated. Critically, microsaccade analysis revealed significantly weaker influence of vertical cues on post-cue microsaccade frequency and direction, suggesting that microsaccadic oscillations are partly mediated by lateralized visuomotor structures. We also simulated these results with our simple saccadic rhythmicity model. Taken together, our results demonstrate that modulations of spatial attentional performance may simply reflect the dynamics of saccadic/microsaccadic oscillatory rhythms.

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23.3045 **Distribution of attention and parallel saccade programming in antisaccades**

Anna Klapetek[1] (anna.klapetek@psy.lmu.de), Heiner Deubel[1]; [1]General and Experimental Psychology, Ludwig-Maximilians-Universität, Munich, Germany

The aim of our study was to investigate the spatiotemporal distribution of attention during the programming of pro- and antisaccades. The visual display consisted of a central fixation dot and six circularly arranged peripheral squares. In each trial one of the targets was briefly highlighted and participants were either instructed to shift their gaze to the cued square (prosaccade task) or to the diagonally opposed square (antisaccade task). At the end of the trial they reported the orientation of a visual probe that had appeared in one of the six squares and indicated whether they had made a correct saccade or a saccade in the wrong direction. In line with the results of previous studies, saccade latencies were longer and error rates were substantially higher in the antisaccade condition as compared to the prosaccade condition. The analysis of discrimination performance in the cue-saccade interval revealed that in the prosaccade condition attention was allocated exclusively to the saccade goal. In contrast, attention in the antisaccade condition was allocated both to the cued location and to the correct antisaccade goal. This was the case both before correct antisaccades and erroneous prosaccades and the amount of attention at the cue was predictive of the occurrence of errors. Interestingly, more than half of the erroneous prosaccades were not recognized. Unrecognized errors had smaller amplitudes and were corrected faster than recognized errors. In conclusion, our results indicate that the goal in the antisaccade task is selected through a competitive process between reflexive attention at the saccade cue and voluntary attention at the antisaccade goal. The occurrence of very short intersaccadic intervals between unrecognized erroneous prosaccades and corrective saccades provides evidence that these saccades were programmed in parallel.

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23.3046 **Functional Consequences of Slow Drift Fixational Eye Movements in Patients with Central Vision Loss**

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Previous studies have shown differences in fixation eye movement (FEM) behavior between normally sighted individuals and subjects with central vision loss (CVL), but there is no evidence of any functional consequences of these differences on vision. A recent theory posits a possible function for the slow drift component of FEM - to decrease the redundancy in retinal image sequences (ie. 'whitening'). Because patients with CVL exhibit greater slow drift amplitudes, in this study, our goal was to determine if the slow drift behavior of patients also whitens image sequences. To answer this question we used the Rodenstock Scanning Laser Ophthalmoscope to image the retinas of 16 young normal subjects, 14 older normal subjects and 17 CVL patients while they fixated a 1 degree cross for 30 seconds. Eye movements were recovered from the digitized image sequences using a brute-force cross-crorrelation algorithm, at a sampling frequency of 540Hz, from which we extracted a 100 millisecond saccade-free segment from each image sequence. Simulated natural scene movies were created with these saccade-free segments. Spatio-temporal amplitude spectra were calculated from the simulated movies. Across the three subject groups (young-normal, older-normal and CVL), fixation stability (based only on slow drift components) measured using the Bivariate Contour Ellipse Area were statistically different, and ranged from 19.32±33.14 to 162.01±240.86 square arc minutes. If there was a decrease in redundancy due to the slow drifts, the slope of the amplitude spectrum would be shallower for a movie than for the static natural image that created the movie. The change in slope ranged from 84.06%±7.33 to 89.29%±12.8, and were not statistically different, across our three subject groups. Our results suggest that the slow drift behavior of patients with CVL does not have any consequential effects on the whitening of natural image sequences that are incident on the retina.

Acknowledgement: NIH Research Grant R01-EY012810

23.3047 **From small to large, all saccades follow the same timeline**

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Purpose: The well-known main sequence of saccadic eye movements can have a large variability; the peak velocity of saccades with the same amplitude can be dramatically different. We explored an alternative approach to describing the saccade characteristics by looking into the in-flight shift timeline of saccades. Methods: We gathered 929 natural saccades made by two subjects with their heads restrained as they watched videos. The saccade duration and amplitude ranged from 13 to 95 ms (mean ± std. = 43ms ± 14.5) and 0.54° to 28.7° (mean ± std. = 9.27° ± 4.5), respectively. For each saccade we analyzed data in two ways: (1) displacement at time points corresponding to different proportions of its overall duration vs. amplitude; and (2) the time taken to reach various proportions of its amplitude vs. total duration. Results: In all the cases, the data showed a strong linear relationship, with slopes converging toward unity and the line-fitting errors reducing as the sampling got closer to the end of saccade trajectory ($R2$=0.62, 0.96, and 0.99 at 20%, 60% and 90% of saccade duration, respectively; and $R2$=0.93, 0.98, and 0.99 at 20%, 60%, and 90% of saccade amplitude, respectively). For the same data, saccade duration vs. amplitude resulted in $R2$=0.65 while peak velocity vs. amplitude was $R2$=0.12. Conclusion: Our finding is consistent with the fact that generally, saccade duration has a linear relationship with its size. The novelty of our finding is that, if normalized by saccade duration or size, all saccades appear very similar in their time course. This consistent time line of the normalized in-flight shift might suggest a universal controlling model in some saccade-related neural circuits, for instance, the paramedian pontine reticular formation.

Acknowledgement: NEI EY023724

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Visual Memory: Individual differences and models

Saturday, May 16, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4001 **Individual differences in representation precision predict adaptation bias**

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The internal representation of stimuli is imperfect and subject to biases. Noise is introduced at initial encoding and during maintenance, degrading the precision of stimulus estimation. Stimulus estimation is also biased away from recently encountered stimuli (adaptation). According to a Bayesian framework, one should expect bias to be greater when stimulus representation (and thus precision) is poor. We tested for this effect in individual difference measures. 101 subjects performed an on-line experiment (https://cfn.upenn.edu/iadapt). During separate face and color blocks, subjects performed three different tasks: an immediate stimulus-match (15 trials), a 5s delayed match (30 trials), and a 100ms delayed match following 5s of adaptation (30 trials). The stimulus space was circular, and subjects entered their responses using a color/face wheel. Bias and precision of responses, while accounting for random guesses, were extracted by fitting a mixture of von Mises distributions. Two blocks of each measure were obtained, allowing for tests of measure reliability. 33 subjects were excluded due to poor model fit. In the remaining subjects, average precision across all tasks was found to vary significantly between subjects ($p< 0.001$), but not vary as a function of task or material. Precision was a reliable subject property ($r=0.67$ over two measures). The adaptation manipulation induced the expected bias in responses (mean±SEM subjects: 7.7±0.5° colors, 4.2±0.6° faces). The magnitude of this bias varied between subjects, and this too had good re-test reliability (color $r=0.69$; faces $r=0.52$). Across subjects, there was a negative correlation between mean precision and bias ($r=-0.29$, $p=0.016$). While a significant correlation between face and color bias was found ($r=0.40$, $p< 0.001$), this did not account for the entire reliable variance of individual differences for the two materials. At the level of individual differences, the precision of perceptual representations negatively predicts the magnitude of adaptation bias.

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23.4002 **Filtering ability in visual working memory cannot be improved by temporal and spatial task cues**

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Previous research argued that filtering efficiency (i.e., the ability to ignore task irrelevant items) might explain individual differences in Visual Working Memory (VWM) capacity, such that low-capacity individuals demonstrate poor filtering efficiency relative to high-capacity individuals. Here, we investigated if low-capacity individuals can compensate for their poor filtering ability by providing a spatial cue, indicating the distractors' positions or a temporal cue, indicating when a filtering trial occurs. Participants performed the change-detection task while ERPs were recorded, with either two targets, four targets, or two targets and two distractors (the filtering condition). In Experiment 1, participants had to memorize the orientation of red bars while ignoring blue bars, and were cued in advance whether the upcoming trial was a filtering trial or a targets-only trial, allowing participants ample time to prepare towards a filtering trial. In Experiment 2, we provided spatial cues signaling the location of the distractors by presenting empty rectangles at constant locations used as placeholders only for distractors, thus the spatial positions of the distractors (but not the targets) were known in advance. In Experiment 3, we provided both a spatial and a temporal cue. Namely, a filtering trial was cued by an arrow cue pointing towards the same target quadrant, keeping the distractor quadrant constant. We used the CDA (a waveform of the event-related potential that reflects the number of items encoded and maintained in VWM) to monitor changes in filtering efficiency. In all three experiments we found that temporal cuing, spatial cuing and both temporal and spatial cuing did not affect the filtering efficiency. These findings suggest that temporal and spatial cues did not help compensate for poor filtering ability, suggesting that filtering ability is an unchangeable cognitive attribute.

23.4003 **Visual Motor Memory: A developing construct**

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Background: Humans possess a remarkable ability to remember visual shapes and generate motor activity from these visual representations. We use the term visual–motor memory to describe this skill. This skill is critically important to humans during development (e.g. when learning to write). Moreover, this ability must have conveyed an evolutionary advantage to humans and is part of the archaeological evidence for the existence of cultural transmission across civilisations over millennia (from Palaeolithic cave drawings through Jiahu symbols to cursive handwriting). Surprisingly little empirical investigation of this unique human ability exists—almost certainly because of the technological difficulties involved in measuring this skill. Methods: We deployed a novel technique for measuring this psychological construct in 87 children (6–11 years old, 44 females). Children drew novel shapes presented briefly on a tablet laptop screen, drawing their responses from memory on the screen using a digitizer stylus. Sophisticated algorithms (using point-registration techniques) objectively quantified the accuracy of the children's reproductions. Results: VMM improved with age and performance decreased with shape complexity, indicating that the measure captured meaningful developmental changes. The relationship between VMM and the children's scores on nationally standardized writing assessments were explored and the results showed a clear relationship between these measures- even after controlling for age. Moreover, a relationship between VMM and the nationally standardized reading test was mediated via writing ability, Conclusion: We have developed an objective measure of visual–motor memory that can be readily deployed in classroom settings. The VMM measures appear to be powerful predictors of reading and writing ability (even when controlling for age). Thus, VMM appears to be important within language development. We have now successfully deployed the VMM test across children within an English city (Bradford), allowing exploration of the effects of ethnicity and socio-economic status on visual memory.

Acknowledgement: National Institute for Health Research Collaboration for Leadership

23.4004 **A guess today may be a strategic error tomorrow: Predicting intra-individual differences in visual working memory**

Kristin Wilson[1] (kristin.wilson@utoronto.ca), April Au[1], Jenny Shen[1], Julie Ardron[1], Justin Ruppel[1], Gillian Einstein[1], Susanne Ferber[1]; [1]Psychology, University of Toronto

Inter-individual differences in visual working memory (VWM) are well documented, however, there has been less work exploring intra-individual differences or how VWM processes may fluctuate over time in healthy young adults. It has also been documented that VWM is impacted by changes in female sex hormones in menopausal woman, however, these hormones also fluctuate across the monthly cycle in young woman, granted to a lesser extent. Given the high prevalence of female participants in the majority of VWM studies, understanding whether there are in fact intra-individual changes in VWM performance over the monthly cycle may not only provide a novel contribution to the discussion of fixed vs. flexible capacities in VWM, but may also help explain unreplicable results or inconsistencies in the literature. Here, we compared performance on a VWM colour-wheel task in women at two time-points (at menstruation and ovulation). Employing the 3-component swap model of VWM (Bays, Catalao, & Husain, 2009), we estimated measures of probability of target, non-target (swaps between target and non-target items), and guess responses, addressing the question of whether VWM performance varies over time within individuals and whether this is due to changes in the number of target responses or the types of errors made. Interestingly the probability of target response did not differ between the two time-points, however, the types of errors did. When VWM is at capacity (load 4 and 6) women made more swap errors at ovulation and more guesses at menstruation. These results suggest that the amount of information held in VWM may increase at ovulation but this results in more interference, with no concomitant increase in target responses. These results reveal the presence of intra-individual differences in VWM performance (types of errors made) that follow cyclical patterns in the monthly hormone cycle in young woman.

Acknowledgement: National Sciences and Engineering Research Council

23.4005 Testing the role of filtering efficiency in determining individual differences in working-memory capacity

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Previous research suggests that visual working memory (WM) capacity is closely connected to filtering ability, so that high-capacity individuals are more efficient at filtering out irrelevant information and representing only the relevant items in the limited WM storage space. The interesting prediction is that low capacity individuals should remember task irrelevant information better than high capacity individuals. In Experiment 1 we used a visual search paradigm, and tested participants' memory for the task irrelevant distractors (pictures of real objects). Indeed, low-capacity individuals remembered better the task irrelevant distractors from the visual search task. Importantly, high-capacity individuals were faster to respond on target-present trials during the visual search, leading us to test in Experiment 2 whether exposure time to distractors underlies the negative correlation between visual WM capacity and memory for distractors found in Experiment 1. To do so, we used a modified visual search task in which there was no need to scan distractors and the exposure time of the display was kept constant. Crucially, keeping the display time constant insured that the time in which distractors can be scanned is constant across subjects. This time high capacity individuals remembered better the distractors. Our results suggest that because high-capacity individuals scan faster they spend less time on irrelevant information which facilitates filtering. Counter-intuitively, it seems that when possible, high-capacity individuals hold less information in visual WM than low-capacity individuals.

23.4006 EEG markers of reduced visual short-term memory capacity in adult attention deficit/hyperactivity disorder

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Attention deficit hyperactivity disorder (ADHD) persists frequently into adulthood. The disease is associated with difficulties in many cognitive tasks, which are assumed to be caused by neurobiologically-based basal dysfunctions. A reduction in visual working memory storage capacity has recently been claimed a testable endophenotype of ADHD. This study aimed at identifying brain abnormalities underlying this deficit by combining parameter-based assessment with electrophysiology. We compared unmedicated adult ADHD patients and demographically matched, healthy controls. We found reduced storage capacity in the patient group and delineated neural correlates of the deficit by analyzing ERP amplitudes according to (1) differences between patients and controls and (2) individual's performance level of storage capacity K: First, the contralateral delay activity (CDA) was higher for individuals with high compared to individuals with lower storage capacity. The component differed between patients and controls only in an early time window (eCDA), in which activity correlated with patients' symptom ratings of hyperactivity/impulsivity. Second, a broadly distributed central positivity (CP) was higher in individuals with higher compared to lower storage capacity. A later section of the CP was further overall increased in the group of ADHD patients relative to controls. Together, the findings indicate that ADHD patients show disease-specific changes in brain mechanisms underlying visual storage capacity, characterized by deficient encoding and maintenance, and increased recruitment of control processes.

23.4007 Episodically defined organization of visual memory

Karla Antonelli[1] (karla.b.antonelli@gmail.com), Carrick Williams[2]; [1]Department of Psychology, Mississippi State University, [2]Psychology Department, California State University San Marcos

One theory proposed to account for the remarkable capacity and fidelity of visual memory is that visual memories are supported by an underlying structure of conceptual knowledge around which visual information is organized. However, some findings of visual memory learned in visual search tasks are not well explained by this theory. This study examines the importance of episodic, task-relevant, visual information in the organizational structure of visual memory. In two experiments, participants learned 36 target objects (750 ms presentation) in serial presentation search tasks, followed by additional searches containing varying numbers of new exemplars of the targets to introduce retroactive interference for the original search targets. Following the search trials, participants completed a 2-AFC memory test. The critical difference between the two experiments was the form of search instructions given. In Experiment 1, search instructions identified targets by color and conceptual category, making a perceptual feature, (i.e., color), relevant to the task, whereas in Experiment 2, the target was defined by the conceptual category alone making the perceptual feature irrelevant. In Experiment 1, memory test results showed that new exemplars that matched learned objects on both color and conceptual category induced more interference (80%) than those matched on conceptual category alone (87%). Experiment 2, in contrast, showed that new exemplar objects that matched only on conceptual category induced the same amount of interference (78%) as those matched on both color and conceptual category (77%). Results indicate that when made task-relevant, perceptual, as well as conceptual, information contributes to the organization of visual long-term memory. However, when made episodically non-relevant, perceptual information does not contribute to memory organization, and memory defaults to conceptual category organization. This finding supports a theory of an episodically defined organizational structure in visual long-term memory that is overlaid upon an underlying conceptual structure.

23.4008 How Automatic is Visual Recognition Memory?

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Humans have an astonishing ability to remember with high fidelity previously viewed scenes with robust memory for visual detail (Konkle et al., 2010). To better understand the mechanism that affords us this massive memory we investigated the automaticity of encoding into visual long-term memory. We studied this in two ways across three experiments. First, measuring the effect of limiting the time of encoding by varying the allotted time to encode each image while keeping overall time of study constant. Second, measuring the effect of an attentionally-demanding concurrent task on subsequent retention by systematically varying the levels of demand imposed by the concurrent executive task. If encoding is automatic neither shorter exposure nor concurrent demand should influence subsequent recognition. If executive attention is required than memory performance should decline as load is increased and encoding time decreases. We tested scene memory using a standard massive memory paradigm with a heterogeneous (452 real complex scenes) and a homogenous (304 doors) image set examining if time of encoding and concurrent tasks affects scene memorability. Even when encoding a very rich heterogeneous set of images the encoding time mattered, with a significant reduction in performance from 3 seconds ($d'= 1.11$) to 1 second ($d'=.60$) study time. Interestingly, further reduction in encoding time to 0.5 seconds shows no significant decrement suggesting that encoding might follow a two-step process. Further, high fidelity encoding is reduced when during encoding there is a competing working memory task both for heterogeneous ($d'=.91$ for no load to $d'=.41$ for high load) as well as homogenous ($d'=.65$ for no load to $d'=.21$ for high load) image sets with amplified reduction when there is little idiosyncratic detail in the image. Results suggest that visual recognition memory encoding is the outcome of a two-stage rather than an automatic process.

23.4009 Quantifying Context Effects on Image Memorability

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Why do some images stick in our minds while others fade away? Recent work suggests that this is partially due to intrinsic differences in image content (Isola 2011, Bainbridge 2013, Borkin 2013). However, the context in which an image appears can also affect its memorability. Previous studies have found that images that are distinct, interfere less with other images in memory and are thus better remembered (Standing 1973, Hunt 2006, Konkle 2010). However, these effects have not previously been rigorously quantified on large-scale sets of complex, natural stimuli. Our contribution is to quantify image distinctiveness and predict memory performance using information-theoretic measures on a large collection of scene images. We measured the memory performance of both online (Amazon Mechanical Turk) and in-lab participants on an image recognition game (using the protocol of Isola 2011). We systematically varied the image context for over 1,754 images (from 21 indoor and outdoor scene categories), by either presenting images together with other images from the same scene category or with images from different scene categories. We use state-of-the-art computer vision features to quantify the distinctiveness of images relative to other images in the same experimental context and to correlate image distinctiveness with memorability. We show that by changing an image's context, we can change its distinctiveness and predict effects on memorability. Images that are distinct with respect to one context may no longer be distinct with respect to another. We find that images that are not clear exemplars of their image category experience the

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largest drop in memory performance when combined with images of other categories. Moreover, image contexts that are more diverse lead to better memory performances overall. Our quantitative approach can be used for informing applications on how to make visual material more memorable.

23.4010 A new model for the contents of visual working memory.

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Current models of visual working memory (VWM) have very different views about the structure of VWM, while they all appear to share assumptions about its contents. Specifically, current models assume (1) that the contents of memory are best characterized as values within continuous spaces (e.g., a value on a hue circle), and (2) that memory operates identically on all contents (e.g., experimental conditions being equal, red is remembered the same way as green). Here, we propose a revised model for accurately characterizing the contents of working memory, a model that can then be generalized to study the limits of color working memory. Categorization is an intuitive and universal aspect of color perception, and one that likely involves early visual processing. We have recently shown that category structure has large influences on behavioral responses in the widely used delayed estimation task, and also in an undelayed version of the task. We demonstrate that these influences can be parsimoniously explained by a dual content model that integrates a continuous value with a noisy category assignment. The model parameters are not fit; instead, we derive estimates of category centers and boundaries from a separate set of behavioral experiments with different observers. Finally, we demonstrate the applicability of the model to other stimulus features (e.g. orientation), and how existing models of VWM can incorporate dual contents to test hypotheses about memory limits. Currently, inferences about memory limits rest on differences in behavioral performance resulting from experimental manipulations (e.g. set size). But without accurate characterization of memory contents, stimulus-specific variations in performance are confounded with effects of experimental manipulation. The dual content model more directly situates working memory in its appropriate place as an intermediary between perceptual inputs and behavioral responses, rather than a stand-alone system.

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23.4011 Dual-trace Iconic Memory

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Previous literature suggests object perception and recognition may be supported by two parallel systems, a coarse-grained representation and a fine-grained representation. The present study tested whether this dual-trace representation could also underlie iconic memory. In the first experiment, six colors were presented for 200 milliseconds. Immediately after the offset of the colors, an arrow appeared indicating the position of one of the six colors in the memory set. Participants recalled the color originally in the cued location by matching it to a continuous color wheel. Performance in this immediate estimation task was modeled as a mixture of two von Mises distributions differing in standard deviation, which outperformed Zhang & Luck standard mixture model consisting of a mixture of a von Mises distribution and a uniform distribution. This was replicated in Experiment 2 in which the memory set size was increased to 16 and 24. In the next two experiments, a short-term memory condition was included, in addition to the iconic memory condition, by introducing a delay interval of 800ms (Experiment 3) or location changes (Experiment 4) between memory encoding and the test. Again, the mixture model of two von Mises distributions outperformed Zhang & Luck standard mixture model for the iconic memory conditions. In contrast, Zhang & Luck mixture model outperformed the mixture model with two von Mises distributions for the working memory conditions. Two other alternative models from visual working memory literature, including the flexible resource and variable precision models, were fit to iconic memory data across experiments and compared against the mixture model with two von Mises distributions. Overall, the latter captured the data the best. Together, these results support a dual-trace theory of iconic memory.

23.4012 Visual Metamemory: Metacognitive Control and Monitoring of Long-Term Visual Memory for Objects and People

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People have a remarkable long-term memory for scenes and objects – recognizing thousands of images from only a few moments of study each. We asked whether this visual memory capacity is associated with any metacognitive functions: What sense do viewers have of their abilities to encode – and subsequently access – such large numbers of stimuli? We tested whether allowing participants to control the time studying each image (self-paced) would – relative to fixed display durations (computer-paced) – increase their performance in a 2AFC old-new recognition test. We also tested whether participants had some metacognitive knowledge about their visual memory traces, through their 'bets' on having successfully recognized each item. In Experiment 1, when participants were allowed an average of two seconds of study for each item, recognition performance was significantly higher for self-paced than computer-paced study items. In the self-paced condition, the amount of time studying items was not only a significant predictor of their successful recognition but also of viewers' metacognitive awareness (i.e. confidence) about their accuracy. Studying objects again in Experiment 2 and individual people in Experiment 3, participants completed a self-paced block on Day 1 with unlimited study time, and completed a computer-paced block using the average of their self-paced study time on Day 8. Although performance was again higher after the self-paced study of objects in Experiment 2, such was not the case when controlling their study of people in Experiment 3 – perhaps complicated by factors such as attractiveness and distinctiveness. In both Experiment 2 and 3, the amount of time studying each item was again not only a significant predictor of recognition accuracy, but also of participants' confidence in their identification. The study of visual material may be profitably informed by metacognitive control and during retrieval later by metacognitive monitoring.

23.4013 Sensory Memory is Allocated Exclusively to the Current Event Segment

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The Atkinson-Shiffrin modal model forms the foundation of our understanding of human memory. It consists of three stores (Sensory Memory (SM), also called iconic memory, Short-Term Memory (STM), and Long-Term Memory (LTM)), each tuned to a different time-scale. Since its inception, the STM and LTM components of the modal model have undergone significant modifications, while, SM has remained largely unchanged, representing a large capacity system funneling information into STM. Moreover, how SM can work in ecological viewing conditions remains an unsolved problem. In the laboratory, visual memory is usually tested by presenting a brief static stimulus and, after a delay, asking observers to report some aspect of the stimulus. However, under ecological viewing conditions, our visual system receives a continuous stream of inputs, which is segmented into distinct spatio-temporal segments, called events. Events are further segmented into event-segments. We show, in a set of 5 experiments, that SM is not an unspecific general funnel to STM but is allocated exclusively to the current event-segment. We presented observers with an event stimulus consisting of multiple dots (n=1 to 4) moving along bilinear trajectories with a single deviation at the mid-point of each trajectory. The synchronized deviations in the trajectories yielded two event-segments, corresponding to pre-deviation and post-deviation event-segments. Observers were cued to report the directions of pre- or post-deviation trajectories. By analyzing observers' responses in partial- and full-report conditions, we investigated the involvement of SM for the two event-segments. The hallmarks of SM hold only for the current event segment. As the large capacity SM stores only items involved in the current event-segment, the need for event-tagging in SM is eliminated, speeding up processing in active vision. By characterizing how memory systems are interfaced with ecological events, this new model extends the Atkinson-Shiffrin model from laboratory settings to ecological conditions.

23.4014 "We remember what we like?": Aesthetic value and memorability for photos and artworks - a combined behavioral and computational study

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Several studies testing long-term pictorial memory have claimed nearly unlimited memory capacity even for large amounts of stimuli. Additionally, theories in empirical aesthetics have suggested that the aesthetic appreciation of a stimulus and its memorability may be linked – "we remember what we like". In the present study we investigated these questions for two types of stimuli: photos and artworks. Specifically, we

tested whether the memorability of a photo or artwork may be connected to its aesthetic value. A total of 52 participants took part in a two-phase experiment. In the first phase, 750 images (photos of everyday scenes, Korean artworks, and Western artworks) had to be memorized and rated for aesthetic value. In the second phase one day later, these images had to be recognized in an old-new paradigm. Overall, participants' long-term memory capacity proved to be significantly more limited than suggested before (average d-prime=0.987). Nonetheless, memorability scores themselves were reliable across participants. Surprisingly, artworks – although appreciated more aesthetically – were less memorable (d-prime=0.854) than everyday scenes (d-prime=1.201). Furthermore, aesthetic ratings correlated only marginally with memorability (r=0.174), suggesting that these two variables need to be examined separately in future research and modeling. For our computational study, we then tested a large set (n=1025) of pictorial, low-level image features in terms of correlations with the behavioral results. The features were able to predict the correct stimulus class with 85% accuracy (chance=33%). Interestingly, we found small, yet significant correlations for some low-level measures for aesthetic ratings (maximum r=0.312), but not for memorability scores (maximum r=0.15). Overall, however, computational features only provided a small amount of explanatory power. Taken together, these results show that aesthetic appreciation and memorability are two independent concepts (for both art and everyday scenes). In addition, memory representations and aesthetic experience seem driven largely by high-level interpretation processes.

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23.4015 **Emotional Context and Visual Long-Term Memory**

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Emotion exerts great impacts on memory. For instance, negative emotions can enhance memory encoding or reduce retrieval-induced forgetting. In addition, congruent mood states between encoding and retrieval (e.g., negative emotions at both stages) can also improve memory performance relative to incongruent mood states (e.g., negative emotion in encoding, but positive encoding in retrieval). However, it is unclear whether mood congruency between memory retrieval and encoding increases the probability of successful retrieval or enhance the quality of retrieved memory representations. The current study directly tested these two hypotheses using a visual long-term memory recall task. In the study phase, participants remembered a sequence of colorful objects. Each object was presented on top of a gray-scale negative image from the International Affective Picture System (IAPS). Participants gave a valence rating for each IAPS image for emotion induction. In the test phase, participants reconstructed the colors of the previously studied objects by continuously adjusting their colors under negative or positive emotional contexts using the same emotion induction procedure as that from the study phase. Negative IAPS images used for the negative emotional context were different from, but with matched valence as, those in the study phase. Positive images for the positive emotional context had comparable arousal levels as negative images. We found that memories encoded in negative context but retrieved in positive context (the incongruent condition) were less precise than memories encoded and retrieved both in negative context (the congruent condition). In contrast, no significant difference in the probability of successful retrieval was found between the two conditions. Follow-up experiments ruled out alternative interpretations that either negative emotion or positive emotion at the retrieval alone could account for the memory quality effects observed in the first experiment. Taken together, the present results support a resolution account for mood-congruency memory effect.

23.4016 **A hippocampal temporal gating mechanism for episodic visual memories**

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Our visual systems undoubtedly process far more than we can actually remember. But what determines whether something is remembered or not? Here, I propose that the key to storage could be the duration of neuronal activation. Even when presented in an RSVP stream at 72 images per second, briefly presented stimuli can be fully processed and activate selective neurons in monkey IT (Keysers et al, 2001, J Cog Neurosci). However, this activation is usually very brief, lasting only a few tens of milliseconds. But for some stimuli, the activation could last longer for a range of possible reasons. For example, the image might match a target in a visual search task, allowing activity to be boosted by top-down feedback. Alternatively, the stimulus could be very surprising, or emotionally powerful. Whatever the reason, prolonged activation lasting for around 150 ms or so could be used to decide that the input pattern is worth storing in an episodic memory trace. I propose that measuring the duration of the cortical activation could be a key function of the hippocampus. Specifically, hippocampal neurons could effectively test whether the same cortical input pattern is present on two successive cycles of a hippocampal theta rhythm. If so, the hippocampal neurons should fire and allow the pattern to be stored. Such a temporal gating mechanism could explain the puzzling fact that hippocampal visual response latencies in humans are typically 280-300 ms – much longer that the neocortical neurons that provide their inputs and which probably become active at around 120-150 ms after stimulus onset. It would also explain the remarkably close match between hippocampal activation and conscious awareness (Quian-Quiroga et al, PNAS, 2008) because only consciously perceived stimulus would generate activation patterns that last long enough for storage.

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23.4017 **Modeling information integration in sequential visual decision-making**

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Current models of human visual decision making based on sequentially provided samples posit that people make their next decision by unconsciously compensating the statistical discrepancy between measures collected in the long past and those collected very recently. While this proposal is compelling, it does not qualify as a rigorous model of human decision making. In addition, recent empirical evidence suggests that human visual decision making not only balances long- and short-term summary statistics of sequences, but in parallel, it also encodes salient features, such as repetitions, and in addition, it relies on a generic assumption of non-discriminative flat prior of events in the environment. In this study, we developed a normative model that captures these characteristics. Specifically, we built a constrained Bayesian ideal observer with a generative model having features as follows. First, data is generated randomly but not necessarily independently depending on its parameter selection. Second, the system has a memory capacity denoted by a small window size = t, and a world representation denoted by a large window size = T, the latter reflecting the observer's belief of the volatility of the world, i.e. the extent to which changes should be represented. Third, events can be described with p_i appearance probability, which is not constant in time but changes according to a Markovian update, and it has an initial strong peak at 50%. Fourth, observations are noisy so that the observer can collect only limited amount of information ($\square_i$) from each sample image. We implemented the above model and training on human data, we determined the optimal parameters for T, t, and inferred the evolving p_i for each subject. Our model could capture the behavior of human observers, for example their deviation from binomial distribution based on T,and t, and the negative correlation between recent and past decisions.

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23.4018 **The Loss of Information from Visual Working Memory depends on Retro-Cue Reliability**

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Retrospectively cueing an item retained in visual working memory during maintenance is known to improve its retention. However, literature has provided conflicting results regarding the costs of such retro-cues for non-cued items, which has led to a variety of theories on the role of cueing in visual working memory. We hypothesized that the differences in the reliability of retro-cues across studies might be a factor underlying conflicting results. We predicted that the more reliable the cues, the larger the costs for non-cued items. Participants performed a working memory task while electroencephalography (EEG) was recorded. Retro-cues indicated which of several items was most likely to be tested. We manipulated, between blocks, the ratio of trials on which the cue was valid vs. invalid. In addition to memory performance, we investigated the contralateral delay activity (CDA) in the EEG, which is claimed to index visual working memory maintenance. We also applied multivariate pattern analysis (MVPA) in the frequency domain to decode the location of the cued item. Reconciling previous contradictory findings, costs of invalid retro-cueing on recall performance (i.e. probability and precision estimates) were found only for highly reliable cues. Nevertheless, benefits of valid cueing were present for both reliabilities, though larger for highly reliable cues. Moreover, the CDA emerged only after a highly reliable cue. Finally, decoding accuracy was above chance level in the high alpha band (i.e. 10-12 Hz) following a retro-cue and was larger for highly reliable cues. Our results suggest that

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non-cued representations are removed from working memory only if the retro-cue reliability is high. Moreover, the presence of valid cueing benefits in the absence of invalid cueing costs suggests that an item in working memory can be prioritized without reallocation of memory resources.

Acknowledgement: Netherlands Organisation for Scientific Research

23.4019 **Visual long term memory is spatially specific, but only after a brief consolidation period** Yoolim Hong[1] (yhong1204@gmail.com), Andrew Leber[1]; [1]Department of Psychology, The Ohio State University

For successful commerce with the world, it is essential that we remember objects that we encounter within the proper contexts. Consistent with this, visual long-term memory is known to be context dependent. However, the way in which these context dependent memories manifest has been relatively unexplored. Here, we measured the degree to which visual object memory is tied to spatial location. We manipulated the retention interval to explore how spatially specific memories emerged over time. During an initial encoding phase, we presented two placeholders on the screen (one on the left, one on the right), and we presented a series of 200 face stimuli. To associate each face stimulus with specific spatial context, half of them appeared inside the left placeholder and the other half appeared inside the right placeholder. Participants were instructed to discriminate each face's gender, regardless of its location. Subsequently, participants began the recognition phase. Critically, for one group of participants (No Retention Group), the recognition phase began immediately after encoding was finished, while for the other group (Retention Group), the recognition phase began after a 15 min retention interval in which a visual search task was performed. During the recognition phase, we presented one previously viewed (old) face and one novel face on each of 200 trials. Participants had to discriminate the side of the display containing the old face. To manipulate context dependency, we presented half of the faces inside the same placeholder as during encoding ("matching" condition) and the remaining faces inside the other placeholder ("nonmatching" condition). Results showed that the Retention group's recognition memory was significantly better in the matching condition than the nonmatching condition, while the No-Retention group's performance was equivalent in the two conditions. These results implicate a key role of consolidation in the genesis of context-specific visual memory.

23.4020 **Waking up buried memories** Christelle Larzabal[1,2] (christelle.larzabal@cerco.ups-tlse.fr), Nadège Bacon-Macé[1,2], Simon Thorpe[1,2]; [1]Université de Toulouse, UPS, Centre de Recherche Cerveau et Cognition, France, [2]CNRS, CerCo, Toulouse, France

One of the most amazing features of our brain is its capacity to retain sensory memories for years or even decades. For example, people may recognize the names or faces of classmates fifty years after they have left school (Bahrick et al., 1975) or the title of TV programs fifteen years after their broadcast (Squire et al. 1975). In such cases, it is quite possible that the memories have been reactivated in the intervening period. For instance, people may have seen their classmates more recently, or seen a repeat of the TV program. But are those re-exposures really necessary to hold a memory for decades? Would people still be able to recognize stimuli when we can be certain that it is impossible that they could have experienced the stimulus more recently? To address this question we designed an experiment in which thirty four participants were shown the opening sequence of 50 TV programs that had been broadcast on French television between the late 50s and early 70s. They have not been rebroadcast since and are not available in the public domain. Based on the percentage of correct responses and the confidence level across participants seven videos were identified as being recalled. Performed on a single case level 15 extra clips were also correctly remembered by at least one of the participants which brings the total to 22 videos positively remembered. This study provides new evidence that it is possible to reactivate memories that were encoded several decades ago, sometimes more than 50 years, without the need for re-exposure in the intervening period. This puts severe constraints on the biological mechanisms that could allow such extreme long-term memories.

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23.4021 **Representations of retrieved face information in visual cortex** Sue-Hyun Lee[1] (lees11@mail.nih.gov), Brandon Levy[1], Chris Baker[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health, National Institutes of Health

Despite the high similarity of human faces, we can easily recognize and discriminate dozens of faces based on our memories and can retrieve how people look. Here, we asked how retrieved face information is represented in cortex? To address this question, we performed an event-related functional magnetic resonance imaging (fMRI) experiment, comprising separate perception, learning and retrieval sessions. During the perception session, inside the scanner, participants were presented with fixed pairings of six auditory cues (pseudowords) and face images (e.g. 'greds'-man1, 'drige'-man2), and six auditory cues and shoe images. During the learning session, on a separate day outside the scanner, participants were trained to memorize the pseudoword-image associations for about one hour. Finally, one day after the learning session, participants were scanned and instructed to retrieve each image in response to the paired pseudoword cue. To test the veracity of the retrieved visual information, participants were asked to perform forced-choice tests after the retrieval scan session. Every participant showed good performance in the forced-choice test (> 95% correct). We focused on the patterns of response in face-selective and object-selective cortical areas. Using multivoxel pattern analyses, we found 1) that face-selective and object-selective areas showed category (faces or shoes) specific patterns during both retrieval and perception, 2) that neither face nor object-selective areas showed patterns specific to individual faces or shoes during perception, but 3) that face-selective areas showed specific patterns of response to individual faces during retrieval. Taken together, these results suggest that retrieval of face information generates more discriminative neural responses for individual faces than that evoked by perception of the very same faces.

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Spatial Vision: Crowding and eccentricity

Saturday, May 16, 8:30 am - 12:30 pm

Poster Session, Pavilion

23.4022 **Peripheral Contrast Sensitivity in Human Adults: Measurements with Gabor Sinusoids Over a Broad Range of Eccentricities** Russell Adams[1,2] (michelem@mun.ca), James Drover[1,2], Michele Mercer[1], Stephanie Scott[1], Avery Earle[1]; [1]Dept of Psychology, Faculty of Science, Memorial University, [2]Discipline of Pediatrics, Faculty of Medicine, Memorial University

Purpose: Contrast sensitivity (CS) is considered the most comprehensive single measure of human spatial vision. Although solid data exist for CS in the near periphery (0 to 20o), few studies have examined CS at greater eccentricities and even fewer have employed Gaussian filtered sine waves (Gabor patches) which provide both reliable measurements and relative freedom from detection artifacts. In addition to a better understanding of retinal and neural mechanisms, establishing normative CS data across a broad range of eccentricities provides help in the assessment of eye diseases which target peripheral vision (e.g. glaucoma, RP, retinal degeneration). Methods: Right eyes from 20 young adults were tested with vertically-oriented sinusoidal Gabor patches that ranged logarithmically in spatial frequency (SF) from 0.375 to 18 cy/deg and in contrast from 0.001 to 0.30. Contrast thresholds at each SF were obtained foveally and from 100 to 800 within the temporal visual field. Testing was repeated 3 to 5 times for each adult. Results: CS was highest with central vision (M (across SF) = 145.9) but declined progressively at 100 (M = 57.1), 200 (M= 37.4), 400 (M=15.3), and 600 (M= 5.6). No consistent responses were obtained at 800. Across all eccentricities, CSFs displayed the typical inverted-U shape but peak CS shifted progressively to lower SF. Repeated measurements were highly consistent across all SF (r = 0.62 to 0.85). Conclusions: CS can be measured reliably up to at least 600 in the periphery. Spatial functioning decreases by about 0.24 log units per 10o across the periphery with the rate of reduction relatively greater for higher spatial frequencies. Overall, these psychophysical data are consistent with anatomical and physiological data describing the relative ratios and efficiency of P-cells in the peripheral retina.

Acknowledgement: NSERC, Janeway Hospital Foundation

23.4023 **Temporal dynamics of feature integration in peripheral vision and saccadic eye movement** Masahiko Terao[1] (masahiko_terao@mac.com), Ikuya Murakami[1]; [1]The University of Tokyo

In peripheral vision, a stimulus surrounded by multiple stimuli in close proximity can appear to look similar to the nearby stimuli (e.g., Greenwood et al, 2009). This perceptual assimilation also affects the landing point of a saccade (Terao & Murakami, 2014, APCV), indicating that both the visual and oculomotor systems integrate feature information over a certain spatial

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window. Here we investigated the temporal dynamics of these phenomena. A target cross and two flanker crosses vertically surrounding the target were presented at 12 degrees to the right of the fixation point. The crossing points of the flankers were deviated leftward or rightward. We varied the stimulus onset asynchrony between the target and the flankers and asked observers to judge the apparent position of the crossing point of the target. The results showed that the flankers presented prior to the target were not effective whereas the flankers presented at or after the target onset biased the horizontal position of the target's crossing point toward the flankers'. The temporal window of this effect was approximately 200 ms, with the maximum effect obtained at 25 ms after the target onset. In another experiment, observers were asked to make a saccade to the non-deviated crossing point of the target as soon as its onset. The results showed that the saccadic landing position was horizontally biased toward the deviated crossing points of the flankers even when they were presented 75 ms after the target onset. The effect was seen even when the flanker onset was only 80–40 ms earlier than the saccade onset. Our findings indicate that the visual and oculomotor systems integrate feature information not only over a large space but also over a long time in peripheral vision and that it is within a very short latency that the integration affects eye-movement statistics.

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23.4024 **Effects of Flankers Within the Crowding Zone** Susana Chung[1] (s.chung@berkeley.edu); [1]School of Optometry, University of California, Berkeley

Crowding refers to the inability to recognize an object that separates from its neighbors (flankers) less than the critical spacing. One account of crowding is that features from the target and flankers are combined erroneously within the crowding zone. Currently, little is known about what happens within the crowding zone. Here, we examined whether the adverse effect of flankers is combined linearly within the crowding zone. We measured the identification accuracy of a target letter presented at 10° nasal field or 10° lower field, with two flanking letters presented along the radial meridian. We first measured the identification accuracy of the target letter for six target-flanker separations, when the separation between the inner flanker and the target, and the separation between the outer flanker and the target, were yoked. A cumulative-Gaussian function was used to fit this set of data, from which we derived the critical spacings corresponding to 30%, 50%, 70% and 90% identification accuracies. Next, we measured the identification accuracy of the target by fixing the inner[outer] flanker at one of the critical spacings determined above, but varying the separation between the target and the outer[inner] flanker. Identification accuracy was also measured when only the inner or the outer flanker was present. In general, performance was better with only one, than two flankers. When two flankers were present with one at a fixed separation from the target, the critical spacing of the movable flanker was consistently smaller than the critical spacing for the yoked condition, by 51% and 34% for the inner and outer flanker, respectively. Our results suggest that within the crowding zone, the effectiveness of a flanker on the target depends on the presence of, and the location of other flankers. The overall crowding effect is not a linear combination of the effects of individual flankers.

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23.4025 **Similarity effects in crowding of Chinese characters** Yuk Ting Leo Cheung[1] (leo.yt.cheung@gmail.com), Sing-Hang Cheung[1]; [1]Department of Psychology, The University of Hong Kong

Introduction. Crowding severely limits the identification of a flanked target in peripheral vision. Previous research had shown weaker crowding with dissimilar flankers, i.e., the similarity effects on crowding. Here we manipulated configural legitimacy (Experiment 1) and contour integrity (Experiment 2) of flankers to investigate the effects of similarity on crowding in Chinese character recognition. Method. Ten normally-sighted observers participated in Experiment 1 and five in Experiment 2. Target stimulus in each trial was always a real, frequently-used and randomly-drawn Chinese character from a set of 176 (Experiment 1) and 190 (Experiment 2) characters. The target (size=1.5°) was presented for 100 ms at 5° eccentricity in the right visual field. Two horizontal flankers at 2° center-to-center distance were also presented in the flanked conditions. Contrast thresholds in a target identification task (Experiment 1: 25-alternative-forced-choice [25-AFC]; Experiment 2: 20-AFC) were measured using QUEST in a target-only and different flanked conditions. Flankers in Experiment 1 were (a) real, (b) pseudo- (non-existent but configurally legitimate), (c) non- (configurally illegitimate), or (d) scrambled characters. Flankers in Experiment 2 were (a) phase-intact (i.e. real) or (b) phase-scrambled characters. Results. No statistically significant variations were found among mean threshold elevations (TEs) in the four flanked conditions of Experiment 1 (real: 3.59±0.46 [SE]; pseudo: 3.08±0.45; non: 3.47±0.44; scrambled: 2.68±0.36). In Experiment 2, TE was significantly higher with phase-intact flankers (4.97±0.65) than with phase-scrambled flankers (2.34±0.49). Conclusions. The null effect of configural legitimacy suggests that the well-documented similarity effects may be restricted to low-level visual features. We found weaker crowding with phase-scrambled flankers, inconsistent with findings from previous research (e.g., Shin, Wallace & Tjan, 2010). It is possible that visible contours in flankers determine crowding strength only when the target is of high visual complexity, as in the case of Chinese characters.

Acknowledgement: This study was studied by a grant from the Hong Kong Research Grants Council, GRF HKU-741213.

23.4026 **Effect of spatial complexity on resolution, mislocations and crowding** Deyue Yu[1] (yu.858@osu.edu); [1]College of Optometry, Ohio State University

Reading is limited by three sensory factors: resolution (letter acuity), mislocations (uncertainty about spatial arrangement of letters), and crowding (the deleterious interference of nearby letters on target identification). Previous studies found a negative impact of flanker complexity on letter identification. Here we investigated whether the modulatory effect of complexity is restricted to crowding. Eight subjects identified single letters or the middle letters of trigrams presented at 10° to the left or right of the fixation point. Flankers were always duplicate letters, either identical or different from the middle target letter. Averaged across subjects, identification accuracy was 98.6% for the single-letter condition, 83.4% for the identical target-flanker condition, and 57.4% for the nonidentical condition. Multiple linear regressions were performed to assess the effect of letter complexity. In single-letter identification, higher complexity was associated with more errors. In the nonidentical condition, flanker and target complexities played opposite roles on performance with stronger influence from flankers. Higher flanker complexity led to more errors while higher-complexity targets made identification easier. Given the stronger effect of flanker complexity, we expected and indeed found that for the identical target-flanker condition the average effect of complexity (across target and flankers) on performance was negative (i.e. poorer performance for higher complexity). For the nonidentical condition, we teased out mislocation and crowding errors and found that mislocations depended on target complexity ($r< 0$) whereas crowding errors correlated with flanker complexity ($r>0$). Our findings demonstrate a general impact of letter complexity on reading-related sensory constraints. The effect of flanker complexity on crowding is consistent with the view that crowding may be due to compulsory averaging of target and flanker features or flanker substitution. However, substantial crowding under the identical condition indicates that change in target appearance in this case may be attributed to a process other than assimilation and substitution.

23.4027 **The Role of Peripheral Position Uncertainty in Overt Search** Yelda Semizer[1] (yelda.semizer@rutgers.edu), Melchi Michel[1]; [1]Rutgers University

Uncertainty regarding the position of the search target is a fundamental component of visual search. This position uncertainty can be either extrinsic (EPU)—uncertainty regarding where a stimulus might appear, or intrinsic (IPU)—uncertainty regarding the distal source of the perceived stimulus. Previous measurements indicate that IPU increases approximately linearly with visual eccentricity and that it accounts for impaired detection and localization performance in the periphery (Michel & Geisler, 2011). Our aim in the current project was to characterize the role of IPU in overt visual search and to determine whether it is a limiting factor in search performance. Human observers completed two tasks. First, the observers completed a detection task to measure sensitivity to the target as a function of visual field position. Then, they completed a search task, which required localization of the target signal within a noisy environment. Observers were allowed to make a maximum of six fixations. To examine the effect of IPU, two different experimental conditions were created. In the 'cluttered' condition, the display was tiled uniformly with feature clutter (in the form of 1/f noise) to maximize the effect of IPU. In the 'uncluttered' condition, the clutter at irrelevant locations was removed to decrease the effect of IPU. The amount of EPU was also manipulated across conditions. We developed a constrained ideal searcher model, in which the searcher is limited by IPU measured for human observers. Introducing IPU to the ideal searcher impaired overall overt search performance, but not uniformly. In the 'uncluttered' condition, performance decreased steeply as a function of increasing EPU. However, in the 'cluttered' condition, the effect of IPU dominated and performance flattened as a function of EPU. Measured performance for human searchers showed similar trends. Our findings suggest IPU as a limiting factor in overt search performance.

23.4028 **Crowding suppresses cortical responses to the target in human early visual cortex** Ziyun Zhu[1] (zzyladette.aicfc@pku.edu.cn), Dongjun He[1], Fang Fang[1,2,3]; [1]Department of Psychology and Key Laboratory of Machine Perception (Ministry of Education), [2]Peking-Tsinghua Center for Life Sciences, [3]PKU-IDG/McGovern Institute for Brain Research, Peking University

Crowding is the identification difficulty for a target in the presence of nearby flankers. Recent studies (Chen et al., 2014; Millin et al, in press) have shown that, using an indirect fMRI/ERP measure, the magnitude of crowding effect was closely associated with an early mutual cortical suppression between the target and flankers in V1. Here, we used the fMRI-based population receptive filed (pRF) technique to directly assess the effect of crowding on cortical responses to the target and flankers in human visual areas. The target was centered at 7.25° eccentricity in the upper-left visual quadrant with two adjacent flankers positioned radially. The target and flankers were a circular patch of a sine-wave grating (radius: 1.75°; contrast: 1.0; spatial frequency: 2 cycles/°) and were presented in a uniform gray background. The orientation of the flankers could be either perpendicular or parallel that of the target, resulting in a weak or strong crowding effect, which was confirmed by a separate psychophysical test. We identified voxels responding to the target and flankers based on their pRF parameters. We found that the responses of the target voxels in V1 and V2 were significantly weaker in the strong crowding condition than in the weak crowding condition, while the responses of the flanker voxels showed no difference in the two crowding conditions. We also found that the suppressive effect with the target voxels depended on subjects' spatial attention to the stimuli. These results provide direct evidence that the suppressed cortical responses to the target in human early visual cortex and spatial attention may play a critical role in visual crowding.

23.4029 **Rapid reduction of crowding by training** Amit Yashar[1] (amit.yashar@nyu.edu), Jiageng Chen[1], Marisa Carrasco[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Sciences, New York University

Background: Crowding refers to people difficulty to identify a letter in the peripheral visual field in the presence of nearby letters. The processes that underlie crowding are still debated. Some postulate the larger receptive fields and spatial integration in the periphery as the underlying mechanism for crowding. According to this view crowding is hardwired and cannot be rapidly changed. Recent studies have shown that crowding can be alleviated after 8-10 days of training but the speed of this improvement is still unclear. Objective: We tested whether a short period of training can alleviate crowding. Method: Observers were asked to identify the orientation of a letter in the periphery surrounded by two flanker letters. Observes were tested before (pre-test) and after (post-test) training (800 trials). We tested different components of feature selection by keeping letter color constant between training and test blocks as follows: 1) the target letter (feature selection); 2) the flankers (feature suppression); 3) both (selection and suppression). Results: Following training, all groups showed a reduction in crowding as assessed by the critical distance; i.e., the target–flankers distance at which the flankers no longer interfere with target identification. Conclusion: Our results show that training can rapidly reduce crowding and that the training stimuli need not be identical to the test stimuli. Observers not only can learn to identify the target but also to ignore the irrelevant flankers.

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23.4030 **The effects of precueing the target location on temporal crowding** Shira Tkacz-Domb[1] (shirtzi@yahoo.com), Yaffa Yeshurun[1]; [1]University of Haifa, Israel

Spatial crowding refers to impaired target identification when it is surrounded by flankers in space. Temporal crowding refers to impaired target identification when it is surrounded by other stimuli in time. We have recently demonstrated that target identification is impaired by preceding and succeeding stimuli up to an ISI of 300 ms. Additionally, we did not find an interaction between the effect of spatially adjacent flankers and the effect of preceding and succeeding stimuli. This study focused on the role of spatial attention on temporal crowding. Specifically, previous studies suggest that transient attention alleviates spatial crowding. Here we examined whether it can also alleviate temporal crowding. We presented a sequence of 3 displays to the right or left of fixation. Each display included 1 letter. In one of these displays an oriented T appeared. Observers indicated the T's orientation. The other two displays included a distractor letter presented at the same spatial location as the target. The ISI between the displays varied between 125 - 450 ms. In the cued condition an auditory precue was presented to the left or right ear, prior to the onset of the letters sequence. This auditory precue indicated the onset of the sequence and its location (left vs. right). In the neutral condition, an auditory precue was presented simultaneously to both ears, indicating the sequence's onset but not its location. Similar to our previous study we found a long-lasting effect of ISI. However, precueing improved performance only when the target appeared in the first display. Moreover, there was no cueing x ISI interaction. These findings suggest that unlike spatial crowding, temporal crowding is not effected by transient attention. Still, because a visual cue may be a stronger attractor of visual attention we are currently testing the effects of a visual cue on temporal crowding.

23.4031 **How to measure the spatial interaction zone of crowding?** Kilho Shin[1] (kilhoshi@usc.edu), Bosco Tjan[1,2]; [1]Department of Psychology, University of Southern California , [2]Neuroscience Graduate Program, University of Southern California

Clutter impedes object identification in peripheral vision. "Crowding zone" refers to the spatial extent surrounding a peripheral target within which the presence of a flanker impedes target identification. Several methods are commonly used to measure the crowding zone, but these methods do not necessarily measure the same quantity. When luminance contrast threshold is measured as a function of target-flanker spacing, a common approach is to fit the threshold vs. spacing function with a pair of lines: a line of negative slope intersecting with the horizontal line that represents the contrast threshold for identifying an isolated target. The target-flanker spacing at the intersection is taken as the spatial extent of crowding. When accuracy is a dependent variable, a comparably defined "full" spatial extent of crowding is the target-flanker spacing associated with the upper elbow of the psychometric function – spacing beyond which identification accuracy is the same as that for an isolated target. This, however, is not the common practice. Rather, most studies that use accuracy as a dependent variable define the crowding zone as the spacing associated with a specific level of accuracy somewhere at the middle of the psychometric function (e.g. 75% correct). This "partial" crowding zone is related to the "full" crowding zone by the slope of the psychometric function. We tested 11 subjects, each at 5 retinal locations and 2 eccentricities, for up to 6 different combinations of letter-like targets and flankers. We found while the full and partial spatial extent of crowding did correlate, there were a great deal of variability between the two, indicating that the slope of the psychometric functions varied significantly across conditions. We derived an efficient method for estimating the full crowding zone based on the adaptive psi method (Kontsevich & Tyler, 1999; Prins, 2013), rendering any reliance on partial estimation unnecessary.

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23.4032 **Onset transients recover target discriminability during crowding by directing attention to its salient features** Jeffrey Nador[1] (nador.j@husky.neu.edu), Adam Reeves[1]; [1]Northeastern University (Psychology, College of Science)

Previous research has demonstrated that applying onset transients to crowded targets can improve their orientation discriminability (Greenwood, Sayim & Cavanagh, 2014). We replicate this finding, but specify that the advantage conferred by onset transients occurs only 1) when there is a pre-existing feature contrast between the target and flankers 2) when attention is directed to the target near the time of transient onset. A cued RSVP procedure controlled attention--a sequence of white L's and R's was shown at fixation; after a variable delay, the last letter became black. Observers shifted their attention left or right, depending on the identity of the last white letter, to a flanked 3cpd target Gabor. The Gabors were shown 10 deg. left and right of fixation throughout each trial; only after the L or R cue did the observers know which would be the target. Having shifted attention, subjects reported the target's tilt, left or right, from vertical (mean 3 deg.). The flankers were either nearly parallel or nearly orthogonal to the target. A 50ms transient 'blink' was applied to a subset of stimulus elements randomly: either targets, or flankers, or both, or none. Preliminary results: orientation discrimination of orthogonal targets was improved when transients were applied to the target within ±100ms of the RSVP cue. Otherwise, transients had no effect. In sum, when a target is both top-down attended and featurally salient, an additional 'bottom-up' attention-capturing transient can partially recover the target from crowding. Why? Transients may boost the target signal even further, or briefly reduce the zone of integration.

23.4033 **Reaction time as a predictive marker for crowding** Maria Lev[1] (mariale2@post.tau.ac.il), Uri Polat[1]; [1]Tel Aviv University, Sackler Faculty of Medicine, Goldschleger Eye Research Institute, Tel Hashomer

Visual crowding, the inability to recognize objects in clutter, limits visual perception, conscious, and object recognition throughout most of the visual field. Crowding is measured as a reduction of the target's performance such as letter identification in the presence of flankers. We recently showed (Lev, Yehezkel, and Polat, Scientific Reports 2014) that foveal crowding may be absent for long presentation times but is evident for short times. However, the reaction time (RT) is remarkably slower under crowded conditions even without reduced accuracy. Since RT and response accuracy are used to explore the processing load, we hypothesized that RT can serve as a marker for processing the load imposed by spatial crowding. We asked subjects to identify the letter E embedded in a matrix of other letters for presentation times from 30 to 240 msec. The results show that foveal crowding is remarkable for short presentation times of 30 and 60 msec but is insignificant for 240 msec. However, RT was largely slower (~100 msec) even in cases without reduced accuracy (no crowding effect). Furthermore, RT for 240 msec predicts crowding effect for a more demanding task; for subjects that exhibit a slower RT for 240 msec, a larger crowding effect is measured for the shorter durations. Therefore, a slower RT can serve as a marker for an implicit increase in processing load to overcome reduced accuracy, suggesting reduced processing speed in crowding; hence it can be regarded as temporal crowding. Recently our perceptual learning studies showed that training improves the processing speed (Lev, Ludwig, Gilaie-Dotan, et al., Scientific Reports, 2014), thus enabling the crowding to be overcome for shorter presentation times. Hence, improved temporal crowding may be followed by reduced spatial crowding, thus eliminating "bottlenecks" for further cognitive tasks.

Acknowledgement: Israel Science Foundation (ISF)

23.4034 **Perceptual learning reduces crowding effect and the size of population receptive field in V2**

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Crowding is the identification difficulty for a target in the presence of nearby flankers. Previous studies have shown that perceptual learning could reduce crowding effect. However, the underlying neural mechanisms of the perceptual improvement are still largely unknown. It has been hypothesized that the reduction of crowding effect might be due to the shrinkage of neurons' receptive field by training. Here, we used the fMRI-based population receptive field (pRF) technique to examine this issue. Subjects were trained with an orientation discrimination task for five days. In the task, a target grating (radius: 1.25°; contrast: 1.0; spatial frequency: 2 cycles/°) was centered at 6.25° eccentricity with two adjacent flankers positioned radially. The target and flankers rotated round the fixation point and were displaced 20° every 2 seconds. Subjects needed to detect a near-threshold orientation change in the 2 second intervals. Before and after training, subjects viewed the same stimuli and performed the same task as those during training. Meanwhile, we acquired BOLD signals for estimating the pRF of the voxels in visual cortex. We found that, after training, subjects' orientation discrimination threshold reduced by 66% and the pRF size in V2 decreased significantly. These results support the above mentioned hypothesis. We speculate that the pRF size reduction might serve to prevent the interference from flankers and thus weaken the crowding effect.

23.4035 **Interocular differences in crowding and their variation across the visual field**

John Greenwood[1] (john.greenwood@ucl.ac.uk), Samuel Solomon[1], Steven Dakin[2,3]; [1]Experimental Psychology, University College London, London, UK, [2]Optometry & Vision Science, University of Auckland, Auckland, NZ, [3]Institute of Ophthalmology, University College London, London, UK

Crowding occurs when an object that is visible in isolation becomes unrecognisable in clutter. Typically strongest in peripheral vision, it is thought to be a "late" process that occurs after binocular integration (e.g. since flankers crowd the target similarly whether presented to the same or different eyes; Kooi et al, 1994). This pattern differs markedly in amblyopia however, where crowding is strongly elevated in the fovea of the amblyopic eye and minimal in the unaffected eye. Does this interocular difference (IOD) make amblyopic crowding a distinct process, or have we simply missed the IODs of the "normal" periphery? To assess this, we measured crowding in eight directions from fixation and at two eccentricities. Observers judged the orientation of a target Gabor, presented either alone or with two abutting flankers on an iso-eccentric axis. Stimuli were presented entirely to either the left or right eye. When crowded, thresholds were 1.1-37.9 times greater than uncrowded levels, depending on visual field location. IODs were clearly present within this range, with values between 0-21.7 threshold elevation units. The direction and magnitude of these IODs varied heterogeneously across the visual field – for a given location, some observers showed significantly greater left-eye crowding, where others were more right-eye crowded. IODs did not however depend on either the dominant/sighting eye or a simple naso-temporal asymmetry. Nonetheless, they are repeatable over a period of months. Similar variations were also observed within the "interference zone" for crowding by measuring the above with a fixed target location and varied flanker locations. We conclude that peripheral crowding does indeed vary between the two eyes. This points to an early monocular component to crowding that bridges the gap between processes in normal vision and the more extreme variations seen in amblyopia.

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23.4036 **Electrophysiological correlates of suppressive lateral interactions**

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The visibility of image elements can be reduced by other elements in their vicinity. This is usually explained by inhibitory lateral interactions among neurons in the primary visual cortex, although there is little evidence for the involvement of intracortical inhibition. Further, the mechanisms underlying these interactions remain unknown. We investigated the neural bases of suppressive lateral interactions by recording visual evoked potentials together with psychophysical measures for visual targets in the presence of flanking stimuli. High-density EEG's were recorded in eight observers with normal or corrected-to-normal vision in response to a foveally viewed Gabor as a function of the spacing of horizontally adjacent Gabors. Inter-element spacing ranged from 1.5 to 6 cycles from the centre of the target to the centre of either of its adjacent flankers. The central target had the same or a different orientation (0 º, ±15º, ±30º, and ±60º) and spatial frequency as the flankers (0, ±.5, and ±1 octave). Each stimulus configuration was repeated 80 times and stimuli were interleaved. We analyzed the power density and spectral coherence over the time-frequency plane (in the central occipito-parietal region). Power density ($p = 0.015$) as well as short- ($p = 0.005$) and long-range ($p = 0.005$) spectral coherence decreases as inter-element spacing decreased to reach conditions under which the psychophysical test produced the greatest suppression in the apparent contrast of the central Gabor. A similar pattern of results was found when the spatial frequency and orientation of the flankers were systematically varied. These findings support the cortical origin of suppressive lateral interactions through short- and long-range functional connectivity. Further, synaptic inhibition likely causes a breakdown of synchronisation in the network response, consistent with the proposition that a function of surround suppression is to remove the statistical redundancies by increasing the sparseness or selectivity of sensory responses.

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23.4037 **Exploring the vertical meridian asymmetry: Is poor performance restricted to the vertical meridian?**

Leslie Cameron[1,2] (lcameron@carthage.edu), Michael Levine[2,3], Jennifer Anderson[2]; [1]Department of Psychological Science, Carthage College, [2]Department of Psychology, University of Illinois at Chicago, [3]Laboratory of Integrative Neuroscience, University of Illinois at Chicago

The vertical meridian asymmetry (VMA) refers to better performance below ("south"; S) than above ("north"; N) the point of fixation on the vertical meridian. Here we explore whether poor performance is restricted to the vertical meridian by testing a greater range of stimulus locations, particularly near the vertical meridian, than previous studies. Methods: We measured percent correct on a 2AFC orientation discrimination task of 8cpd Gabor patches presented at each of 36 locations, primarily concentrated within 30 deg. of the vertical meridian at about 4.5 deg. eccentricity. Target contrast was chosen for each observer in pilot threshold tests. Visual performance fields were fit with ellipses, which were constrained by performance at all locations except for the vertical meridian. The ellipse method is advantageous because it takes into consideration other well-known inhomogeneities (see Anderson et al., 2014). We computed difference scores (predicted percent correct based on the ellipse fit minus observed percent correct, at each location) and examined how the difference scores varied as a function of angular degree. Results: In the upper visual field difference scores were largest at the N location and were diminished as stimuli were placed further from the vertical meridian. The greatest effect was observed within 20 angular degrees on either side of the vertical meridian. In the lower visual field difference scores were relatively constant; performance

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was only marginally lower at the S location but the data were reasonably well fit by an ellipse. Conclusion: Although performance is known to be poorer in the upper visual field compared to the lower visual field, it is particularly poor within 20 deg. of the vertical meridian. This has implications for both vision research and the optimal design of visual displays.

23.4038 Perceptual Consequences of Elongated Eyes Guido Maiello[1,2,3] (guido.maiello.13@ucl.ac.uk), William Harrison[2], Fuensanta Vera-Diaz[4], Peter Bex[2]; [1]UCL Institute of Ophthalmology, University College London, London, UK, [2]Department of Psychology, Northeastern University, Boston, MA, USA, [3]Department of Informatics, Bioengineering, Robotics and System Engineering, University of Genoa, Genoa, Italy, [4]New England College of Optometry, Boston, MA

Myopic eyes are elongated compared to the eyes of normally-sighted, emmetropic observers. This simple observation gives rise to an empirical question: what are the physiological and perceptual consequences of an elongated retinal surface? To address this question, we developed a geometric model of emmetropic and myopic retinae, based on magnetic resonance imaging (MRI) data [Atchison et al. (2005)], from which we derived psychophysically-testable predictions about visual function. We input range image data of natural scenes [Howe and Purves (2002)] to the geometric model to statistically estimate where in the visual periphery perception may be altered due to the different shapes of myopic and emmetropic eyes. The model predicts that central visual function should be similar for the two eye types, but myopic peripheral vision should differ regardless of optical correction. We tested this hypothesis by measuring the fall-off in contrast sensitivity with retinal eccentricity in emmetropes and best-corrected myopes. The full contrast sensitivity function (CSF) was assessed at 5, 10 and 15 degrees eccentricity using an adaptive testing procedure [Vul et al. (2010)]. Consistent with our model predictions, the area under the log CSF decreases in the periphery at a faster rate in best-corrected myopic observers than in emmetropes. Our modeling also revealed that a target at a given eccentricity projects onto a larger area of peripheral retinal for myopic than emmetropic eyes. This raises the possibility that crowding zones - the area over which features are integrated - may differ between eye types. We measured crowding zones at 5, 10 and 15 degrees of eccentricity using a 26 AFC letter identification task and found no significant differences between myopic and emmetropic observers. This suggests that crowding depends on spatial rather than retinal feature separation, which implies differences in the retino-cortical transformations in myopes and emmetropes.

Scene Perception: Coding and dynamics

Saturday, May 16, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4039 The artistic Turing test: An exploration of perceptions of computer-generated and man-made art Rebecca Chamberlain[1] (rebecca.chamberlain@ppw.kuleuven.be), Caitlin Mullin[1], Johan Wagemans[1]; [1]KU Leuven

The generation of genuinely creative works of art could be considered as the final frontier in artificial intelligence (AI). Several AI research groups are pursuing this by programming algorithms which generate works in various media and styles. The ultimate test of success for such a machine artist would be to convince the onlooker that it was generated by a human being; an artistic Turing test. Previous research has shown that observers can distinguish artworks generated by a skilled human artist over those of a child or an animal using the perception of intentionality- the appearance of a planned final product (Hawley-Dolan & Winner, 2011). However, there is a little research on whether observers can differentiate between computer-generated art and man-made art, and if so, whether these judgments are driven by impressions of intentionality or surface characteristics that identify the mode of production. Furthermore, the decision that an artwork is computer-generated may reflect a negative aesthetic preference, as research has suggested that believing an artwork or musical composition to be computer-generated negatively affects its aesthetic appraisal (Kirk et al, 2009; Moffat & Kelly, 2006). The current study examined whether individuals were able to differentiate between works of art whose creative or representational abilities are defined by computer algorithms, from matched artworks created by human artists. Participants sorted artworks into computer- or human-generated and indicated their aesthetic preference on a 7 point Likert-scale. Results show that participants were able to successfully determine the provenance of the artworks. Perception of intentionality and surface characteristics as well as a subset of image statistics (Pyramid of Histograms of Orientation Gradients (PHOG), luminance spectra) were also investigated in relation to source decision criteria. The results have implications for the way in which AI algorithmic art is created, as well as providing insights into their aesthetic perception.

23.4040 Connecting Time Jason Hays[1] (jason_hays22@mymail.eku.edu), Donald Varakin[1]; [1]Eastern Kentucky University

Past research suggests that scene organization affects duration judgments (Varakin, Klemes, & Porter, 2013, QJEP). The current experiments investigated whether organization affects duration judgments for arrays of abstract geometric shapes, using the gestalt cue of “connectedness” as a test case. In experiment 1, participants (n = 26) performed a temporal bisection task, judging on each trial whether an object array’s duration was closer to a pre-learned short (400ms) or long (1600ms) standard. On each trial, one of two kinds of arrays was presented: unorganized or organized. The 6 elements of unorganized arrays (two lines and four shapes) were presented at random, non-overlapping positions. In organized arrays, each line connected two shapes, thus creating two groupings. Bisection points (BP), calculated separately for each array type for each participant, were used to evaluate duration judgment biases. A BP is the duration at which 50% of the responses are predicted to be long, thus, smaller BPs indicate longer subjective duration. Unlike past work using real scenes, BPs for unorganized arrays (M = 981ms, SD = 109ms) were lower than BPs for organized scenes (M = 1011ms, SD = 115ms), ($p < .05$). To ensure participants attended to connectedness, in experiment 2 participants (n = 24) classified scenes as either organized or unorganized on half the trials, and performed temporal bisection on the rest. Participants did not know which task was to be performed until the end of a trial. In contrast to experiment 1, but consistent with past work using realistic scenes, BPs for organized scenes (M = 952 ms, SD = 155 ms) were smaller than BPs for unorganized scenes (M = 1030 ms, SD = 180 ms), ($p < .05$). Together, these results suggest that connectedness affects duration judgments, but the direction of the effect may depend on how participants process the display.

23.4041 Object motion impacts false memory for the space depicted in scene views (at least locally): A conceptual effect of motion on boundary extension? Christopher Dickinson[1] (dickinsonca@appstate.edu), Sarah Hinnant[1], Odessa-Nanette Fields[1], Kimberly Fiorentino[1], Robert Gucwa[1], Hailey Kerr[1], Marco Alcivar Perez[1], Emily Philipps[1], Chase Simonet[1], Bridget Wasowski[1], Alannah Marie Wray[1]; [1]Department of Psychology, College of Arts and Sciences, Appalachian State University

Does motion impact false memory for scene views’ spatial expanse (i.e., boundary extension)? Some researchers (e.g., DeLucia & Maldia, 2006; Munger, Owens, & Conway, 2005) have tested this question using simulated self-motion (e.g., an object in a scene was shown approaching the viewer), and they generally found greater boundary extension for scenes with simulated self-motion than for static scenes, contrary to predictions based on representational momentum (i.e., boundary restriction). In three experiments, we showed participants scenes with a single object appearing in three locations to simulate leftward or rightward motion – similar to standard representational-momentum paradigms. All backgrounds were color photographs of natural backgrounds (e.g., a field, a forest, a courtyard), and all objects were capable of motion (e.g., a beach ball, a horse, a rollerblader). On each trial, the background was shown continuously for 1.25 s; the object appeared in each location for 250 ms with a 250-ms ISI. Object motion was either forward or backward (relative to the object) and was either coherent (e.g., left, center, right) or incoherent (e.g., center, left, right). Four black borders surrounded all pictures. After a 250-s masked interval, a test picture appeared with the object in the exact same location in which it appeared before the mask. Participants’ task was to recreate remembered stimulus views by adjusting any of the picture’s four borders (test-picture border position was identical to stimulus-picture border position). Across three experiments, we found that for forward motion, participants moved the border closest to the object significantly closer to the object; for backward motion, participants moved the border closest to the object significantly farther away from it. This implies a conceptual effect of motion (e.g., Reed & Vinson, 1996) on false memory for scene views’ spatial expanse. Implications for the relationship between boundary extension and representational momentum will be discussed.

23.4042 Impaired behavioral and neural sensitivity to boundary cues in Williams syndrome Soojin Park[1] (park@cogsci.jhu.edu), Katrina Ferrara[1], Barbara Landau[1]; [1]Department of Cognitive Science, Johns Hopkins University

Boundaries are fundamental features that define a scene. However, not all boundaries are equally effective for navigation. For example, when preschoolers are disoriented and have to reorient by a flat boundary (e.g., a mat), they are unable to use geometry and will randomly search the four corners of the mat. However, when the mat is replaced by a curb 2 cm in height, they demonstrate geometric sensitivity by constraining their searches to the correct corner and its rotational equivalent (Lee & Spelke, 2011). This highlights children's exceptional sensitivity to boundaries that create subtle alterations in geometry. In the present study, we ask whether this sensitivity could be impaired by genetic defect using both behavioral and fMRI methods. Williams syndrome (WS) is a disorder resulting in abnormalities of hippocampal and parietal areas of the brain known to be involved in reorientation. WS children ages 4-12 years (n = 7) and adults ages 22-35 years (n = 5) were tested in three arrays defined by different boundary cues (mat, curb, and full wall). In contrast to typically developing (TD) children, both children and adults with WS randomly searched the 4 corners of the curb, and only geometrically reoriented within full walls. These data demonstrate that the WS reorientation mechanism is fragile, in that it requires the input of especially salient presentation of geometric layout. In a previous fMRI experiment (Ferrara & Park, VSS 2013), we found that the parahippocampal place area in TD adults is sensitive to the presence of a minimal curb cue in visually presented artificial scenes. Analyses of fMRI data from 2 WS adults indicate that this sensitivity is diminished. Collectively, this research suggests that damage to human parietal and hippocampal areas stemming from a genetic deficit can result in impairment of behavioral and neural representation of boundary cues.

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23.4043 **Eye Movements While Watching Narrative Film: A Dissociation of Eye Movements and Comprehension**

John Hutson[1] (jphutson@k-state.edu), Tim Smith[2], Joseph Magliano[3], Grace Heidebrecht[1], Thomas Hinkel[1], Jia Li Tang[1], Lester Loschky[1]; [1]Psychological Science, Arts and Sciences, Kansas State University, [2]Psychological Science, Arts and Sciences, Birkbeck, University of London, [3]Psychology, Arts and Sciences, Northern Illinois University

During reading there is a strong relationship between eye-movements and comprehension, but does this extend to the ubiquitous activity of watching movies? In four experiments we tested two competing hypotheses: H1) Mental Model: viewers' narrative comprehension guides their visual attention, versus H2) Tyranny of Film: Attentional synchrony across viewers washes out comprehension-based differences in attention. We tested these hypotheses by manipulating comprehension through the presence/absence of context while participants watched a clip from "Touch of Evil" (Welles, 1958): the Context condition saw a bomb put in a car to begin the clip, which the No-context condition did not see. We measured comprehension by having participants predict what would happen next after watching the clip. Experiment 1 established a strong comprehension difference; only the Context condition predicted the car exploding. Experiment 2, which added eyetracking, replicated the comprehension difference, but found no differences in eye movements in either attentional synchrony or looking at the car. Experiments 3 and 4 altered the perceived protagonist of the clip by what was shown first: the Context condition still saw the bomb and car first (i.e., car passengers = protagonists), but the No-context began watching later, first seeing a couple walking (i.e., couple = protagonists) and the car temporarily off-screen. Experiment 3 again showed the comprehension difference and overall eye movement similarity; however, when the No-context condition later first saw the car, they looked at it less than the Context condition. Experiment 4 measured on-line comprehension by having participants press a button whenever they perceived a new event. Results showed large differences in comprehension—the No-context condition perceived more events—thus demonstrating substantial differences in comprehension using two qualitatively different measures. However, these comprehension differences minimally affected eye-movements, with one small difference when the protagonist was manipulated, thus generally supporting the Tyranny of Film hypothesis.

23.4044 **Generating bridging inferences while viewing visual narratives**

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While visual narratives are ubiquitous, there has been relatively little research on how they are perceived and comprehended. An important unanswered question in visual narrative comprehension is how viewers generate inferences that connect (or "bridge") events depicted in a narrative. Thus, the goals of the present study were 1) to determine whether bridging inferences occur when comprehending wordless visual narratives, 2) if so, to determine whether the generation of such inferences can be revealed by analyzing picture viewing times in a manner similar to the analysis of sentence reading times in text comprehension, and 3) to identify the roles of linguistic and grounded (visuospatial) knowledge systems in the generation of those inferences in working memory (WM). Participants viewed picture stories containing target episodes consisting of a beginning state, a transition state, and an end state, respectively. Two versions of each target episode were created, in which the transition state image was either present or absent. When absent, viewers would need to infer the transition state action to comprehend the end state image. Experiment 1 showed that when thinking aloud, viewers tended to mention the action depicted in the transition state image more often when it was absent than when it was present, consistent with viewers inferring the missing action. Experiment 2 showed that viewing times were longer for the end state image when the transition state image was missing than when it was present, consistent with viewing times revealing inference generation processes. Experiment 3 showed that both linguistic and visuospatial WM loads attenuated the inference viewing time effect, indicating that both knowledge systems support inference generation during the comprehension of wordless visual narratives. Nevertheless, Experiment 4 showed that an overt linguistic process, subvocalization, did not support the generation of inferences when comprehending wordless visual narratives.

Acknowledgement: National Science Foundation

23.4045 **Effects of Recent Exposure to Atypical Environmental Statistics on Orientation Perception: Analyzing the Plasticity of the Horizontal Effect**

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We investigated how the statistics of the recently viewed environment affect the way that the visual brain processes information. Contrary to the oblique effect of orientation processing (Apelle, Psychol. Bull., 1972) research has determined that, when presented in a naturalistic context, human perception of horizontal orientations is actually worst and oblique orientations are perceived best – the horizontal effect (e.g., Essock,et al., Vis. Res., 2003). This indicates a relationship between encoding of orientation and natural scene statistics; the differential perception of orientations in broadband images closely matches their differential representation in the natural environment (Essock, Haun, & Kim, JOV., 2009). However, the hypothesis that this relationship likely evolved across millennia to make the visual system an efficient information-transmitting system needs to be evaluated in light of recent research showing the modification of orientation perception by exposure to altered environments (Bao & Engel, Proc Natl Acad Sci., 2012; Zhang, et.al., Cur. Bio., 2009) and studies showing later development of adult-like orientation processing (Ellemberg, Hansen, & Johnson, Vis. Res. 2012; Ellemberg, et. al., Percep., 2012). To assess the effect of recent exposure on broadband orientation processing, we modified the orientation content subjects viewed via FFT filtering of their environment in near-real-time. Subjects viewed a filtered visual world via HMD, and the perceptual strength of oriented content (i.e., the horizontal effect) was measured. Results show that experience in an isotropic environment alters anisotropic processing: all subjects show a typical horizontal effect pattern in pre-test, but not in post-test and most show a much more isotropic pattern of orientation perception after adaptation. Moreover, experience in other anisotropic environments adjusts orientation perception in a similarly predictable manner. This change in perception indicates not only that orientation processing is plastic, but that it is related in a predictable way to an observer's recent visual environment.

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23.4046 **When Does Scene Categorization Inform Action Recognition?**

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When comprehending a film, viewers rapidly construct a working memory representation of the narrative called an event model. These models encode the story location first (Kitchen vs. Park) followed by the character's action (Cooking vs. Washing dishes)(Larson, Hendry, & Loschky, 2012). This time course for scene and action categorization was also supported by recent research showing that action recognition is best when it was embedded in real scenes than a gray background. Although, this benefit was not pres-

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ent at early processing times (< 50 ms SOA)(Larson, et al., 2013). This suggests that scene and action recognition are functionally isolated processes at early processing times. However, this conclusion may be an artifact of the design used. Namely, actions from the same scene category were presented in blocks, allowing participants in the gray background condition to predict the scene category that would be presented without relying on the scene's perceptual information. If true, then presenting actions in a random sequence should eliminate this advantage. Participants were assigned to one of three different viewing conditions. Actions were presented either in their original scene background, on a neutral gray background, or on a texture background generated from the original scene (Portilla & Simoncelli, 2000). Visual masking was used to control processing time which varied from 24 to 365 ms SOA. Afterwards, a valid or invalid action category post-cue was presented requiring participants to make a Yes/No response. The results show no difference between the original and gray background conditions at early processing times (< 50 ms SOA), but both conditions were better than the texture background. After 50 ms SOA, performance for the original background was greater than the gray and texture conditions. The data indicates that sufficient scene categorization processing (~ 50 ms SOA) is required before it can inform action categorization.

23.4047 **Scene themes, natural scene structures, and spatial statistics for scene vision**

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Humans can grasp the gist of complex natural scenes quickly and remember rich detail in thousands of scenes viewed for only a brief period. However, little is known about the underlying neural processing. Both global and local features have been proposed to account for this rapid scene perception. Global features such as the gist descriptor encode structures of whole scenes but leave out local visual features and their spatial relationships. Local features such as scale-invariant feature transform encode statistics of local structures but leave out scene attributes at intermediate and large scales. In this study, we propose a theoretical framework of neural codes of natural scenes and scene perception. In this framework, 1) a visual scene is a sample from a probability distribution (PD) of natural scenes in terms of scene themes that specify object categories and their spatial layouts; 2) each scene theme is probabilistically represented by a set of natural scene structures (NSSs), which are patterns of co-occurrences of basic features, and their spatial arrangements; 3) neuronal codes of natural scenes are probabilities evaluated on the basis of scene themes and NSSs and their spatial arrangements; 4) scene perception is generated via statistical inference that involves extensive interaction between bottom-up and top-down processing based on PDs of natural scenes; and 5) scene themes and NSSs and their spatial arrangements facilitate other visual tasks, including space and scene memory, visual search, and object detection. To test this framework, we compiled scene themes and NSSs in several large datasets of scene categories and developed the proposed PDs of natural scenes. We then used these PDs to categorize natural scenes and found that the categorization accuracy is comparable to or better than the state-of-the-art models. This result calls for studies to test the psychophysical and neurobiological implications of this framework.

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23.4048 **Effects of Image Size on Clutter Perception: More Evidence for Proto-Object Segmentation**

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Outside the context of search, little is known about visual clutter perception. This study asked how clutter perception is affected by retinal image size. Following Yu, Samaras, and Zelinsky (2014, JoV), Experiment 1 had participants (n=20) rank order 90 images of random-category realistic scenes from least-to-most cluttered. Scenes were smaller (6.75°×5°) versions of the larger (27°×20°) images from the earlier study. Comparing the median clutter ranking (aggregated over participants) to the median ranking reported for the larger scenes yielded a near perfect correlation (Spearman's ρ = .953, p < .001), suggesting that relative clutter perception is invariant to image size. Experiment 2 had new participants (n=16) again rank order the same 90 images, now evenly divided between small and large (counterbalanced over participants). After obtaining difference scores (small image ranking minus large image ranking) for all 90 scenes we found that smaller images tended to be ranked as more cluttered than larger images (Wilcoxon signed-rank test, p < 0.001), suggesting that absolute clutter perception increases with decreasing image size. Clutter was estimated for each of the 90 small and large scenes using the proto-object model of clutter perception. This model segments an image into superpixels, then merges neighboring superpixels that share a common color cluster to form proto-objects. Clutter estimates were obtained by counting the proto-objects in each scene, and these were rank ordered from least-to-most cluttered. Correlating this ranking with the behavioral ranking from Experiment 1 yielded a Spearman's ρ =.852 (p < .001). We also compared the number of proto-objects in small and large scenes using the method from Experiment 2 and found that smaller scenes were estimated to be more cluttered than their larger counterparts (p < 0.001). We conclude that clutter perception is mediated by proto-objects, a mid-level of visual representation between features and objects.

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23.4049 **How we look tells us what we do: Action recognition using human gaze**

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Can a person's interpretation of a scene, as reflected in their gaze patterns, be harnessed to recognize different classes of actions? Behavioral data were acquired from a previous study in which participants (n=8) saw 500 images from the PASCAL VOC 2012 Actions image set. Each image was freely viewed for 3 seconds and was followed by a 10-AFC test in which the depicted human action had to be selected from among 10 action classes: walking, running, jumping, riding-horse, riding-bike, phoning, taking-photo, using-computer, reading, and playing-instrument. To quantify the spatio-temporal information in gaze we labeled segments in each image (person, upper-body, lower-body, context) and derived gaze features, which included: number of transitions between segment pairs, avg/max of fixation-density map per segment, dwell time per segment, and a measure of when fixations were made on the person versus the context. For baseline comparison we also derived purely visual features using a Convolutional Neural Network trained on fixed subregions of the persons. Three linear Support Vector Machine classifiers were trained, one using visual features alone, one using gaze features alone, and one using both features in combination. Although average precision across the ten action categories was poor, the gaze classifier revealed four distinct behaviorally-meaningful subgroups, walking+running+jumping, riding-horse+riding-bike, phoning+taking-photo, and using-computer+reading+playing-instrument, where actions within each subgroup were highly confusable. Retraining the classifiers to discriminate between these four subgroups resulted in significantly improved performance for the gaze classifier, up from 43.9% to 81.2% (and in the case of phoning+picture-taking; gaze = 81.6%, vision = 65.4%). Moreover, the gaze+vision classifier outperformed both the gaze-alone and vision-alone classifiers, suggesting that gaze-features and vision-features are each contributing to the classification decision. These results have implications for both behavioral and computer vision; gaze patterns can reveal how people group similar actions, which in turn can improve automated action recognition.

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23.4050 **The principles of object continuity and solidity in adult vision: Some discrepancies in performance**

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Infant looking-time results (Spelke, 1994) have shown that pre-verbal infants grasp the continuity principle (i.e. that objects cannot pop in and out of existence) and the solidity principle (i.e. that solid objects cannot pass through one-another) from around 3 months of age. Early theories assimilated both by treating solidity as resulting from a single, general principle of object continuity. However, more recent work on primates and older children (Santos, 2004; Keen, 2003) has suggested that children and primates have a greater mastery over continuity than solidity in action-based tasks. One potential explanation for this is that the vision/action system places a higher priority on continuity than solidity in object tracking. Here we tested this hypothesis directly using a novel object detection task. Adult participants viewed short videos depicting an object rolling behind one or two occluding screens. The occluding screen(s) then dropped, revealing the ball in a location either indicative of a continuity/solidity violation

or non-violation, and participants were required to indicate the location in which they perceived the ball via keypress within 750ms. Participants were tested in one of two learning conditions: a 75% non-violation condition or a 75% violation condition. Across three experiments, we observed (consistent with our original hypothesis): (1) A larger decrease in accuracy for violations relative to non-violations in the continuity than solidity condition. (2) A consistent three-way interaction between learning condition, physical principle (solidity vs. continuity), and violation. This three-way interaction resulted from the fact that in the 75% violation condition, participants learned to overturn solidity but not continuity based anticipations. Taken together these findings suggest that the visual system indeed places a higher priority on object continuity than solidity, and so offer a potential explanation for some puzzling developmental results.

23.4051 **There is beauty in gist: An investigation of aesthetic perception in rapidly presented scenes** Caitlin Mullin[1] (caitlin.mullin@ppw.kuleuven.be), Gregor Hayn-Leichsenring[2], Johan Wagemans[1]; [1]Laboratory of Experimental Psychology, University of Leuven (KU Leuven), Belgium, [2]Experimental Aesthetics Group, Institute of Anatomy I, Jena University Hospital, Friedrich-Schiller-University Jena, Germany

While an artfully crafted painting can evoke profound aesthetic experience, the same applies to a grand ballroom or sunset. Like fine art, everyday scenes contain aesthetic qualities, with some scenes preferred over others. The meaning or semantic label of a scene, known as scene gist, is extracted rapidly and automatically, with just a brief glance, computed mainly using low spatial frequencies (LSF) in the image. Although we can easily identify a scene, the question remains, if an accurate aesthetic impression can be formed from such rapid and coarse overall representation. We investigated the characteristics of scene gist to determine if aesthetic preference can be extracted with such short display durations. Furthermore, given that scene gist is based on an initial coarse representation, we asked whether LSF renderings of these scenes would elicit similar aesthetic judgments. Using a between-groups design, we found a significant positive correlation between aesthetic judgments on real-world scenes for images viewed for an unlimited amount of time and those viewed for only 45ms, but no significant correlation with the LSF set. This demonstrates that aesthetic judgments can be extracted rapidly and are relatively stable across display durations but do not survive image degradation, suggesting that image content outweighs structure. We performed the Implicit Associations Test by using aesthetically pleasing and non-pleasing images from the previous experiment paired with aesthetically pleasing and non-pleasing words, to examine whether these aesthetic judgments are also made automatically when they are irrelevant to the task. Participants made significantly more classification errors and were slower when pleasing scenes were paired with non-pleasing words. This suggests that participants could not help but make aesthetic judgments on real-world scenes. Additionally, we found that the most pleasing and non-pleasing scenes differed significantly on self-similarity and anisotropy, measures of image statistics relating to computational aesthetics.

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23.4052 **Domain-General Representation of Visual Aesthetic Appreciation in the Medial Prefrontal Cortex** Edward Vessel[1,2] (vessel@cns.nyu.edu), Jonathan Stahl[2], Isaac Purton[2], Gabrielle Starr[3]; [1]New York University, Center for Brain Imaging, [2]New York University, Dept. of Psychology, [3]New York University, Dept. of English

Are there "domain-general" neural processes that support aesthetic appreciation regardless of stimulus type, similar to the encoding of abstract expected value of goods? Recent work examining face and place attractiveness reported a common representation of attractiveness in medial prefrontal cortex (MPFC; Pegors et al., in press). We sought to test a) whether moving aesthetic experiences with artwork and architecture, artifacts of human culture that show much more individualistic preferences than landscapes or faces, rely on similar domain-general patterns of activation in MPFC, and b) whether such putative domain-general mechanisms overlap with the default-mode network (DMN), previously shown to be engaged by highly moving artworks (Vessel et al., 2012). Thirteen observers made aesthetic judgments ("how much does this image move you?") about images of artworks, natural landscapes, or architecture on a continuous scale while being scanned using fMRI. Classifiers were trained to distinguish most vs. least moving trials using patterns of trialwise BOLD responses. When provided data from the entire MPFC, classifiers trained on one category and tested on another performed better than chance for all train/test combinations (63-67%, $p < 0.01$), providing evidence for a domain-general aesthetic mechanism in the MPFC. Furthermore, classifiers trained on patterns from a spatially restricted ROI corresponding to the left anterior MPFC portion of the DMN (derived from subject-specific "rest" scans), also performed better than chance (55-62%, $p < 0.02$), providing strong evidence that this portion of the DMN contains domain-general information about aesthetic appreciation. We also found that when classifiers were trained and tested on images of the same category (halfwise-split; using the entire MPFC), performance was best for artworks (72%, $p < 0.01$), followed by landscapes (60%, $p < 0.05$), and lastly architecture (53%, n.s.), which suggests that MPFC as a whole contained more information about the aesthetic appeal of artworks than for the other categories.

Acknowledgement: NYU University Challenge Research Fund

Multisensory Perception: Neural substrates and synesthesia

Saturday, May 16, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4053 **Spatiotopic maps in calcarine sulcus of the congenitally blind** Petra Vetter[1] (petra.vetter@unige.ch), Lior Reich[2], Amir Amedi[2]; [1]Dept. of Neuroscience, University of Geneva, Switzerland, [2]Dept. of Medical Neurobiology, Hebrew University Jerusalem, Israel

Here we studied how congenitally blind subjects represent space in the brain and whether they have spatiotopic maps similar to the sighted. We asked 8 congenitally blind subjects to read specifically designed braille letters with a dot missing in either of the four corners of the braille grid (upper right, upper left, lower right and lower left) and to represent that part of space in their imagination while we acquired fMRI BOLD signals. Preliminary results show that functional maps corresponding to the four areas of space exist in the occipital pole close to calcarine sulcus. However, the coding of these maps differs across blind subjects and also differs from the coding of retinotopic maps in the sighted. The results suggest that visual brain structures evolved to represent space through visual input in the sighted can be rewired to represent space through tactile input in the congenitally blind.

Acknowledgement: Academy of Medical Sciences, UK

23.4054 **The neural dynamics of letter perception in blind and sighted readers** Santani Teng[1] (santani@mit.edu), Radoslaw Cichy[1], Dimitrios Pantazis[2], Aude Oliva[1]; [1]CSAIL, MIT, [2]Martinos Imaging Center, MIT

Functional changes in visual cortex as a consequence of blindness are a major model for studying crossmodal neuroplasticity. Previous studies have shown that traditionally visual cortical regions activate in response to a wide range of nonvisual tasks (Merabet & Pascual-Leone, 2010; Kupers & Ptito, 2013). However, the underlying computations, while often inferred to be similar for the blind and the sighted, have almost never been examined in detail. Here we used magnetoencephalography (MEG) and advanced multivariate pattern analysis to compare visual letter recognition with Braille reading (Sadato et al., 1996; Reich et al., 2011). We presented blind and sighted volunteers with 10 single letters in random order while recording brain activity. Sighted subjects were presented with Roman visual letters, while blind subjects were presented with Braille tactile letters. We used linear support vector machines to decode letter identity from MEG data. We found that the classification time course of letter recognition in sighted subjects was generally faster, briefer, and more consistent than in blind subjects. We then used representational similarity analysis (Kriegeskorte et al., 2008) to compare how sighted and blind subjects represented letters both within and across groups. This analysis revealed high within-group correlations at ~200 ms for sighted and ~600 ms for blind subjects. Correlations between groups were an order of magnitude lower, though overall significantly positive. The results suggest that blind and sighted letter reading may be largely driven by distinct processes, but that brain regions recruited crossmodally may be performing some common underlying computations for analogous tasks. This work was supported by NIH R01-EY020484 to A.O.

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23.4055 **Audiovisual integration in amblyopia** Michael Richards[1,2,3] (michael.richards@mail.utoronto.ca), Herbert Goltz[2,4], Agnes Wong[1,2,3,4]; [1]Institute of Medical Science, University of Toronto, Toronto, Canada, [2]Department of Ophthalmology & Vision Sciences, University of Toronto, Toronto, Canada, [3]Department of Ophthalmology & Vision Sciences, The Hospital for Sick Children, Toronto, Canada, [4]Program in Neuroscience & Mental Health, The Hospital for Sick Children, Toronto, Canada

Introduction: Amblyopia is a developmental visual impairment resulting from abnormal visual experience in childhood. While it used to be thought of as a low-level sensory disorder, recent studies have shown higher-level perceptual deficits. This study will define the temporal and spatial characteristics of audiovisual sensory binding, and will employ the Ventriloquism Effect to determine the relative weighting of audition and vision in spatial localization in amblyopia compared to visually normal controls. Methods: Participants with amblyopia (n=4) and normal controls (n=12) judged simultaneity of acoustic and visual signals at 13 levels of onset asynchrony, and judged co-localization of acoustic and visual signals at 9 levels of horizontal spatial separation. Point of subjective equality and precision for unimodal (auditory or visual) and bimodal (audiovisual) spatial localization was determined using a 2-AFC task. Auditory stimuli were click trains with perceived position controlled by interaural level difference. Visual stimuli were Gaussian blobs flashed on a large LED screen. Spatial reliability of the visual signal was manipulated by changing the Gaussian blob size. All experiments were carried out in a dark acoustic chamber under binocular viewing conditions. Results: Participants with amblyopia perceived audiovisual simultaneity over a significantly broader range of signal onset asynchrony than normal controls, particularly when the visual signal occurred first. Unimodal and bimodal spatial localization precision was lower in participants with amblyopia than in controls at every Gaussian blob size. Both participant groups demonstrated superior spatial localization precision for bimodal stimuli than for either of the component unimodal stimuli. Conclusion: Participants with amblyopia appear to have diminished ability to detect audiovisual asynchrony and reduced precision in visual spatial localization, even when viewing binocularly. Similar to visually normal controls, however, they appear to integrate visual and auditory spatial signals to achieve a 'bimodal advantage' to enhance localization precision of bimodal stimuli.

23.4056 Frequency-tuned auditory motion responses within hMT+ as a result of early blindness

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Introduction: Several fMRI studies have found directionally tuned responses to auditory motion in hMT+ in blind and sight recovery subjects (e.g. Jiang et al. 2013). Here we examined whether these auditory motion responses are tuned to frequency using sight recovery subject MM, who re-acquired vision during adulthood after becoming blind at age three. We previously showed that his hMT+ shows cross-modal responses to auditory motion, but can nonetheless be identified accurately using a visual motion localizer (Saenz et al. 2012). Methods: Data were collected on MM and 3 sighted controls. The auditory stimulus was band pass noise, with 7 center frequencies (125-3952 Hz). Each frequency band was presented for 2s and frequencies were presented in either ascending, descending, or semi-random order across scans. Auditory motion was simulated (using ITD and Doppler) as pairs of 1s bursts travelling at 30 m/sec from left to right or vice versa along the fronto-parallel plane. Subjects either listened passively or performed a one-back task in which they reported the repetition of a frequency (3 repeats/scan). The frequency tuning of each voxel was estimated as a Gaussian in log frequency space using population receptive field (pRF) modeling (Thomas et al., 2014). Results: Reliable tonotopic maps were found in primary auditory cortex in both MM and sighted controls for all conditions. No tonotopic responses were found within hMT+ in sighted controls for any condition. In MM we found robust frequency-tuned responses within both left and right hMT+ for the moving stimulus with the one-back task. However, hMT+ frequency-tuned responses were attenuated in MM when the stimulus was either stationary or there was no task, resembling responses seen in anophthalmic subjects by Watkins et al. (2013). Thus, MM's auditory responses in hMT are tuned for frequency as well as motion, and are modulated by attention.

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23.4057 Audiovisual reaction time enhancement is achieved through auditory-magnocellular interaction

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Reaction times (RTs) to crossmodal audiovisual stimuli are typically faster than reaction times to their unimodal components. This enhancement cannot be completely explained by simple statistical facilitation and is often referred to as the 'redundant signals effect'. It is unknown, however, which aspects of visual processing contribute toward this effect. Here, we considered the separate visual contribution of magnocellular and parvocellular activity; two anatomically and functionally distinct pathways at early processing levels. To attenuate the contribution of magnocellular activity, we presented visual stimuli on a diffuse red background—a condition known to selectively suppress [1] and slow responses to stimuli processed by the magnocellular pathway [2,3]. An isoluminant diffused green background was used for a baseline condition. Stimuli were 40% luminance increment spots with auditory tones, varying in onset relative to visual onset, between -100 (sound first) and 100 (spot first) ms in steps of 20 ms. The results show that when a red background was used, RTs were consistently slower across the range of onset asynchronies. More importantly, we found significantly smaller redundant signals effects for the red background condition. This pattern of results suggests the very fast crossmodal RTs associated with the redundant signals effect are mediated primarily by auditory interaction with magnocellular processes and links crossmodal RT advantage with visual mechanisms that mainly contribute to spatial orientation and action. 1. de Monasterio, F.M. (1978). Properties of concentrically organized X and Y ganglion cells of macaque retina. Journal of Neurophysiology, 41, 1394–1417. 2. West G.L., Bedwell J., Anderson A.K., Pratt J. (2010) Red diffuse light suppresses the accelerated perception of fear. Psychological Science, 21, 992–999. 3. Breitmeyer, B.G., & Breier, J.I. (1994). Effects of background color on reaction time to stimuli varying in size and contrast: Inferences about human M channels. Vision Research, 34, 1039–1045.

23.4058 Non-random association between vowel sounds and colors

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It has been suggested that graphemes of similar sound tend to be associated with analogous synesthetic colors in grapheme-color synesthesia (Asano & Yokosawa, 2011; 2012; Shin & Kim, 2014). A work in our group also showed that graphemes sharing phonetic rules – i.e., the place and the manner of articulation – tend to induce similar synesthetic colors (Kang et al., ASSC 2014). In the present study, we investigated whether phonetic properties are associated with colors in a specific manner even when other visual and linguistic features of graphemes are removed. We employed Haskins Laboratories articulatory synthesizer to generate vowel sounds as our stimuli by systematically manipulating gender (male and female voice) and tongue body position ('frontness' and 'height') (Iskarous et al. 2010, Nam et al. 2004). Four Korean grapheme-color synesthetes and nine non-synesthetes underwent a modified version of the standardized color-matching procedure (Eagleman et al., 2007) where they matched colors three times for each auditorily presented vowel sound. The matched RGB values were converted to HSV values and to CIE Lab color coordinates. Results showed the difference in both saturation and value of matched colors between male and female voices in most participants. However, only the synesthetes showed a consistent trend; male voices were associated with less saturated and darker colors than were female voices. In addition, saturation and value of the matched colors were higher for the vowel sounds generated at front. For the four participants (two synesthetes and two non-synesthetes) who showed statistically significant color-matching consistency, the front and high vowel stimuli were associated with brighter colors (L), and the high vowel stimuli were matched with more greenish colors (a*) on a red-green color axis. These results imply that the association between phonetic features and colors is not random, and this synesthetic association might be extended to individuals without synesthesia.

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23.4059 Texture-Color Associations in Non-synesthetes

Jose Hatem[1] (jhatem@berkeley.edu), Joshua Peterson[1], Thomas Langlois[1], Stephen Palmer[1]; [1]University of California, Berkeley

Previous work has revealed that non-synesthetes exhibit cross-modal music-to-color associations that appear to be mediated by emotion: e.g., people chose happy-looking colors as going best with happy-sounding music and angry-looking colors as going best with angry-sounding music (Palmer et al., 2013). A series of further studies revealed that music-to-texture associations (Langlois et al., VSS-2014; Peterson et al., VSS-2014) and shape-to-color associations (Malfatti et al., VSS-2014) also appear to be mediated by emotion, although non-emotional mediators are present as well. Here we show that emotional mediation generalizes to cross-modal associations from visual texture to color and from color to visual texture. We used the 37 colors of the Berkeley Color Project: saturated, desaturated, light, and dark shades of 8 hues (red/orange/yellow/chartreuse/green/cyan/blue/purple), plus white, black, and 3 grays. The textures consisted of the same 28 simple line-based textures generated by Langlois et al. (VSS-2014). In the color-to-texture condition, participants viewed each color indi-

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vidually and selected the three textures that were most consistent with it and then the three textures that were least consistent. Participants then rated each texture and each color individually on 5 emotional dimensions (e.g., happy/sad, angry/not-angry) and 5 non-emotional dimensions (e.g., safe/harmful, sharp/smooth). For each dimension, we computed an index of the color-texture associations (CTAs) as a weighted average of the relevant emotional (e.g. happy/sad) or non-emotional (e.g., sharp/smooth) ratings of the 6 textures chosen as going best/worst with each color. In the texture-to-color condition, each texture was shown individually, and participants selected the three colors that were most (and later, least) consistent with it, from which we computed an index of the texture-color associations (TCAs) in an analogous manner to the CTAs. Consistent with previous results, participants in both conditions reliably associated colors and textures that have similar emotional content for most of the emotional dimensions.

23.4060 **Relation between synesthetic grapheme-color associations and the sub-types of synesthesia** Kazuhiko Yokosawa[1] (yokosawa@l.u-tokyo.ac.jp), Michiko Asano[2]; [1]The University of Tokyo, [2]Rikkyo University

Grapheme-color synesthesia is a condition in which a visual letter or character induces a specific color sensation. By taking advantage of special characteristics of the Japanese language, we have revealed involvement of several linguistic properties of graphemes (e.g., phonology, orthographical shape, meaning or concepts) in determining grapheme-color synesthesia. For example, synesthetic colors for the Japanese phonetic scripts, Hiragana and Katakana, rely on sound quality, not visual shapes of graphemes. This is revealed by a remarkable consistency between synesthetic color choices for Hiragana characters and those for their Katakana counterparts that share phonemes but which are visually dissimilar graphemes (Asano & Yokosawa, 2011). Meaning and phonology both influence synesthetic colors for logographic Kanji characters (Asano & Yokosawa, 2012). To clarify the mechanisms underlying grapheme-color synesthesia the present study examined whether the sub-type of synesthetes (i.e. projector/associator) is related to processing grapheme-color associations. Projectors report experiencing synesthetic colors in external space, whereas associators report experiencing synesthetic colors “in the mind’s eye. Seventeen Japanese grapheme-color synesthetes participated in this study. According to the questionnaire by Skelton, Ludwig, & Mohr (2009), eight subjects were classified as projectors with the remainder classified as associators. Results revealed that the sub-type of grapheme-color synesthesia affected neither the degree of grapheme-color matching consistency over time nor the overall impact size of each linguistic factor (i.e., phonology, orthographic shape, and meaning or concepts) on grapheme-color associations. Nevertheless, the Hiragana–Katakana color consistency effect did show slightly greater, but statistically significant, strength for associators than for projectors. These findings suggest that although these sub-types differ in how they experience synesthetic colors, the process of determining grapheme-color associations is the same for both projectors and associators. Also we discussed implications of these results for a developmental model of grapheme-color association (Asano & Yokosawa, 2013).

Face Perception: Emotion 1

Saturday, May 16, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4061 **Similarity in Older and Younger Adults’ Emotional Enhancement of Visually-Evoked N170 to Facial Stimuli** Andrew Mienaltowski[1] (andrew.mienaltowski@wku.edu), Nicole Chambers[1,2], Brandy Tiernan[1]; [1]Department of Psychological Sciences, Ogden College of Science and Engineering, Western Kentucky University, [2]Department of Psychology, Harpur College of Arts and Sciences, Binghamton University

Emotional facial expressions elicit enhanced P1 and N170 components of visually-evoked event-related potentials (ERP) over posterior scalp regions associated with vision. Specifically, younger adults’ perception of and attention to facial stimuli are enhanced by positive and negative emotional expressions, with negativity leading to a greater benefit than positivity. Conversely, older adults demonstrate a positivity bias, devoting more attention to positive stimuli and less to negative. It is unclear if age differences in these attentional preferences emerge due to differences in how their perceptual systems respond to positive and negative stimuli. The current study examined the extent to which angry and happy facial expressions evoked differential patterns of P1 and N170 enhancements in younger (n = 21, ages 18-30) and older (n = 20, ages 60-76) adults. Participants were presented with happy, angry, and neutral faces under four instructional conditions: passively view, passively view but consider emotion, categorize emotion, and categorize gender. ERPs were recorded from the posterior scalp electrodes of a 128-channel high density electrode array and were time-locked to the onset of facial stimuli. The recordings were segmented and averaged based on the instructional condition and emotional expression of the stimulus. Analyses of the average P1 and N170 latencies revealed no age differences. Overall, participants displayed larger amplitude P1 and N170 to all stimuli when asked to categorize gender or emotionality. Contrary to expectations, both younger and older adults displayed larger N170 amplitudes for angry and happy expressions relative to neutral ones. Although older adults display a positivity bias in allocating attention to emotional stimuli, in the current study, younger and older adults both displayed an enhanced N170 for emotional faces relative to neutral faces, suggesting that the perceptual systems of younger and older adults are similarly engaged in processing positive and negative facial expressions at early time points.

23.4062 **Emotion categorization of facial expressions: Age differences in the utilization of diagnostic features** Marie Smith[1] (marie.smith@bbk.ac.uk), Daniel Grühn[2], Ann Bevitt[1], Mark Ellis[1], Oana Ciripan[1], Louise Ewing[1]; [1]Psychological Science, Birkbeck College, University of London, [2]Department of Psychology, North Carolina State University

The ability to accurately determine the emotional state of others is critical for successful social functioning. However older adults can demonstrate selective difficulties in identifying negative emotions from faces while the ability to identify positive emotional faces is preserved. In younger adults the categorization of facial expressions of emotion has been shown to rely on the processing of specific subsets of visual information (e.g. broadly smiling mouth in happiness, wide open eyes in fear)1,2. However it remains unclear whether healthy older adults process the same specific visual cues as younger adults in a less efficient manner when processing negative expressions, or if they attend to and encode qualitatively different information. We investigated whether the diagnostic information underlying the correct emotion categorization of five basic facial expressions (happy, fear, disgust, anger and sadness) changes as a function of observer age (young vs. older adults) and facial age (young vs. middle-aged vs. older faces). We applied the bubbles reverse correlation methodology with two groups of participants: younger (N=15, 18-35 years) and older adults (N=15, 65+ years). Results revealed that younger and older adults used qualitatively equivalent information to accurately categorize happy and fearful faces, but that the information used by both groups differed when they categorized fear in younger vs. older adult face stimuli. Older adults generally experienced more difficulty with the remaining negative emotions (disgust, anger and sadness) and exhibited a sub-optimal use of the diagnostic facial features. These results constitute a novel, highly detailed account of the specific visual features underlying the classification of facial expressions as across observer and transmitter of the emotional expressions stimulus age. 1Smith Cottrell, Gosselin & Schyns, 2005, Psychological Science 2Smith & Merlusca, 2014, Emotion

23.4063 **Orientation biases for facial emotion recognition in early childhood and adulthood** Jamie Schmidt[1] (jamie.schmidt.2@ndsu.edu), Benjamin Balas[1,2]; [1]Department of Psychology, College of Math and Science, North Dakota State University, [2]Center for Visual and Cognitive Neuroscience, North Dakota State University

Face recognition in adults relies on information in specific spatial frequency and orientation subbands. Depending on the task, adults will perform better or worse based on what information is present in face images. An example of such an information bias is adults’ reliance on horizontal orientation energy for recognition; adults are generally able to recognize a face when horizontal information is retained and have substantial difficulty identifying a face when primarily vertical information is presented. While several recent studies have demonstrated various ways that horizontal orientation energy contributes to adult face processing, there have been as yet no studies describing how this bias emerges developmentally. Currently, we recruited participants between the ages of 5 and 6-years-old (N=16) to perform a simple emotion categorization task using face images with either primarily horizontal orientation energy, primarily vertical orientation energy, or both orientation subbands. A group of adults (N=18) were also run through the same task to determine the extent to which horizontal and vertical orientation energy contributed to recognition as a function of age. Specifically, we wished to determine if an adult-like bias for horizontal orientation energy is present early in childhood, or if this bias develops over the course of middle childhood. Our results demonstrated that both groups exhibited a horizontal orientation energy bias, though this bias differed as a function of age. Both groups were better able to classify facial emotion when

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horizontal features were retained than when only vertical features were available. However, children performed at chance when presented with vertically-filtered images, apparently unable to use sub-optimal features for emotion recognition. By comparison, adults' performance was worse for vertically-filtered images, but still well above chance levels. We therefore propose that one feature of visual development may be the capability to use sub-optimal or weakly diagnostic information to support recognition.

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23.4064 **Tracking Emotional Expressions in Dynamically Changing Crowds**

Kelly Chang[1] (kchang4@berkeley.edu), Allison Yamanashi Leib[1], David Whitney[1]; [1]UC Berkeley

Previous research shows that individuals can accurately determine the average characteristics of crowds (e.g., average emotion, gender, or identity) even when viewing crowds for a split second (Haberman et al., 2007, 2009;, DeFockert et al., 2009). While prior research has investigated whether participants can perceive average emotional characteristics from static displays of crowds, it remains uncertain how participants track emotional fluctuations of crowds in real-time. In this experiment, we display a crowd of continuously morphing emotional faces, and ask participants to track the average emotion of the crowd using an online method of adjustment approach. By tracking participants' perception in real-time, we can determine whether participants are able to precisely report rapidlydynamically-changing crowd emotion. In our experiment, participants viewed crowds comprised of 1, 4 or 6 faces. While each individual face in the crowd changed its emotion every 50 ms, the overall average emotion of the crowd smoothly morphed between happy, angry, and sad following a semi-biased random walk trajectory (with 147 possible variations in between). Participants were able to precisely track the average emotion of the crowd as a whole, despite individual face percepts being disjointed. Additionally, our paradigm allows us to determine whether participants' perception lags behind the average crowd emotion, and if so, by how much. A cross correlation analysis suggests that participants' responses are tuned to the emotion of the crowd presented a few seconds earlier, potentially suggesting a perceptual lag or smoothing. Our results show that participants' overall perception of a unified crowd emotion remains intact, despite high individual face variation. Our results extend previous experiments by showing that participants are able to precisely perceive the overall emotional tenor of the crowd—even in dynamic, rapidly fluctuating scenes.

23.4065 **Synchrony enhances ensemble perception of dynamic emotional crowds**

Elric Elias[1] (elric.elias@gmail.com), Michael Dyer[2], Timothy Sweeny[1]; [1]Department of Psychology, University of Denver, [2]Department of Psychology, Hamilton College

Coordinated group behavior is common for many species, including humans. Perceiving groups is important, too, especially when that group displays emotion. To see a crowd, like a laughing audience or an angry mob, the visual system engages a mechanism known as ensemble coding, which compresses information about the individuals into a summary representation. This ensemble, or "gist", perception is remarkably quick, allowing people to judge the emotion of a large crowd with a mere glance, as if from a snapshot. But emotions are dynamic, and the way group members express their emotions—either in-sync or out-of-sync—may be critical for understanding their collective affect. If groups are defined not just by the proximity of their members, but also by their collective behavior, then ensemble representation should be particularly powerful for extracting emotional information from synchronous groups. On each trial, observers estimated the average emotional expression of a crowd of twelve faces, which included four unique identities. All crowd members displayed the same category of emotional expression (happy, angry, or fearful, on a given trial); each member began at a unique intensity. Across the 1-second presentation, each crowd member oscillated between weak and intense versions of that particular emotion. Critically, the individuals in some crowds changed their expressions synchronously, whereas the individuals in other crowds acted asynchronously. Additional trials contained only a single dynamic face. Observers perceived the emotion of synchronous groups more precisely than asynchronous groups. The benefits of coordinated behavior were so pronounced that synchronous crowds were perceived more precisely than even a single dynamic face. In contrast, asynchronous crowds and single faces were perceived with comparable precision. Our results show that ensemble representation is remarkably sensitive to synchronized group dynamics, and more generally, that collective behavior is critical for understanding and perceiving emotion as it occurs in crowds.

23.4066 **Angry expression detriment recognition decision of face memory: a diffusion model analysis**

Wenfeng Chen[1] (chenwf@psych.ac.cn), Ke Tong[1], Wei Tang[1], Huiyun Li[1], Naixin Ren[1], Xiaolan Fu[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences

It is known that emotion at encoding and consolidation memory can largely modulate face memory. However, how emotional cues at retrieval plays their roles remains unclear (Phaf & Rotteveel, 2005; Sergerie, Lepage, & Armony, 2007). Here we investigated the independent modulation of emotional cue on face recognition decision without the emotional impact at encoding and consolidation, and demonstrated how face recognition may be affected by facial expression at retrieval in terms of diffusion model decision biases. By comparing memory performance of angry, happy and neutral faces learned with neutral expression in a standard old/new recognition task, we found higher threshold separation (a), lower drift rate (v), lower starting point (z) for angry expression cue relative to happy expression cue, indicating a detrimental effect of angry expression cue on face recognition decision. Overall, these results suggested that an old/new decision for angry faces is characterized with the larger amount of information and the slower speed of information accumulation, which may result from the impaired holistic processing of angry faces (Curby, Johnson, & Tyson, 2012). It also indicated that a priori biases to "old" response of angry face with higher false alarm rate

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23.4067 **Effect of spatial frequency on facial expression adaptation and awareness of emotion**

Hong Xu[1] (xuhong@ntu.edu.sg), Pan Liu[1], Yuan Yuan[2], Weisi Lin[2]; [1]Division of Psychology, Nanyang Technological University, [2]School of Computer Engineering, Nanyang Technological University

Spatial frequency plays an important role in face perception (Wu et al., 2009). Previous studies (Goffaux & Rossion, 2006) found that low spatial frequency signalled holistic face processing. However, its effect on face adaptation and awareness of emotion is largely unknown. In particular, does spatial frequency affect facial expression adaptation and awareness of emotion? We designed two experiments, the first was to test the adaptation effect by manipulating the spatial frequency of the adapting faces, and the second was to test the disciminability of these faces. First, we manipulated the spatial frequency of a sad real face, and created three faces with normal, high and low spatial frequency. We adapted the subjects to these faces, and tested their facial expression judgement of subsequently presented faces. We found that both the normal- and low-spatial-frequency adapting faces induced significant facial expression aftereffects (both $ps < .01$), with equivalent magnitudes ($p > .05$). In contrast, we did not find any significant facial expression aftereffect when adapting to the high-spatial-frequency face ($p > .05$). This suggests that coarse information preserved in the high-spatial-frequency adapting faces is sufficient to bias subsequent face perception. This result points to the holistic nature of facial expression adaptation. We then examined the facial expression discriminability of these adapting faces. Results showed that participants could always differentiate facial expressions for both normal- and low-spatial-frequency faces accurately. However, the accuracy of high-spatial-frequency faces was at chance level (50%; $p > .05$), suggesting that participants could not tell facial expressions from these faces. To summarize, the results from our adaptation study indicate the holistic nature of facial expression adaptation, and this effect of spatial frequency is likely to be influenced by the adaptor's discriminability. Therefore, our study sheds light on the holistic nature of face processing and awareness of emotion during adaptation.

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23.4068 **Time Spent Fixated at Mouth is Related to More Positve Interpretations of Ambiguity in Surprised Faces**

Monica Rosen[1] (rosen.monica@huskers.unl.edu), Tien Tong[1], Alex Enerson[1], Maital Neta[1], Michael Dodd[1]; [1]Psychology, University of Nebraska-Lincoln

The purpose of this study was to investigate the interactions between eye movements on valence ratings of intact, low-spatial frequency (LSF), and high-spatial frequency (HSF) filterations of emotional faces (surprised and fearful). Previous research has shown that LSFs are processed quickly and efficiently (Hughes et al., 1997; Bar et al., 2006) and they benefit processing of emotional expressions, whereas HSFs are processed more slowly and benefit facial identification (Aldora et. al, 2007; Winston, Vulleuier, & Dolan, 2003). Surprised faces tend to be more ambiguous in nature, with the likelihood that these faces will be viewed as positive or negative depends critically on whether the upper (e.g., eyes) or lower (e.g., mouth) half of the face is processed. For this reason, we hypothesized that individuals would be more likely to interpret surprise positively when fixating longer on the mouth. Participants rated intact, LSF, and HSF filtered images of surprised and fearful faces as either positive or negative while eye movements were being recorded. As predicted there was a significant difference between fixation patterns in the eyes and mouth for surprise versus fear. More importantly, longer fixation time on the mouth was associated with a more positive judgment bias for the LSF and HSF conditions. These findings suggest that valence bias may be driven, at least in part, by differential attention to lower region facial features.

23.4069 **Subdermal Blood Flow Reveals Differential Responses to Emotional Stimuli** Larissa Vingilis-Jaremko[1] (vingilln@mcmaster.ca), Pu Zheng[1], Kang Lee[1]; [1]University of Toronto

Humans are known to react to emotional stimuli. For example, stimuli with different emotional valences elicit different cortical and behavioural responses (Dolan, 2002). However, human emotions can also lead to transient changes in blood flow within the facial vasculature (e.g. blushing; Darwin, 1872; Dolan, 2002; Drummond, 2013). Here we present a novel imaging method that examines participant responses to emotional stimuli using changes in haemoglobin concentration beneath the facial epidermis. In this study, 32 participants passively viewed a series of emotional stimuli, each of which was visible for 15 seconds. Participants' faces were positioned in a chin rest and centred between two LED panel lights. A Pike colour video camera recorded participants' faces at 15 frames per second with polarizing filters placed in front of the camera and LED lights. Because 1) light can penetrate the surface of the skin and be re-emitted, affected by the dominant chromophores (mainly haemoglobin and melanin); and 2) haemoglobin and melanin have different colour signatures, we developed a novel image processing method to obtain images of haemoglobin concentration distributions under the epidermis. We defined 9 areas of interest on the face from which to extract blood flow information (nose, and left and right forehead, eyes, cheeks, and chin). Each trial comprised 225 frames yielding changes in haemoglobin concentration over the time course. We focused the analysis on a subset of trials that depicted emotional stimuli with faces. We found greater variance in the waveform of haemoglobin concentration in response to the disgust face than the sad face in three areas of interest: right cheek, left cheek, and nose (all ps=.04). This study provides the first evidence that emotion-related blood flow beneath the facial epidermis can be imaged remotely and non-invasively in response to stimuli with different emotional valences.

23.4070 **Impact of task demands on the neural processing of facial emotions** Karly Neath[1] (kneath@uwaterloo.ca), Roxane Itier[1]; [1]Psychology, University of Waterloo

The Early Posterior Negativity (EPN) (~250-350ms post-stimulus) ERP component is a known marker of facial emotion processing however whether the face-sensitive N170 (~100-200ms post-stimulus) component is also sensitive to emotional faces remains debated. Possible causes for the previous inconsistent results are the use of different tasks involving varying degrees of attention to the emotional faces and the lack of control of point-of-gaze on the faces. We investigated whether emotion sensitivity of the N170 and EPN varied as a function of task in a sample of 33 participants. ERPs were recorded in response to the same fearful, joyful, or neutral faces during an explicit emotion discrimination task, a gender discrimination task, and an oddball detection (flower detection) task. Task order was counterbalanced across participants. Using an eye-tracker, fixation was restricted to the nose (i.e., centre of mass) where holistic processing is maximal. Results revealed N170 modulation by emotion with larger responses for fearful than happy or neutral faces in all tasks. As predicted, the EPN was modulated by emotion with larger responses for fearful compared to neutral faces. The EPN was also modulated by task with largest responses during the gender discrimination task, followed by the emotion discrimination task and smallest responses for the oddball detection task. Results suggest that when conditions for holistic processing are maximized with fixation to the centre of mass, the N170 is sensitive to fear irrespective of the degree of attention to the face placed by task demands.

23.4071 **Increased attention orienting by fearful faces varies with Stimulus-Onset Asynchrony** Sarah McCrackin[1] (sdmccrac@uwaterloo.ca), Roxane Itier[1]; [1]University of Waterloo

Spontaneous orienting of attention towards an observer's gaze direction is typically measured using a gaze-cuing paradigm in which a centrally-fixated face shifts its gaze towards (congruent) or away (incongruent) from a peripheral target. The reaction time (RT) difference between incongruent and congruent targets (gaze-orienting effect; GOE) indicates attention orienting based on gaze-cues. Studies have reported an increased GOE when the face expresses fear compared to happy or neutral expressions that might be due to the signaling of threat in the environment. However, the time course of this effect remains unclear. We used a dynamic gaze-cuing paradigm in which a neutral face with direct gaze looked to the side (averted gaze shift) and then either expressed fear or performed a neutral movement (tongue protrusion). The target was then presented after one of five Stimulus-Onset Asynchronies (SOAs; 300, 400, 500, 600, or 700 ms), the time between the gaze shift and the target onset. Overall, RTs decreased with increased SOAs, were faster for fearful than for neutral gaze-cues and faster for congruent than incongruent trials (classic GOE). The GOE was significantly larger for fearful than neutral faces, due to faster RTs for fearful than neutral faces in congruent trials, and this effect of emotion was largest at 400 and 500ms SOA. Thus, fearful expressions and gaze-cues interact to enhance orienting to congruent targets and this interaction is maximal at 400-500ms SOA. These results will be compared to gaze-cue orienting to happy and neutral faces in a second participant group.

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23.4072 **Image properties from the internal and external features of the face differentially predict patterns of neural response to expression and identity in human visual cortex** Mladen Sormaz[1,2] (ms930@york.ac.uk), Andrew Young[1,2], David Watson[1,2], Timothy Andrews[1,2]; [1]Department of Psychology, University of York, UK., [2]York Neuroimaging Centre, University of York, UK.

Models of human face perception propose parallel pathways. One pathway is responsible for processing changeable aspects of faces such as expression, and the other pathway is responsible for relatively invariant aspects such as identity. However, it remains unclear what image properties are encoded in these different visual pathways. Here, we ask how image properties from the internal and external features of the face contribute to the neural representation of facial identity and expression. In the first experiment, we measured patterns of brain activity using fMRI while participants viewed images posing different facial expressions (fear, anger, disgust, sadness, happiness). Next, we asked whether these neural patterns of response could be explained by variation in the image properties of the face when posing different facial expressions. We found that neural patterns of response to facial expressions in face-selective regions could be predicted by image properties from the internal, but not the external features of the face. In the second experiment, we measured patterns of brain activity using fMRI while participants viewed images of faces with different identities. We then asked whether these neural patterns of response could be explained by variation in the image properties across faces with different identities. In contrast to facial expression, we found that neural patterns of response to facial identity in face-selective regions could be predicted by the image properties from the external, but not the internal features of the face. These results reveal a direct link between image properties from different parts of the face and the neural representation of facial expression and identity in the human brain.

Face Perception: Wholes, parts, and configuration

Saturday, May 16, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4073 **Auditory attentional entrainment modulates the holistic perception of faces** Arnaud Leleu[1], Jean-Yves Baudouin[1], Daniel Zagar[2], Renaud Brochard[1]; [1]Centre des Sciences du Goût et de l'Alimentation – UMR 6265 CNRS – UMR 1324 INRA – Université de Bourgogne, Dijon, France, [2]Université de Lorraine, Campus Lettres et Sciences Humaines, Nancy, France

When a background auditory rhythm is played, visual objects are processed faster when presented in synchrony with the beat than out of synchrony, reflecting the oscillating entrainment of attention (Brochard et al., 2013; Escoffier et al., 2010). The present study aimed to investigate whether attentional entrainment induced by an irrelevant rhythm modulates the holistic perception of faces by using the composite face illusion. Participants had to judge whether the top half of a face belonged to "Nicolas Sarkozy". Three conditions were used: "same" (the bottom half of the face also belongs to "Nicolas Sarkozy"),"bottom different" (the bottom half belongs to an unknown person), "different" (both halves belong to an unknown person). The two parts of the face were aligned or misaligned. A rhythm was played during the task and the onset of faces was in-synchrony (on-beat) or out-of-synchrony (off-beat). Results showed the composite face effect in accuracy: i.e., deteriorated performance for recognizing "Nicolas Sarkozy" in the upper part of the face when it is aligned with the lower part of another face as compared to misaligned. No main effects or interactions involving synchrony were found in accuracy. Interestingly, in correct RTs, the composite face effect (i.e., slower processing for aligned "bottom different" faces than misaligned ones) interacted with synchrony, as it was observed only when faces were presented on-beat. Indeed, shorter responses were found for misaligned "bottom different" faces presented on-beat as compared to off-beat, whereas synchrony did not speed up responses for aligned "bottom different" composite faces (i.e., the ones eliciting the illusion). Because correct RTs in this condition reflect the time needed to accurately recognize the upper part of the face without taking into account the misleading lower part, the present results suggest that auditory entrainment of attention might enhance the holistic perception of faces.

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23.4074 **What Type of Facial Information Underlies Holistic Face Processing?** Isabelle Bülthoff [1] (isabelle.buelthoff@tuebingen.mpg.de), Mintao Zhao [1]; [1]Max Planck Institute for Biological Cybernetics

Holistic face processing is often referred to as the inability to selectively attend to part of faces without interference from irrelevant facial parts. While extensive research seeks for the origin of holistic face processing in perceiver-based properties (e.g., expertise), the present study aimed to pinpoint face-based visual information that may support this hallmark indicator of face processing. Specifically, we used the composite face task, a standard task of holistic processing, to investigate whether facial surface information (e.g., texture) or facial shape information underlies holistic face processing, since both sources of information have been shown to support face recognition. In Experiment 1, participants performed two composite face tasks, one for normal faces (i.e., shape + surface information) and one for shape-only faces (i.e., without facial surface information). We found that facial shape information alone is as sufficient to elicit holistic processing as normal faces, indicating that facial surface information is not necessary for holistic processing. In Experiment 2, we tested whether facial surface information alone is sufficient to observe holistic face processing. We chose to control facial shape information instead of removing it by having all test faces to share exactly the same facial shape, while exhibiting different facial surface information. Participants performed two composite face tasks, one for normal faces and one for same-shape faces. We found a composite face effect in normal faces but not in same-shape faces, indicating that holistic processing is mediated predominantly by facial shape rather than surface information. Together, these results indicate that facial shape, but not surface information, underlies holistic face processing.

Acknowledgement: This research was supported by the Max Planck Society.

23.4075 **Interactions between dynamic facial features** Ben Brown[1] (ben.brown.13@ucl.ac.uk), Alan Johnston[1]; [1]Experimental Psychology, University College London

Dynamic facial expressions entail coordinated movement of multiple facial features. Cook et al. found illusory slowing of eye blinks in the presence of mouth movement, arguing against independent processing in favour of global encoding of dynamic facial features (Cook, Aichelburg & Johnston, Psychological Science, in press). The present work extends the search for feature motion interactions from perception to performance. Principal Component Analysis occlusion studies highlight the importance of the eyebrow and mouth regions for determining global configuration. We asked whether the detection threshold for misaligned eyebrow movement might change in the presence of mouth movement. In a 2AFC design participants viewed two animated facial avatars, displayed for 3 seconds, either side of fixation, whose eyebrows oscillated sinusoidally at 1.5Hz. The standard's eyebrows moved in phase, while the comparison's were offset by between 1 – 30 degrees of phase angle (increments of around 5 degrees; standard/comparison position switching randomly). Participants judged which face's eyebrows were misaligned. The 75% point on the fitted psychometric function was taken as the dynamic misalignment discrimination threshold. In separate blocks both mouths were either closed or oscillating at 1.5Hz, and faces were upright or inverted. The inversion manipulation allowed us to differentiate between face-specific and lower-level mechanisms. Thresholds for 4 out of 5 participants increased in the presence of mouth movement by around 3.5 degrees of phase. Mouth movement therefore interferes with eyebrow movement discrimination, despite the spatial separation. The threshold shift either disappeared or reversed for inverted faces (mean shift around -0.9 degrees of phase). Face-specific processes can therefore be implicated in causing the interference as opposed to distraction, crowding or other low-level interactions. It would appear that the grouping of mouth movement with eyebrow movement disrupts the capacity of participants to discriminate eyebrow motion patterns.

Acknowledgement: BBSRC

23.4076 **Is the Flashed Face Distortion Effect expertise-based? - a systematic experimental investigation** Sandra Utz[1] (Sandra.Utz@uni-bamberg.de), Claus-Christian Carbon[1,2]; [1]Department of General Psychology & Methodology, School of Psychology, University of Bamberg, Bamberg, Germany, [2]Bamberg Graduate School of Affective & Cognitive Sciences (BaGrACS), Bamberg, Germany

The Flashed Face Distortion Effect (Tangen, Murphy & Thompson, 2011) describes an illusion that emerges when participants fixate on a central fixation cross while faces are presented quickly and simultaneously to the left and right of the center field. After a short period of time participants report to peripherally perceive the faces as grotesque and distorted. Despite broad coverage of the phenomenon via several media, it is not really clear how the perceived effect arises. Aim of the present study was to further investigate the necessary conditions and causes in a systematic way: as flankers we varied the stimuli by using Caucasian, black, inverted, negative, and monkey faces at different presentation rates (1, 4 or 10 Hz). Additionally, we tested the effectiveness of the phenomenon when only unilateral flankers were used. When participants had to evaluate the level of grotesqueness of the faces peripherally observed, they showed significant decreases of grotesqueness when faces were inverted or negativated, and also when they stemmed from other ethnic groups or species. Such a decrease of grotesqueness was also revealed when the presentation rate was at 10 Hz compared with the base rate of 4 Hz—meanwhile the slowest change of flankers, realized by the 1 Hz condition, showed the highest grotesqueness ratings. Contrary to the original authors' notion, unilateral flankers did not reduce the effect. Our results provide evidence that the Flashed Face Distortion Effect is based on configural processing which is typical for face expertise processes.

23.4077 **Speeded Breakthrough of Faces in Interocular Suppression Requires Configural Information** Katherine Wood[1] (katherinemwood@berkeley.edu), Anna Kosovicheva[1], Benjamin Wolfe[1], David Whitney[1]; [1]University of California Berkeley

The face inversion effect, wherein an upright face is recognized more readily than an inverted one, is well-documented (Yin, 1969; Maurer et al., 2002; Epstein et al., 2006). It has also been observed under interocular suppression (IOS), a technique in which a stimulus is presented to one eye, while the other eye views high-contrast, dynamic noise, rendering the low-contrast stimulus invisible. When the suppressed stimulus increases in contrast, it eventually becomes visible; upright faces "break through" faster—they require lower contrast to overcome suppression (Jiang et al., 2007). What information contributes to this speeded conscious access to upright versus inverted faces remains undetermined. To investigate this, we performed two experiments using IOS as described above. In Experiment 1, subjects viewed three categories of either upright or inverted faces (two-tone Mooney faces (Mooney, 1957), emoticons, and grayscale photorealistic faces) under IOS, and we measured breakthrough times. We found that photorealistic faces and emoticons exhibit a significant inversion effect ($p = .04$), but Mooney faces do not. This difference suggests that some information about the face other than the holistic percept is required for speeded breakthrough. In Experiment 2, we investigated whether configural or featural information about the face is required. Subjects viewed photorealistic faces under IOS, with either configural or featural information preserved. We found that the configurally intact face was not significantly different from the unmodified face, but the face lacking configural information was significantly slower to break through than both the configurally intact face ($p = .006$) and the unmodified face ($p < .001$). Thus, it is configural information that gains speeded access to awareness under IOS, and not holistic or feature-based information. This also suggests that IOS is resolved before the stage at which Mooney faces are recognized, supporting dissociable stages of processing for Mooney versus photorealistic faces.

23.4078 **The nose-size illusion: Testing the role of visual context** Pu Zheng[1] (zzzpi99@gmail.com), Yan Dong[1,2], Yi Le[2], Yuhao Sun[1], Guoliang Yu[3], Paul C. Quinn[4], Kang Lee[1]; [1]Dr. Eric Jackman Institute of Child Study, University of Toronto, [2]Departiment of Psychology, Renmin University of China, [3]Institute of Psychology, Renmin University of China, [4]Department of Psychological and Brain Sciences, University of Delaware

The nose-size illusion refers to the fact that when the size of a face's frame is changed but the nose size unchanged, we observe the nose size to be different from that in the original face frame (Rakover, 2011; Xiao et al., 2014). Here, we examined whether this illusion is face-specific or a result of visual expertise by comparing the size of the nose illusion in the context of face or word processing. In Experiment 1, in the face condition (Figure 1c & d), Chinese participants (n = 29) judged which nose was bigger on two otherwise identical upright or inverted faces. The face frame sizes differed from the original by 6%, 14% & 20% with the nose size unchanged. In the word condition (Figure 1a & b), participants judged which square (the lower-half part of the word) was bigger on two otherwise identical upright or inverted Chinese words. The frame was square to resemble the Chinese word shape. In Experiment 2, the frame was changed to oval to resemble the face shape (Figure 1b & d). Participants' illusory perception was greater on Chinese faces than Chinese words at all degrees of variations in both experiments (Figure 2a & b), $F(1, 28) = 52.90$, $p < .05$, $\eta 2 = .65$; $F(2, 26) = 40.61$, $p < .001$, $\eta 2 = .76$. In Experiment 2, stimulus category, orientation, and degree of variation was significant, $F(2, 26) = 4.07$, $p < .01$, $\eta 2 = .24$. Further, the illusion on upright faces was greater than that on inverted faces, but the square-size illusion was greater on the inverted words than upright words (Figure 2b). These findings suggest that different visual expertise may play different role in engendering the nose versus square illusions, and more generally how we perceive feature sizes in a context.

23.4079 **The eye-size illusion in the face composite task: Evidence for a direct role of holistic processing**

Yan Dong[1, 2] (dongpsy@gmail.com), Yan-Fei Jia[1], Pu Zheng[2], Naiqi Xiao[2], Guo-Liang Yu[3], Paul Quinn[4], Kang Lee[2]; [1]Department of Psychology, Renmin University of China, [2]Dr. Eric Jackman Institute of Child Study, University of Toronto, [3]Institute of Psychology, Renmin University of China, [4]Department of Psychological and Brain Sciences, University of Delaware

The eye-size illusion refers to the fact that when the size of a face's frame is changed but the eye size is unchanged, observers judge the eye size to be different from that in the original face frame (Rakover, 2011; Xiao et al., 2014). Indirect evidence suggests holistic processing to be involved in engendering this illusion (Xiao et al., 2014). To test directly the role of holistic processing in the eye-size illusion, we used the composite face paradigm (Young et al., 1987), a gold standard test of holistic processing. Participants (n=30) judged which eyes were bigger in two conditions (Figure 1). In the original-composite face condition (Figure 1a & c), one face is the original face and another is the composite face (the top is the same as the original but the bottom is a different person's). In the composite-composite condition (Figure 1b & d), two faces are identical composite faces. In each condition, the faces were either aligned (Figure 1a & b) or misaligned (Figure 1c & d). The face sizes differed from the original by 6%, 10%, or 14% with the eye size unchanged. Participants' eye-size illusion was greater with a smaller face frame, replicating the robust eye-size illusion, $F(2, 28) = 11.59$, $p < .001$, $\eta 2 = .45$. Their eye-size illusion was greater in the aligned than misaligned faces, suggesting the involvement of holistic processing, $F(1, 29) = 8.62$, $p < .01$, $\eta 2 = .23$. Participants also showed a greater eye-size illusion in the original-composite condition than in the composite-composite condition, $F(1, 29) = 18.88$, $p < .001$, $\eta 2 = .39$, further supporting the role of holistic processing. These results together suggest that holistic face processing plays an important in the perception of the eye size illusion.

23.4080 **When the fat face illusion meets the Thatcher illusion**

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Thompson (2010) reported a fat face illusion in which an upright face looks 'fatter' when placed next to an inverted face (Figure 1a). Sun et al. (2012) observed that the adjacent face need not be inverted for the illusion to emerge: when two identical faces are presented vertically, the bottom face appears 'fatter' (Figure 1b). When both faces are inverted or when clocks are presented, the illusion is not observed. Sun et al. (2013) also manipulated face contour and internal parts and found that face contours (without internal features) or inner parts (without an external contour) induce the illusion, suggesting that face contour and internal features play important roles in producing the fat face illusion. The Thatcher illusion (Thompson, 1980) offers a paradigm to separately manipulate the orientation of face contour and internal parts in face photographs. Using this paradigm, we further probed the role that face contour and internal features play in producing the fat face illusion. In Experiment 1, upright normal faces, Thatcherized face photos (with eyes and mouth inverted), and enhanced Thatcherized face photos (with eyes and eyebrows inverted together, and mouth inverted) induced the fat face illusion, suggesting that the illusion follows the orientation of face contour when faces are upright, regardless of the orientation of the internal features. In Experiment 2, using inverted versions of the faces used in Experiment 1, Thatcherized and enhanced Thatcherized faces induced the illusion, whereas normal faces did not. These latter data suggest that the illusion (1) still follows the orientation of the face contour when faces are inverted, but (2) is mediated by the orientation of the internal features when they are in the inverted face contour. Collectively, the findings suggest that external contour and internal features play different roles in producing the fat face illusion.

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23.4081 **The Use of Eyebrows as a Visual Feature**

Jacqueline Castro[1] (jcastro_93@csu.fullerton.edu), Jessie Peissig[1], Cindy Bukach[2]; [1]California State University, Fullerton, [2]University of Richmond

Previous research suggests that although faces are processed holistically, concealing or erasing parts of the face impairs recognition. Recent research suggests that eyebrows play a key role in facial recognition (Sadr, Jarudi, & Sinha, 2003). What has yet to be understood is what exactly that role is. Eyebrows may serve as placeholders, to measure spatial distances within the face (White, 2004). If so, then changing eyebrows will have no effect on recognition, so long as the eyebrows remain in the same position. Eyebrows may also be used as recognition features of the face. If this is the case, altering eyebrows will impair recognition. Seventy-two participants were tested with faces on a same/different task. Participants were presented with two faces sequentially and reported whether the two individuals were the same or different. There were four conditions for the two faces presented: Same faces (no changes), different faces (no changes), same faces with different eyebrows, or different faces with the same eyebrows. When eyebrows were replaced, the new eyebrows were placed in the same position as the original eyebrows. Testing consisted of 320 trials, 80 trials in each condition. It was expected that if eyebrows are used as a feature for recognition, then having different eyebrows on the same trials and the same eyebrows on different trials should both yield poorer performance. Results confirmed these predictions (see Figure 1), showing a significant difference between same trials with the original face and same trials with changed eyebrows. We also found a significant difference between different trials with the original faces and different trials in which the eyebrows were the same. These results show that participants attend not only to the location of the eyebrows but also their visual appearance, suggesting that they could serve a role as visual feature of face recognition.

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23.4082 **Framing of faces: Similarly impaired holistic perception from disruption of grouping- and configural- cues**

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The mechanisms that integrate facial features into holistic perceptual units are relatively unknown. Evidence suggests that basic perceptual grouping mechanisms can contribute to holistic face perception: holistic processing of face, but not non-face objects, indexed via the congruency effect, is significantly reduced when the backgrounds upon which faces are presented are themselves misaligned and colored differently, cues that discourage grouping of face halves into cohesive (object) units (Curby, Goldstein, & Blacker, 2013). To further probe the influence of perceptual grouping cues on holistic face perception, participants made part-matching judgments about faces presented in either an intact external (oval) frame or a frame made from misaligned oval parts to discourage the grouping of the face halves into cohesive (object) unit. Notably, the external contour of the face image in the misaligned frame condition is the same as that in the standard misaligned condition used in the composite task indexing holistic perception. However, unlike in the standard misaligned condition, the configuration of features within the face remained intact. For comparison, participants also made part judgments about faces where both the face parts and frames were misaligned together (i.e., as in the standard misaligned condition). Intriguingly, the effect of disrupting only the frame, and not the configuration of the face, on the congruency effect was indistinguishable from that of disrupting both the frame and configuration together. This comparable attenuation of holistic perception by the disruption of basic perceptual grouping mechanisms provides further support for the contribution of such mechanisms to holistic face perception.

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23.4083 **Testing Asymmetric Holistic Processing within a Face: No evidence from the Complete composite Task.** Chao-Chih Wang[1,2] (ccu.gary@gmail.com), Gary C.-W. Shyi[1,2]; [1]Department of Psychology and Center for Research in Cognitive Sciences, National Chung Cheng University, Chia-Yi, Taiwan, [2]Advanced Institute of Manufacturing with High-tech Innovations (AIM-HI), National Chung Cheng University, Chia-Yi, Taiwan

Face composite task has been one of the most popular research paradigms for securing evidence for holistic processing of upright faces. Aside from the fact that the exact mechanism underlying holistic processing remains elusive and controversial, some studies have suggested that holistic processing may not be evenly distributed in that processing the top-half of a face might induce stronger holistic processing than processing its bottom-half counterpart. Here in three experiments we further examined the possibility of asymmetric holistic processing. In Experiment 1, we equated perceptual discriminability between the top-half and the bottom-half of a face by showing only face halves and found no differences in performance between the two halves. In Experiment 2, using the face composite task with a complete design to reduce response bias, we failed to obtain evidence that would support the notion of asymmetric holistic processing between the top-half and bottom-half faces. Finally, in Experiment 3, in order to further reduce performance variability and to remove lingering holistic effect observed in the misalignment condition of Experiment 2, we doubled the number of trials and enlarged misalignment between top half and bottom half of a face to make it more visible. Even with these additional manipulations, we were unable to find evidence indicative of asymmetric holistic processing. Taken together, these findings suggest that holistic processing may well distribute homogenously within an upright face and support the perceptual field hypothesis where an upright face would induce relatively large perceptual field encompassing the entire face.

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23.4084 **Global and Local Priming Evoke Different Face Processing Strategies: Evidence From An Eye Movement Study** Zhijie Cheng[1] (chengzj@hku.hk), Tim Chuk[1], William Hayward[2,4], Antoni Chan[3], Janet Hsiao[1,4]; [1]Department of Psychology, University of Hong Kong, [2]School of Psychology, University of Auckland, [3]Department of Computer Science, City University of Hong Kong, [4]ARC Centre of Excellence in Cognition and its Disorders

Recent research has observed two basic eye movement patterns in face recognition: central (fixations are around the nose) and triangular (fixations are on the two eyes and mouth). Here we aim to examine the link between eye movement patterns and engagement of global/local attention. Eye movements of Asian participants were monitored in an old/new face judgment task. Participants received global or local priming by matching two Navon stimuli at the global or local level respectively between the study and recognition phase, and in the beginning of each recognition trial. A hidden Markov model (HMM) based approach (Chuk, Chan, & Hsiao, 2014) was used to analyze the eye movement data. We modeled each participant's eye movement pattern with an HMM, and clustered these HMMs into two general patterns according to their similarities; one of the resulting patterns resembled the central (holistic) pattern, whereas the other resembled the triangular (analytic) pattern (Figure 1). We then calculated the log likelihoods of each participant's eye movement pattern belonging to the two patterns with and without priming. The results showed that compared with the baseline (no priming) condition, local priming significantly increased the likelihood of participants' eye movement pattern being classified as the analytic pattern, whereas global priming did not significantly change the likelihood (Figure 2). This effect can also be seen in fixation maps (Figure 3), although it is relatively harder to interpret the differences. In addition, participants had better recognition performance after local priming than global priming (Figure 4), suggesting an advantage of the analytic strategy in face recognition. Thus, our results suggest that the holistic pattern is linked to engagement of global attention/global information processing, whereas the analytic pattern represents the use of local attention/featural-based processing. Local priming helps participants direct attention to facial features and may consequently enhance recognition performance.

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23.4085 **Face inversion does not affect the information content coded during the N170** Fei Yi[1] (f.yi.1@research.gla.ac.uk), Katarzyna Jaworska[1], Robin Ince[1], Philippe Schyns[1], Guillaume Rousselet[1]; [1]Institute of Neuroscience and Psychology, College of Medical, Veterinary and Life Sciences, University of Glasgow, United Kingdom

Face inversion dramatically disrupts our ability to process faces, which is known as the face inversion effect. Previous electrophysiological studies have indicated that the N170 ERP component is delayed and sometimes larger in response to inverted compared to upright faces. However, the nature of these effects remains elusive because we do not yet understand the information coding function of the N170 in upright and inverted faces. Here, we assessed what facial information the N170 codes and when it does so for upright and inverted faces. To this aim, we used one of the simplest socially relevant tasks: face detection. In this task, 10 healthy adults (5 females, median age=23, 20-29) saw pictures of faces and noise textures revealed through ten small Gaussian apertures (bubbles). Participants performed two sessions of trials with upright faces, and two sessions with inverted faces, for a total of 4400 trials. We applied reverse-correlation methods coupled with information theory to reveal the image pixels statistically associated with behaviour and neural responses. In both upright and inverted faces, we found that presence of the left eye modulated the reaction times (RTs) of all participants. In upright faces, the eye contralateral to the left and right posterior lateral electrodes strongly modulated early face ERPs. In particular, the N170 latency and amplitude coded the presence of the contralateral eye (Rousselet et al. Journal of Vision 2014, 14(13): 7, 1–24). This association was about 35% weaker in inverted faces, and delayed by about 30 ms, compared to upright face. In conclusion, our results suggest that, in a face detection task, the N170 mostly code the presence of a single feature: the contralateral eye. Inversion leads to an inefficient coding of the same feature, which is reflected in weaker and delayed feature sensitivity.

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23.4086 **The role of interattribute distances in face recognition and their relation to holistic processing** Nicolas Dupuis-Roy[1] (nicolas@dupuis.ca), Véronique McDuff[1], Frédéric Gosselin[1]; [1]Département de Psychologie, Université de Montréal

To understand the impact of interattribute distances (IADs) in face recognition, we correlated the performance of 42 participants in the Cambridge Face Memory Test (CFMT) and in the Face Composite Task to their sensitivity to IADs, as indexed by three novel tasks. In the first task, participants needed to adjust the length of an horizontal line to match the interocular distance (IOD) of a briefly presented face (1000ms). Face stimuli were shown in various sizes. White positional noise with constant energy was added independently to the xy-coordinates of the left eye, and the y-coordinates of the nose, the mouth and the left brow. The right eye and brow were kept symmetrical to the left ones. Performance was measured as the correlation between the adjusted length and the veridical IOD. In the two other tasks, two face stimuli were shown successively for 500ms, and participants had to decide if they were identical or different. The stimuli were created the same way as in the first task, except that in 50% of the trials, both faces had identical IOD (second task) or identical IADs (third task). The level of noise was adjusted to maintain an accuracy of 75% and was taken as a index of performance. The third task was significantly correlated with the CFMT ($r=-.4$, $p< 0.01$), suggesting that it reflects global visual processing capabilities in face identification. However, no significant correlation was found between our three tasks and the five indexes of the Composite Face Effect (CFE; DeGutis, et al, 2013; Konar et al., 2010; Richler, et al. 2011). This suggests that global sensitivity to IADs and the capacity to use IOD while ignoring other IADs, are not associated with holistic face processing. Specific links between the CFE and facial scaling will be tested with models on the positional noise.

23.4087 **Testing additivity of kinship information in complementary facial regions** Laurence Maloney[1,2] (ltm1@nyu.edu), Maria Dal Martello[3]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University, [3]Department of General Psychology, University of Padova

Background: Allocentric kin recognition – recognition that individuals are close genetic relatives – plays an important role in social organization and kin selection (Hamilton, 1964). Facial judgments – including kin recognition – are typically modeled as a form of cue combination but with the identity of cues currently unknown. In two experiments, we examined human ability to classify pairs of children as siblings or not siblings and tested

whether kinship information in different facial regions combined as statistically independent cues. We used complementary masks to occlude a face region or present it in isolation (Exp. 1 eye region; Exp. 2: mouth region) and tested whether we could predict performance with the unmasked face from performance in the two masked conditions. Methods: 30 pairs of photographs, each portraying a frontal view of a child's face. Half were siblings, half unrelated. A total of 122 adult observers (Exp. 1) or 121 (Exp. 2) judged whether each pair were siblings in one of three conditions. We summarized performance in each condition by signal detection d′ estimates. Conditions: Experiment 1: Eye region masked (EM), eye region only (EO), full face (FF). Experiment 2: mouth region masked (MM), mouth region only (MO), full face (FF). Results: Experiment 1: Performance was above chance in all three conditions. FF: d′ = 1.067, EM d′ = 0.677, EO d′ = 0.991. 2: Performance was above chance in all three conditions. FF: d′ = 1.132, MM d′ = 1.249, MO d′ = 0.416. We tested additivity of kinship information in facial regions: whether the sum of d′ values squared for the masked conditions was equal to the square of the d′ for the masked face. We did not reject the hypothesis of additivity ($p > 0.05$) for either experiment.

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23.4088 **A holistic advantage in face drawing: higher accuracy when drawing upright faces** Jennifer Day[1] (jeaday@ucsc.edu), Nicolas Davidenko[1]; [1]Psychology Department, UC Santa Cruz

It is a common conception among beginner face illustrators that drawing or copying a face that is vertically inverted (upside-down) will improve the accuracy of the drawing because there will be less interference from how we expect the face to look. This study looks into that conception; decades of research have shown that holistic processing of faces is disrupted when they are inverted. The disruption of holistic processing should thus lead to more accurate face drawings. We tested this theory by having participants draw upright and inverted parameterized face profiles and analyzing their accuracy. We constructed a parameterized profile face space by recording the location of 66 landmark points on a collection of 720 profile faces (see Davidenko, 2007). For this study, we generated 16 parameterized faces by sampling from the first 8 dimensions of this face space. In each trial, participants were shown a face on the left side of the screen and had 45 seconds to copy it on the right side of the screen, using a stylus on a Windows 8 Surface tablet. Each participant drew each of 16 faces both upright and inverted (the presentation order was randomized and counterbalanced across subjects). We carefully recorded the location of the 66 landmark points on each face drawing, allowing us to compute a distance metric between each drawing and its corresponding original face [see supplementary materials fig.1]. This distance metric served as a measure of accuracy, with higher distances corresponding to greater errors. Contrary to common belief, people's drawings were significantly more accurate for upright versus inverted faces ($t(15) = 4.9$; $p=0.0002$) [see supplementary materials fig.2]. Our results suggest that holistic processing may be vital to accurate face drawing.

23.4089 **The importance of the natural contour for visual feature integration in face processing.** Sandra Lafortune[1] (lafs37@uqo.ca), Caroline Blais[1,2], Justin Duncan[1,3], Amanda Estephan[1,3], Daniel Fiset[1,2]; [1]Université du Québec en Outaouais (Département de psychologie), [2]Centre de recherche en neuropsychologie et cognition (CERNEC), [3]Université du Québec à Montréal (Département de psychologie)

Hills and coll. (2014) have suggested that the natural face contour is a fundamental part of the whole face. Here, we investigated the impact of the natural contour on face recognition by measuring the integration index (Φ), a measure of feature integration in face processing (Gold et al., 2012). Twelve participants (8 women) completed 840 trials per day (divided into three blocks) for 3 consecutive days. The experiment was composed of seven conditions based on the features available for the task: I) right eye, II) left eye, III) nose, IV) mouth, V) all former features (as in Gold et al.), VI) facial contour and VII) whole face. On each trial, a target stimulus from one of the seven conditions (randomly intermixed across trials) was briefly presented (500 ms), and followed by the simultaneous presentation of six stimuli from the same condition. The task was to identify which of the six was the same as the one previously presented. For each condition, contrast of the target stimulus was adjusted using QUEST (Watson & Pelli, 1983) to reach an accuracy threshold of 75%. Performance, as indexed by the contrast at which each participant reached the threshold level (provided by QUEST at the end of each block of day 2 and 3), was significantly better with contour than without ($t(11)= 4.14$, $p= 0.002$). This observation can be explained by the fact that the former contains more information than the latter. Most importantly, the integration index was significantly higher for the condition with ($\Phi= 1.39$) than without ($\Phi= 0.64$) contour ($t(11)= -3.2$, $p= 0.008$). These results suggest that presence of the natural face contour is important for efficient integration during face processing.

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23.4090 **The impact of face size and natural contour on spatial frequency tuning: still no difference between upright and inverted faces!** Jessica Royer[1,2] (royer.jessica91@gmail.com), Verena Willenbockel[3], Caroline Blais[1,2], Frédéric Gosselin[2,4], Sandra Lafortune[1,2], Daniel Fiset[1,2]; [1]Département de Psychoéducation et de Psychologie, Université du Québec en Outaouais, [2]Centre de Recherche en Neuropsychologie et Cognition, [3]The Institute of Neuroscience, Newcastle University, [4]Département de Psychologie, Université de Montréal

Goffaux and Rossion (2006) proposed that holistic face processing is based on low spatial frequencies (SFs) whereas featural processing relies on higher SFs. Since upright faces are supposedly recognized through holistic processing and inverted faces, using features, we can easily take the leap and suggest a qualitatively different SF tuning for both orientations. Two independent studies (Gaspar et al., 2008; Willenbockel et al., 2010) tested this question and found the same SF tuning for both orientations. However, these studies used small faces presented through an elliptical aperture, i.e. stimuli of poor ecological value; differences in the SF tuning for upright and inverted faces were thus possibly missed. The present study revisits the SF tuning for upright and inverted faces using SF Bubbles. This method randomly samples SFs on a trial-by-trial basis and determines which SFs are correlated with accurate face identification. Experiment 1 (n=16) compared the SF tuning for upright and inverted smaller faces (5° of visual angle) when natural facial contour was present or hidden. Experiment 2 (n=14) compared the same conditions as Experiment 1, but using larger face stimuli (9.1° of visual angle). A Pixel test (Chauvin et al., 2005) was applied to the classification vectors to determine significance (S_r=256, FWHM=3.53, Z_{crit}=3.45). In Experiments 1 and 2, the SF tuning for both orientation conditions did not significantly differ ($p>.05$). These results bring further support to the hypothesis that the face inversion effect is due to quantitative differences in the efficiency with which information from the same SF band is used in both orientations, regardless of the ecological value of the stimuli.

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23.4091 **Holistic Processing Supports Familiarity-Based Associative Recognition for Faces** Mitchell Meltzer[1] (mam362@gmail.com), Gowtham Ganesan[1], Michelle Min[1], James Bartlett[1]; [1]The University of Texas at Dallas

Associative recognition memory is measured by assessing discrimination between copies of studied items (intact items) and re-combinations of parts of studied items (conjunction items). Such intact/conjunction (I/C) discrimination has often been thought to require recollection, a process supporting the retrieval of qualitative information about a previous encounter. However, recent findings indicate that recognition of associations encoded in a holistic or unitized fashion can rely on familiarity, a mnemonic signal varying only in strength. To test this possibility, we applied a modified process dissociation procedure to an associative recognition paradigm for four classes of stimuli; upright faces, which are thought to be processed in a unitized or holistic fashion, inverted and misaligned faces, both thought to be processed in a part-based fashion, and faces which were both inverted and misaligned. Participants studied a list of faces, and were presented with intact, conjunction, and new faces at test. I/C discrimination was then compared for "exclusion" participants, for whom such discrimination was encouraged, and "inclusion" participants, for whom it was discouraged. According to process dissociation logic, familiarity-based associative recognition is inferred if exclusion and inclusion participants exhibit similar levels of I/C discrimination. By contrast, greater I/C discrimination in the exclusion condition as compared to the inclusion condition with no corresponding group difference in intact/new discrimination indicates recollection-based associative recognition. Consistent with previous findings, a negligible I/C discrimination advantage for exclusion versus inclusion participants was found with upright faces. Howevever, a robust I/C discrimination advantage for exclusion participants over inclusion participants was found with inverted-misaligned faces, consistent with the idea that such stimuli were processed in a part-based fashion. Broadly speaking, our results suggest that holistic processing of faces supports the use of familiarity in associative recognition, and that such processing is susceptible to a combination of face inversion and face misalignment.

23.4092 **Changing camera-to-subject distance changes face matching performance** Eilidh Noyes[1] (ecn508@york.ac.uk), Rob Jenkins[1]; [1]Department of Psychology, University of York

Accurate face recognition is easy for viewers who are familiar with the faces concerned, but highly error prone for viewers who are unfamiliar with them (Bruce, 1986; Burton et al. 1999). An influential proposal is that people become good at recognizing a face by learning its configuration—specifically, distances between facial features. Here we test this proposal experimentally using a natural manipulation of these distances. Harper & Latto (2001) showed that changing camera-to-subject distance also changes distances between features. However, their pioneering study did not test implications of these image changes for identification performance. Following Harper & Latto (2001), we photographed volunteer models at both Near (32 cm) and Far (270 cm) viewing distances, resulting in changes to inter-feature distances in the image, confirmed by anthropometry (Kleinberg et al. 2007). Experimental participants who were either Familiar (N = 22) or Unfamiliar (N = 23) with these faces viewed pairs of images in a matching task that required Same Identity or Different Identity judgments. Images were paired to create Same Distance (i.e. Near+Near or Far+Far) and Different Distance (Near+Far or Far+Near) conditions. Familiar viewers performed accurately in both the Same Distance condition (M = 99%, SE = .29) and the Different Distance condition (M = 97%, SE = .89). In contrast, Unfamiliar viewers performed much more poorly in the Different Distance condition (M = 81%, SE = 1.42) than in the Same Distance condition (M = 91%, SE = 1.04). The finding that Familiar viewers were impervious to these non-linear changes in facial configuration suggests that familiar face recognition is not strongly dependent on distances between features in the face image.

Face Perception: Individual differences

Saturday, May 16, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4093 **Magnocellular and parvocellular pathway contributions to face processing in adolescents** Jill Grose-Fifer[1,2] (jgrose-fifer@jjay.cuny.edu), Danielle Mascarelli[1], Elvira Kirilko[1], Kevin Constante[1], Amy Medina[1,2], Danielle diFilipo[1,2]; [1]Psychology Dept., John Jay College, CUNY, [2]Psychology Dept., The Graduate Center, CUNY

Prior research has shown that magnocellular (M) pathways are less mature than parvocellular (P) pathways during adolescence, which might explain why adolescents have difficulties recognizing facial expressions. M pathways (associated with holistic face processing) should drive the face inversion effect more than the P pathways (which play an important role in analyzing finer facial features). Therefore, adolescents should show greater immaturities in the face inversion effect for faces filtered with low pass (LP) than with high pass (HP) spatial frequency filters. In this study, adults and adolescents viewed upright and inverted faces and objects (chairs) that were either unfiltered, LP or HP filtered. Consistent with prior research, we found that P1 and N170 were sensitive to inversion for face stimuli, but not for other stimuli. For adults, the face inversion effect on N170 amplitude was larger for fearful faces than for happy faces, but the opposite was true for adolescents. This finding is consistent with other reports that show face processing develops more quickly for happy than for fearful faces. We also found that the P1 and N170 face inversion effect was differentially modulated by LP and HP spatial frequency filtration. The face inversion effect for N170 amplitude was attenuated in the HP condition compared to the LP and unfiltered conditions. Notably, adults and adolescents showed topographical differences in their P1 inversion effect for LP faces. For adults, we found the P1 amplitude inversion effect to be larger over the right hemisphere (as is commonly reported), whereas for adolescents, it was larger over the left hemisphere. Our data suggest that the neural correlates of face processing are still maturing during adolescence. Furthermore, these immaturities were more apparent for stimuli that accentuated the contributions of the M pathways.

Acknowledgement: CUNY COLLABORATIVE GRANT

23.4094 **Relating orientation tuning and feature utilization during facial expression recognition** Justin Duncan[1, 2, 3] (justin.duncan@mail.mcgill.ca), Charlène Cobarro[1], Frédéric Gosselin[1, 3, 4], Caroline Blais[1, 3], Daniel Fiset[1, 3]; [1]Département de Psychologie et Psychoéducation, Université du Québec en Outaouais, [2]Département de Psychologie, Université du Québec À Montréal, [3]Centre de Recherche en Neuropsychologie et Cognition (CERNEC), Université de Montréal, [4]Département de Psychologie, Université de Montréal

Facial expression recognition (Huynh & Balas, 2014) correlates with horizontal information utilization, and it also correlates with local information utilization (e.g. mouth; Blais et al., 2012). However, the link between these two aspects of visual processing remains elusive. Our aim was to provide a first examination of this link, and refine current knowledge on orientation tuning. Twenty participants each performed 1,400 trials in a facial expression recognition task using 7 expressions. Seventy pictures of faces (10 identities; face width= 4deg) depicting the six basic emotions plus neutrality were used as stimuli. Images were randomly filtered in the orientation domain (orientation bubbles) and presented for 150ms. We developed this method to allow precise extraction of orientation utilization and exclude adaptation to predefined filters as a possible confound. Classification Images (CIs) were derived with a weighted sum of orientation samples, using Z-transformed accuracy scores as weights. A Pixel Test (Chauvin et al., 2005) was used on Z-transformed CIs (ZCIs) to establish statistical significance. Horizontal information significantly correlates with performance (Z-obs>Zcrit= 1.89) for anger [0°-6°; 173-180°], sadness [0°-3°; 176°-180°], disgust [0°-9°; 175°-180°], fear [0-10°; 176°-180°], happiness [0°-8°; 175°-180°], and neutrality [0°-10°; 175°-180°]. For surprise, vertical/oblique [64°-76°] information is significant. Participants also completed the same task, but with location randomly sampled (location bubbles; Gosselin & Schyns, 2001). The link between orientation tuning and location tuning was examined by regressing orientation ZCIs with location ZCIs. Interestingly, individuals more horizontally tuned rely significantly (Z-obs>Zcrit= 3.57) more on diagnostic locations (eyebrow junction for anger, left eye and mouth for fear, and mouth for all others) than those less tuned. Differences weren't reliable at other angles. Our results therefore imply that horizontally tuned individuals are more efficient at extracting local diagnostic information from faces. Implications for face processing will be discussed.

Acknowledgement: National Sciences and Engineering Research Council of Canada (NSERC)

23.4095 **Dominance of reflectance over shape in facial identity processing is related to individual abilities** Marlena Itz[1] (marlena.itz@uni-jena.de), Jessika Golle[3], Stefanie Luttmann[1], Stefan Schweinberger[1,2], Jürgen Kaufmann[1,2]; [1]Department of General Psychology and Cognitive Neuroscience, Institute of Psychology, Friedrich Schiller University of Jena , [2]Person Perception Research Unit, Friedrich Schiller University of Jena, [3]Hector Research Institute of Education Sciences and Psychology, Eberhard Karls University of Tübingen

For processing of facial identity, observers utilize visual information from both shape and reflectance. Recent evidence suggests an increasing importance of reflectance, at the expense of shape, with increasing face familiarity (Itz et al., 2014). Moreover, poor compared to good face recognizers were reported to disproportionately rely on shape when attempting to recognize learned faces (Kaufmann et al., 2013). In two experiments, we investigated the relative diagnosticity of shape and reflectance for matching of familiar and unfamiliar faces (Experiment 1) and identification of familiar and newly learned faces (Experiment 2). Within each familiarity condition, faces derived from a 3D camera system were morphed selectively in either shape or reflectance in steps of 20%, while holding the respective other dimension constant. Experiment 1 consisted of an identity matching task with unaltered S1 followed by morphed S2 stimuli. In Experiment 2 familiar and recently learned faces had to be identified from morphs. Individual scores from three tests were used to assess individual differences: the Bielefelder Famous Faces Test (BFFT), the Glasgow Face Matching Test (GFMT), and the Cambridge Face Memory Test (CFMT). Using multi-level model analyses, we examined probabilities of same versus different responses in Experiment 1, and probabilities of original identity vs. other/unknown identity responses in Experiment 2. Overall, our data revealed higher diagnosticity of reflectance compared to shape for both matching and identification, particularly for familiar faces. Moreover, compared to the respective average performance in each test, above-average BFFT (i.e. familiar face) performance was associated with higher utilization of reflectance, whereas both above-average CFMT and GFMT (i.e. unfamiliar face) performance coincided with higher utilization of shape. Our findings highlight the importance of reflectance information for face matching and identification, and indicate different underlying strategies with respect to familiar compared to unfamiliar face processing skills.

Acknowledgement: DFG, German Research Foundation

23.4096 Over-Connectivity in the Face-Processing Network is Related to Weaker Face Recognition Ability

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Face recognition is a complex behavioral skill and requires a distributed neural network. There are limited findings linking individual differences in activation within distinct nodes of this network (e.g., FFA) and recognition behavior, which may be related to the notion that complex behavior likely emerges from activation across distributed networks and less from individual regions within networks. Importantly, there is no work investigating whether variations in face recognition behavior are related to variations in the patterns of functional connections within the face-processing network. To address this issue, we developed a battery of face recognition tasks that are highly sensitive to individual differences in face recognition behavior in typically developing young adults. We identified 40 individuals who varied in face recognition behavior on a continuum that spanned ± 1 SD around the mean of a sample of more than 200 individuals tested in this battery. These participants were scanned in an fMRI task in which they passively viewed blocks of dynamic movies of faces, objects, and navigational scenes. Regions in the face-processing network were functional defined at the group level and then fit to each participant's individual activation. For connectivity, the best-fit model for 13 regions was assessed using unified structural equation modeling separately for high (> 1 SD), average (within 1SD), and low (< 1 SD) performers. Low performers had networks with more edges, higher global efficiency, and shorter path lengths compared to average and high performers. Furthermore, each of these network properties negatively correlated with behavioral performance on the face recognition tasks across the entire sample. In sum, people with weaker face recognition abilities have vastly over-connected and redundant network topologies. In contrast, relatively stronger recognizers have more sparsely connected networks. These results suggest that distributed, but not overly redundant, functional organization is required for proficient behavior.

23.4097 Individual differences in the activation of mental representations of famous faces by lookalikes

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The underlying mechanisms for inter-individual differences in face recognition ability are still poorly understood. We investigated whether participants performing high or low in a Famous Face Recognition Test differ in effects of face priming. Identity self-priming typically results in behavioural benefits and consistent event-related potential (ERP) modulations, even when familiar target faces are preceded by different (Schweinberger et al., 2002) or geometrically distorted (Bindemann et al., 2008) images of the same identity. This argues for robust, largely image- independent representations of familiar faces, a prerequisite for the ability to put different images of the same identity together (Jenkins et al., 2011). Here, we tested in good and poor recognizers, whether face representations can also be activated by faces of different identities, when these look similar to familiar targets. In an immediate-repetition-priming paradigm, famous target faces were either preceded by i) a different image of the famous face, ii) the face of a "lookalike", i.e. an unfamiliar face resembling the famous target face in appearance, or iii) a different famous face. Participants performed a face familiarity task on the targets. In addition to response times and accuracies, ERPs for target faces were analyzed. First, in line with previous studies, repetition priming effects occurred when famous faces were preceded by different images of the same faces (RT, ACC, P200, N250r, N400). Second, attenuated repetition priming effects were found when famous target faces were preceded by faces of unfamiliar lookalikes (RT, ACC, N250r, N400). Third, repetition priming effects in the N250r and N400 for lookalike primes were more reliable for participants with high face recognition skills. This suggests that i) mental representations in good recognizers are characterized by a larger flexibility, and ii) that high and low performers also differ at the level of post perceptual access to semantic information about familiar persons.

Acknowledgement: Deutsche Forschungsgemeinschaft (DFG)

23.4098 The Vanderbilt Face Matching Test (VFMT 1.0)

Mackenzie Sunday[1] (mackenziesunday@gmail.com), Jennifer Richler[1], Isabel Gauthier[1]; [1]Department of Psychology, Vanderbilt University

The Cambridge Face Memory Test (CFMT, Duchaine & Nakayama, 2006) is a measure of face recognition ability. It was designed to prevent use of salient diagnostic features, problematic in older tests, and is expected to promote holistic processing, a hallmark strategy of face recognition. However, the actual strategy used on the CFMT has not been directly tested. Attempts to correlate CFMT performance with holistic processing have produced conflicting results, but holistic processing measurements are often unreliable. A recent high-powered study with the first test designed for reliable individual differences in the measurement of holistic processing (the Vanderbilt Holistic Face Processing Test, VHPT-F; Richler et al., 2014, reliability ~.6) found no relationship between holistic processing and the CFMT. Unlike previous measures of holistic processing, faces do not repeat across trials in the VHPT-F, so we hypothesize that the correlation between the CFMT and prior holistic processing measures may stem from stimulus repetition. Because stimuli repeat in the CFMT (6 target faces are repeatedly tested), it is possible that the face learning ability measured by the CFMT is most relevant when only a handful of faces are discriminated across trials, reducing the relevant dimensions and promoting a part-based strategy. We created a new test of face matching ability similar to the CFMT but without face repetition. On each trial, 2 faces are studied for 4s, followed by a 3-AFC. We collected data from 100 subjects for two separate forms of the VFMT1.0 (each 48 trials) in an online sample. It revealed good performance on catch trials, a good spread of item difficulties, average performance of 60% (SD = 20%), and reliability of .7 for both versions. In future work, we will use item analyses to refine the test, and explore correlations with CFMT, the Vanderbilt Expertise Test with objects, and the VHPT-F.

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23.4099 Westerners and Easterners use different spatial frequencies for face recognition

Jessica Tardif[1,2,3] (jessica.tardif.1@umontreal.ca), Ye Zhang[4], Daniel Fiset[1,2], Qiuju Cai[4], Canhuang Luo[4], Dan Sun[4], Sophie Tanguay[1,2], Amanda Estéphan[1,2], Frédéric Gosselin[2,3], Caroline Blais[1,2]; [1]Department of psychoeducation and psychology, Université du Québec en Outaouais, [2]Centre de Recherche en Neuropsychologie et Cognition (CERNEC), [3]Department of psychology, University of Montreal, [4]Center for Cognition and Brain Disorders, Hangzhou Normal University

During face recognition, both Easterners and Westerners need information from the eyes and mouth to recognize faces (Caldara, Zhou, & Miellet, 2010). However, Easterners make fewer fixations to the eyes and mouth regions and more fixations to the nose region than Westerners (Blais et al., 2008; Miellet et al., 2012). These results suggest that Easterners extract more information in periphery of their retina and may rely more on lower spatial frequencies (SF). We used spatial frequency Bubbles (Willenbockel et al., 2010) to measure the SF useful for face recognition in Westerners (N=23; Canadians) and Easterners (N=27; Chinese). This method consists in creating filters that allow only random subsets of the SF contained in a face to be represented in the stimulus. On each trial (3050), such a randomly filtered face was presented, and participants recognized its identity (among eight identities of the same ethnicity, learned beforehand). Group classification images showing the SF tuning of Westerners and Easterners were obtained by performing a multiple regression on the SF sampled and the accuracy of the participants on each trial, separately for the Asian and the Caucasian faces. The SF significantly linked with performance were found using the Stat4CI (Chauvin et al., 2005; Zcrit=4.43; p< 0.001). For Westerners, a 2.75 octaves wide SF band peaking at 19.9 cycles per face (cpf) and a 2.53 octaves wide band peaking at 16.6 cpf were significant for Asian and Caucasian faces, respectively. For Easterners, a 3.98 octaves wide band peaking at 9.6 cpf and a 2.85 octaves wide band peaking at 11.1 cpf were significant for Asian and Caucasian faces, respectively. A 2-way ANOVA shows that Easterners' peaks are significantly lower (p=.01). Our results confirm that Easterners rely more than Westerners on lower SF and use a wider range of SF, especially when recognizing Asian faces.

Acknowledgement: NSERC

23.4100 The Vanderbilt Holistic Face Processing Test (VHPT-F): A Short and Reliable Measure of Holistic Processing

Jennifer Richler[1] (jennifer.j.richler@vanderbilt.edu), R. Jackie Floyd[1], Chao-Chih Wang[2], David Ross[3], Isabel Gauthier[1]; [1]Vanderbilt University, [2]National Chung Cheng University, [3]University of Massachusetts Amherst

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Studying individual differences requires measures with sufficient reliability, often ignored in high-level vision. Holistic processing is central to research on face recognition and, more recently, to the study of individual differences in this area. A popular measure of holistic processing, the composite task, is highly sensitive in group studies (Richler & Gauthier, 2014), but shows low reliability (~.2; DeGutis et al., 2013; Ross et al., 2014). We present a measure of holistic face processing, the Vanderbilt Holistic Face Processing Test (VHPT-F), specifically designed for individual differences research. As in the composite task, subjects try to match a target face segment while ignoring the rest of the face, and holistic processing is measured as a failure of selective attention. The VHPT-F adopts a 3-AFC design, with variability among trials to increase discriminability at various levels of holistic ability. The VHPT-F 1.0 was more reliable than the composite task (.41) and produced the expected interaction between holistic processing and alignment ($\eta 2_p$=.61, p< .001). While misaligned trials are critical to establishing the measure's validity, we found little shared variance between congruency effects on aligned and misaligned trials (r=.14); regressing out misaligned performance does not affect the measure of holistic processing and was deemed unnecessary. The VHPT-F 2.0 with only aligned trials had a large effect size ($\eta 2_p$=.75) and higher reliability (.56). The VHPT-F appears to measure a stable trait, with test-retest reliability of .52 after 3 weeks. Holistic processing in the VHPT-F and composite task were nearly as correlated (r=.28; n=136) as might be expected by the reliability of the composite task, suggesting they measure the same ability. Surprisingly, the VHPT-F did not correlate with the Cambridge Face Memory Test (CFMT) (r=-.17; n=97), suggesting that either holistic processing does not contribute to face recognition, or that the CFMT promotes the use of other strategies.

23.4101 Holistic Processing of Faces May Underlie Age Differences in Performance on Taiwanese Face Memory Test (TFMT)

Gary Shyi[1,2] (cwshyi@gmail.com), Kuan-Hao Cheng[1], Ya-Hsin Cheng[1], Vicky Chen[1]; [1]Department of Psychology and Center for Research in Cognitive Sciences, National Chung Cheng University, [2]Advanced Institute of Manufacturing with High-tech Innovations, National Chung Cheng University

The main goal of the present study was threefold: (a) to establish a test that utilizes face images collected and normed in the Taiwanese society in order to provide a culturally calibrated tool for assessing face memory ability, (b) to examine the relationship between face memory performance and a range of face tasks to reveal underlying processing that may play an important role in face memory, and (c) to investigate the relationship between age differences in face memory performance and those in holistic processing as revealed by the face composite test. To create the Taiwanese face memory test (TFMT), we followed the procedure of Cambridge Face Memory Test (CFMT) (Duchaine & Nakayama, 2006), and used images from the Taiwanese face database (Shyi, Huang, & Yeh, 2013). Like CFMT, TFMT was administered in three stages with increasing difficulty. The results of TFMT from 52 young-adult participants revealed an almost identical pattern reported by Duchaine & Nakayama (2006). We then correlated participants' performance on TFMT with their performances on three face tasks tapping component, configural, and holistic processing of faces, respectively. Only performance on the face composite task with a complete design was significantly correlated with that on TFMT, and in particular the latter two stages of TFMT, which tapped memory for face identities rather than mere face images. Finally, while showing an overall inferior performance on TFMT than the young adults, older adults nonetheless exhibited a similar interaction between alignment and congruency effect. More intriguingly, as they progressively aged, older adults were increasingly likely to display a pattern of diminishing holistic processing. Taken together, these findings not only highlights the importance of creating culturally calibrated tool for assessing face memory ability, but also implicates that holistic processing of faces may underlie participants' performance and in particular age differences on TFMT.

Acknowledgement: Ministry of Science and Technology, Taiwan, ROC

23.4102 Reciprocating the gaze of others: how we look and how long we like to be looked at.

Nicola Binetti[1] (nicolabinetti@gmail.com), Charlotte Harrison[1], Antoine Coutrot[2], Isabelle Mareschal[3], Alan Johnston[1]; [1]Department of Experimental Psychology, UCL, [2]CoMPLEX, UCL, [3]School of Biological and Chemical Sciences, Queen Mary, University of London

Mutual eye contact is a key aspect that accompanies any social interaction. Through mutual gaze we establish a communicative link with another person and inform him/her of our goals and motivations. While much attention has been directed to studying the mechanisms of perception / classification of gaze direction, we know very little on the temporal aspects of mutual gaze. We have all likely experienced instances of uncomfortable eye contact, while for example speaking with a stranger or standing in front of someone in an elevator. Here we studied in a very large subject pool (>400 participants) what constitutes a preferred time of mutual eye contact and how these estimates of preferred mutual gaze relate to participant eye behaviour. Participants viewed movies of actors (4 female, 4 male) establishing eye contact with them for variable amounts of time. At the end of each movie participants classified the period of mutual gaze as being "uncomfortably short" or "uncomfortably long", thus yielding an estimate of "preferred" time of mutual gaze. We also collected ratings on a set face traits of the actor viewed in the clips. We found that the preferred period of mutual eye contact varied as a function of subjective ratings of actor threat, trustworthiness & attractiveness. Threatening faces were associated with lower periods of preferred eye contact, while conversely trustworthy faces were associated with longer periods of preferred mutual gaze. Analysis of patterns of eye fixations showed that fixations tend to be more concentrated in the actor's eye region in participants exhibiting longer preferred periods of mutual gaze, suggesting that these participants are more likely to reciprocate the eye behaviour of the actor. Finally we also observed that the concentration of fixations in the actor's eye region was also associated with higher dominance ratings.

Acknowledgement: Leverhulme Trust

23.4103 Individual differences in preference for mutual gaze duration.

Charlotte Harrison[1] (c.harrison.13@ucl.ac.uk), Nicola Binetti[1], Antoine Coutrot[2], Isabelle Mareschal[3], Alan Johnston[1]; [1]Department of Experimental Psychology, UCL, [2]CoMPLEX, UCL, [3]School of Biological and Chemical Sciences, Queen Mary, University of London

Gaze is an important component of social interaction. While there is a large amount of research about perception of gaze direction, there has been comparatively little looking at gaze duration. As social interactions are inherently dynamic, understanding how long a person looks is at least as important as where they are looking. The current experiment was a normative study investigating individual differences in preference for mutual gaze duration. An international sample (n > 400) were shown a series of video clips of an actor (chosen at random) gazing directly at them for varying lengths of time. Participants then had to classify the amount of eye contact occurring during the clips as being either too long or too short to be "comfortable". Demographic information and personality data based on the Big Five Inventory were also gathered. It was found that the average length of preferred gaze duration was normally distributed with a mean of 3.2 seconds (± 1 second). The results showed a significant correlation between higher agreeableness self-ratings and preference for longer mutual gaze duration; this was particularly true for female participants viewing male actors. Further, higher extraversion and openness scores were found to positively correlate with higher variance in clip classification, indicating that participants who score more highly on these measures have a less strict categorisation of what constitutes a comfortable amount of mutual gaze duration. Differences between nationality and response variance were also found. The results suggest that while on average preference for length of mutual gaze is stable, individual preference in duration is influenced by multiple factors such as gender, age and nationality.

Acknowledgement: Leverhulme Trust

23.4104 Intact priors for gaze direction in autism spectrum conditions

Philip Pell[1] (Philip.Pell@mrc-cbu.cam.ac.uk), Isabelle Mareschal[2], Michael Ewbank[1], Simon Baron-Cohen[3], Andrew Calder[1]; [1]MRC Cognition and Brain Sciences Unit, Cambridge, United Kingdom, [2]Queen Mary University of London, London, United Kingdom, [3]Autism Research Centre, Department of Psychiatry, University of Cambridge, Cambridge, United Kingdom

Autism Spectrum Conditions (ASC) are characterized by a range of perceptual atypicalities, including abnormalities in gaze processing. Pellicano and Burr (2012) recently proposed that perceptual atypicalities might be a consequence of attenuated priors in ASC (i.e. reduced influence of prior knowledge on the perception of sensory information). Evidence from neurotypical populations indicates that under conditions of uncertainty (created by adding noise to the eyes of face stimuli), gaze is more likely to be perceived as direct (Mareschal et al., 2013), suggesting that humans have a prior expectation that other people's gaze is directed toward them. Here we adopted the same paradigm to address two questions: 1) Is the influence of priors on gaze perception reduced as a function of autistic traits within a neurotypical population (Experiment 1)? 2) Do individuals with diagnosis of ASC show evidence for reduced influence of gaze priors (Experiment 2)? Each experiment began with a staircase procedure designed to tailor the noise contrast required for each participant to perform a left/right gaze discrimination at 80% correct. Participants were then required to judge the relative gaze directions of two faces when noise was added to the eyes of one face only. In Experiment 1, participants showed a significant bias towards perceiving uncertain gaze as direct, however this bias was not related to increasing autistic traits. In Experiment 2, individuals with ASC showed a robust direct gaze prior comparable to that of IQ matched controls. Given that noise-thresholds did not differ across groups, this finding is unlikely to reflect a combination of attenuated priors and increased sensory noise in ASC. These results pose a challenge to the hypoprior Bayesian model of ASC and suggest that if ASC is characterized by atypicalities in the use of prior information this is not reflected in their performance on a gaze task.

Acknowledgement: Medical Research Council

23.4105 **Extraversion predicts superior face-specific recognition ability, but through experience, not positive affect** Karen Arnell[1] (karnell@brocku.ca), Blaire Dube[2]; [1]Department of Psychology, Brock University, [2]Department of Psychology, University of Guelph

Experience is an important factor in developing face recognition ability. Given that extraverts show increased social involvement, extraversion may be associated with greater experience with faces, thereby leading to enhanced face recognition ability. However, extraverts also characteristically display high positive affect – an affective state thought to bias visual processing to be more global or holistic in nature. Given the large body of evidence suggesting that faces are processed holistically, positive affect may lead to superior face processing for extraverts aside from their increased social experiences (i.e. positive affect may mediate any relationship between extraversion and face recognition ability). To examine the relationships between extraversion, positive affect, and face and non-face recognition ability, university student participants completed self-report measures of personality and affect before completing the Cambridge Face Memory Task (CFMT), and a matched control task assessing recognition of cars (Cambridge Car Memory Task, CCMT). Each measure was taken twice, separated by one week. All measures showed very high test-retest reliability and scores were therefore averaged across both sessions. A face-specific recognition advantage was observed for individuals high in extraversion in that extraversion predicted better face recognition, even when controlling for non-face recognition. No relationships were observed between state or trait positive affect and recognition ability. Further, statistically controlling for affect strengthened the relationship between extraversion and face-specific recognition ability, suggesting that there is something inherent to extraversion aside from positive affect that benefits face recognition. We suggest that extraverts gregariousness allows greater opportunities for developing face expertise.

Acknowledgement: This work was supported by an NSERC Discovery grant to the first author.

Attention: Space and awareness

Saturday, May 16, 2:30 - 4:15 pm
Talk Session, Talk Room 1
Moderator: James Herman

24.11, *2:30 pm* **The mind-writing pupil: near-perfect decoding of visual attention with pupillometry** Sebastiaan Mathôt[1] (s.mathot@cogsci.nl), Jean-Baptiste Melmi[1], Lotje Van der Linden[1], Stefan Van der Stigchel[2]; [1]Aix-Marseille University, CNRS, LPC UMR 7290, Marseille, France, [2]Dept. of Experimental Psychology, Helmholtz Institute, Utrecht University, The Netherlands

When the eyes are exposed to light, the pupils constrict. This is the well known pupillary light response. What is less well known is that the pupillary light response is not a simple reflex to light, but is modulated by visual attention: When you covertly attend to a bright stimulus, your pupil constricts relative to when you attend to a dark stimulus. Here we describe a human-computer interface that is based on this principle, i.e. decoding the focus of covert visual attention with pupillometry. Participants fixated in the center of a display, and selected (i.e. covertly attended to) one of several stimuli presented in a circular arrangement. Each stimulus was presented on a background with alternating brightness. Small changes in pupil size reflected the brightness alternations of the selected stimulus' background, and this allowed us to determine which stimulus was selected with nearly perfect accuracy on a trial-by-trial basis. An extension of this technique, in which the stimulus array serves as a virtual keyboard, even allows for arbitrary text input. As a human-computer interface, this technique has several key advantages: It is intuitive, because there is a direct mapping between the task (attending to a stimulus) and the goal (selecting a stimulus); It allows for bi-directional communication, because the analysis can be performed on-line; It is non-invasive and can be done with currently available low-cost eye trackers; It is reliable, i.e. decoding accuracy is nearly perfect under good conditions. We discuss potential applications, such as communication with locked-in patients and ultra-secure password input.

Acknowledgement: Marie Curie Action 622738

24.12, *2:45 pm* **Selective attention within the foveola** Martina Poletti[1] (martinap@bu.edu), Marisa Carrasco[2], Michele Rucci[1]; [1]Department of Psychological and Brain Sciences, Boston University, [2]Department of Psychology, New York University

Background: We have recently shown that, contrary to the widespread assumption, vision is not uniform within the foveola, the tiny (~0.8 deg2 in area) high-acuity region of the fovea where rods are absent and cones most densely packed. Performance in fine spatial discrimination drops just a few arcminutes away from the center of the preferred retinal locus of fixation, an effect normally compensated by microsaccades, which precisely bring this locus on the object of interest. Humans can covertly shift attention away from the center of gaze toward objects in the visual periphery. However, it is unknown whether attention can also be selectively controlled within the foveola. Purpose: To test the hypothesis that, like eye movements, attention can also be selectively allocated at this microscopic scale, and facilitate target detection within the foveola. Methods: We manipulated endogenous (voluntary) attention. Observers were asked to detect the presence of targets, as fast and accurately as possible, at cued and uncued locations, with valid, neutral and invalid cues. Measuring attention shifts within the foveola is challenging because fixational eye movements continually displace the projection of the stimulus on the retina. We circumvented this problem by relying on gaze-contingent display control techniques to selectively stimulate a desired eccentricity within the foveola. We presented very small targets (5 arcminutes) at only 10 arcminutes from the center of gaze. Results: Reaction times were faster when targets were presented at cued than uncued locations. The attentional benefit (~25ms) was highly similar to that observed when stimuli were displayed outside the foveola, at 3o eccentricity. Accuracy did not differ significantly across attended and unattended locations for either eccentricity. Conclusion: These findings indicate that we are capable of selectively allocating attention to objects separated by only 20 arcminutes, revealing a remarkably high resolution of endogenous attention within the foveola.

Acknowledgement: Grants: NIH EY18363, NSF 1127216, NSF 1420212

24.13, *3:00 pm* **Control of Spatial Attention by the Primate Superior Colliculus** James Herman[1] (hermanj@gmail.com), Richard Krauzlis[1]; [1]Laboratory of Sensorimotor Research, NEI, NIH

The primate Superior Colliculus (SC) plays a causal role in controlling spatial attention. Microstimulation of the SC improves detection performance at a specific spatial location. Inactivation of the SC causes both a spatially specific deficit for stimuli inside the affected area of the visual field, and an increase in distractability for stimuli outside the affected area. However, all these studies used motion stimuli. To determine the scope of the SC's role in controlling spatial attention, we instead used color, a feature dimension that has only recently been appreciated as having importance in the SC. In separate sessions, we recorded SC neuronal activity or reversibly inactivated SC neurons with muscimol, while a monkey performed a demanding covert attention task utilizing dynamic color stimuli described previously (Herman & Krauzlis, 2014). The animal's task was to respond to color changes in the "cued" stimulus by releasing a joystick and to ignore changes in a second, uncued "foil" stimulus. Color changes were physically isoluminant saturation increases, masked by luminance noise, and kept near the monkey's detection threshold (80%). In most neurons (62/66) color changes evoked brisk firing rate increases, often exceeding that evoked by stimulus onsets (43/66). Also, change-related activity was greater when the animal released the joystick than when he maintained his hold, both for cued and foil changes. Complementing these neuronal data, we found that SC inactivation had a dramatic effect on the monkey's task performance (6 sessions). When the cued stimulus was presented inside the affected area, hit rate dropped from an average of 68% to 26%; concurrently, the animal's rate of erroneously responding to foil changes outside the affected area jumped from 4% to 26%. We conclude that the SC is likely necessary for covert spatial attention regardless of visual feature dimension.

24.14, *3:15 pm* **Egocentric and allocentric neglect after right and left hemisphere lesions in a large scale neglect study of acute stroke patients: Prevalence and recovery.** Nele Demeyere[1] (nele.demeyere@psy.ox.ac.uk), Celine Gillebert[1], Liam Loftus[1], Glyn Humphreys[1]; [1]Cognitive Neuropsychology Centre, Department of Experimental Psychology, University of Oxford

Left neglect is traditionally reported to be much more common and more severe than right neglect. Often this is taken as support for a right hemispheric specialisation of visuo-spatial attention. Here, we explore the incidence and severity of ego-and allocentric neglect in a consecutive acute stroke sample (N=298) and compare left versus right neglect recovery 6 months post stroke (N=121). Patients completed the hearts cancellation task from the Oxford Cognitive Screen on average after 6 days and again 6 months post-stroke. The results demonstrated that egocentric and allocentric neglect are separable subtypes with egocentric and allocentric neglect occurring in isolation in 46 and 27% of the acute neglect patients, respectively. In addition, we found that in participants with only allocentric neglect there was no egocentric spatial laterality to the false positive errors made. Though left egocentric neglect was more prevalent (67%) in right hemisphere patients, the severity was not significantly different from that in left hemisphere cases (in terms of the absolute asymmetry scores). In addition, there was an equal incidence of left and right allocentric neglect (51% vs 49%). However, in terms of recovery, at 6 months post stroke, right neglect was much more likely to recover (only 2 patients still demonstrated right neglect at follow up). There were no differences in recovery rates for ego- vs allocentric neglect. The lack of an effect of egocentric spatial bias to allocentric errors provides strong evidence that these disorders are independent. In addition, the greater likelihood of left neglect continuing at 6 months, despite it having the same severity for left and right hemisphere patients, is consistent with right hemisphere patients (and patients with chronic neglect) having disorders additional to a bias in spatial orienting.

Acknowledgement: Oxford Cognitive Health, NIHR Clinical Research Facility

24.15, *3:30 pm* **Barack Obama Blindness (BOB): Absence of visual awareness to a single object** Marjan Persuh[1] (mpersuh@bmcc.cuny.edu), Robert Melara[2]; [1]Department of Social Sciences and Human Services, Borough of Manhattan Community College, City University of New York, [2]Department of Psychology, City College, City University of New York

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Previous experiments have shown that people miss a visible but unexpected object in a field of other objects when engaged in an attentionally demanding task. Yet no previous experiment has examined the extreme case of blindness to a single object appearing alone in the visual field. In two experiments we evaluated whether a perceiver's prior expectations could alone obliterate his or her awareness of a salient visual stimulus. To establish expectancy, observers first made a demanding visual discrimination on each of three baseline trials. Then, on a fourth, critical trial, a single, salient and highly visible object appeared in full view at the center of the visual field and in the absence of any competing visual input or competing task demands. Surprisingly, fully half of the participants were unaware of the solitary object in front of their eyes. Yet in a control condition these same observers easily detected the same object in the same screen position. Dramatically, observers were even blind when the only stimulus on display was the face of U.S. President Barack Obama. We term this novel, counterintuitive phenomenon, Barack Obama Blindness (BOB). Employing a method that rules out putative memory effects by probing awareness immediately after presentation of the critical stimulus, we demonstrate that the BOB effect is a true failure of conscious vision.

24.16, *3:45 pm* **Bayesian ideal observer predicts weak forms of blindsight in normal observers** Megan Peters[1] (peters.megan@gmail.com), Hakwan Lau[1]; [1]Psychology Department, University of California Los Angeles

It has been reported that damage to V1 can lead to "blindsight": such patients can discriminate simple visual stimuli above chance and yet allegedly report no conscious visual percept. It has also been suggested that similar forms of "unconscious vision" can be demonstrated in normal observers, i.e. under certain experimental conditions (e.g. low-contrast masked stimuli) subjects can perform above-chance discrimination even when rating confidence/stimulus visibility at the lowest level. However, from a signal detection theoretic (SDT) perspective, these findings may be trivial: subjects may report low confidence/invisibility only because the signal falls below an arbitrary confidence/visibility criterion, rather than being truly invisible. We therefore investigated whether perceptual discrimination without subjective awareness can be demonstrated unequivocally by the rigorous standards of ideal observer analyses. To bypass the criterion problem mentioned above, we probed confidence with a 2-interval forced-choice procedure (Barthelmé & Mamassian, 2009, PLoS CB): normal observers viewed paired intervals of masked stimuli, discriminated the orientation of each (left/right tilted), and then chose which decision they were more confident in (Expt 1) or which stimulus was more visible (Expt 2). Importantly, in one interval the stimulus had zero contrast, meaning above-chance orientation discrimination was impossible. Strong evidence for blindsight would consist of subjects' discriminating the stimulus above-chance yet failing to consistently select it as more confident/visible relative to the blank interval. Such suboptimal behavior would violate common models of perception. In both experiments, intriguingly, we found that observers judged confidence/visibility with lower sensitivity than they could discriminate orientation, according to SDT measures, suggesting there may be evidence for compromised subjective awareness. Crucially, however, a Bayesian ideal observer model predicts similar behavior. We argue that traditional SDT analyses make unrealistic assumptions about what observers can do in these tasks, and show with simulations how misleading results could be obtained via conventional procedures.

24.17, *4:00 pm* **Inattentional blindness reflects limitations on perception, not memory: Evidence from repeated failures of awareness** Emily Ward[1] (amyunimus@gmail.com), Brian Scholl[1]; [1]Department of Psychology, Yale University

Perhaps the most striking phenomenon of visual awareness is inattentional blindness (IB), in which a surprisingly salient event right in front of you may go completely unseen when unattended. Does IB reflect a failure of online perception, or only of subsequent encoding into memory — a form of "inattentional amnesia" (e.g. Wolfe, 1999)? Previous work has been unable to answer this question, due to a seemingly intractable dilemma: ruling out memory requires immediate perceptual reports, but soliciting such reports fuels an expectation that eliminates IB. Here we introduce a way to escape this dilemma, reporting two experiments that evoke repeated IB in the same observers, in the same session, and even when unexpected events must be immediately reported, mid-event. We employed a sustained IB task: after several trials of a demanding primary tracking task, an Unexpected Event (UE) occurred: a new object (with a novel shape, color, and motion direction compared to everything else in the display) appeared, after which observers were asked (in various ways) whether they had noticed it. Subsequently, observers had to immediately press a key any time (throughout the rest of the experiment) they saw something different or unexpected. Observers made use of such keypresses when the very same UE was later repeated, but when an equivalent UE with entirely new features (now differing in color, shape, and motion direction from all of the other objects and from the previous UE) subsequently appeared, observers failed to report it — even mid-event, during the 5 seconds that it traversed the display. Thus, observers fail to see salient events not only when they have no expectation, but also when they have the wrong expectations. These experiments demonstrate that IB is aptly named: it reflects a genuine deficit in moment-by-moment conscious perception, rather than a form of inattentional amnesia.

Perception and Action: Reaching, grasping and tracking

Saturday, May 16, 2:30 - 4:15 pm
Talk Session, Talk Room 2
Moderator: Joan Lopez-Moliner

24.21, *2:30 pm* **Continuous Psychophysics: measuring visual sensitivity by dynamic target tracking** Lawrence Cormack[1,2,3] (cormack@mail.utexas.edu), Kathryn Bonnen[2,3], Johannes Burge[4], Jacob Yates[2,3], Pillow Jonathan[5], Alexander Huk[1,2,3]; [1]Department of Psychology, The University of Texas at Austin, [2]Institute for Neuroscience, The University of Texas at Austin, [3]Center for Perceptual Systems, The University of Texas at Austin, [4]Department of Psychology, The University of Pennsylvania, [5]Department of Psychology and Princeton Neuroscience Institute, Princeton University

We introduce a novel framework for estimating visual sensitivity using a continuous target-tracking task in concert with a dynamic internal model of human visual performance. In our main experiment, observers used a mouse cursor to track the center of a 2D Gaussian luminance target as it moved in a Brownian walk in a field of dynamic Gaussian luminance noise. To estimate visual sensitivity, we fit a Kalman filter to the tracking data assuming that humans behave roughly as Bayesian ideal observers. Such observers optimally combine prior information with noisy observations to produce an estimate of target location at each point in time. We found that estimates of human sensory noise obtained from the Kalman filter model were highly correlated with traditional psychophysical measures of human sensitivity ($R2 > 0.97$). Because data can be collected at the display frame rate, the amount of time required to measure sensitivity is greatly reduced relative to traditional psychophysics. While our modeling framework provides principled estimates of sensitivity that are directly comparable with those from traditional psychophysics, easily-computed summary statistics based on cross-correlograms of the tracking data also accurately predict relative sensitivity, and are thus good empirical substitutes for the more computationally-intensive Kalman filter fitting. As a second example, we show contrast sensitivity functions quickly determined using target tracking. Finally, we show that psychophysical reverse-correlation can also be quickly done via tracking. We conclude that dynamic target tracking is a viable and faster alternative to traditional psychophysical methods in many situations.

Acknowledgement: NIH (LKC, ACH, JB, JY, JP), NSF (KLB, JP)

24.22, *2:45 pm* **Sensory-motor adaptation is (mostly) linear** Todd Hudson[1] (hudson@cns.nyu.edu), Jay Lee[2], Michael Landy[1]; [1]Psychology & Center for Neural Science, New York University, [2]Phillips Exeter Academy

Sensory-motor adaptation is usually conceived as an automatic process that maintains the calibration between motor plans and movement outcomes. Viewed as a mechanism that monitors disturbances and produces compensatory motor outputs, sensory-motor adaptation can be thought of as a filter. The first question one normally asks regarding filter performance is whether it is linear. We test homogeneity and additivity using a sinusoidal sensory-motor perturbation of reach endpoints (Landy & Hudson, VSS 2012). Methods: Subjects made center-out reaches on a tabletop with fixed starting point, and with target direction and distance chosen to fall randomly within an annulus centered on the start position. Feedback was shown on a frontoparallel display. During each reach, only the target was shown. Fingertip endpoint was shown (shifted) on reach completion. The amount of shift was either a single or the sum of two sinewaves (over trials), with a peak shift of never more than 6 mm. Homogeneity was tested by measuring the response to sinewave-perturbed endpoints following a single sinusoidal disturbance with amplitude A and, in a separate session, 2A. As a test of additivity, the adaptive response to two sinewaves (A and B, of different frequencies) measured separately was compared to the response to perturbation using their sum. Results: The sensory-motor adaptive response to perturbations in (Cartesian) x- and y-dimensions are consistent with linearity, in that the response to A and B sinusoidal perturbations measured in isolation predict the adaptive response to the 2A and the A+B perturbations. By the same criteria, the polar gain dimension also displays linearity. However, the polar angle dimensions displays a small but statistically significant deviation from linearity in its phase response in the additivity condition: its response to the A+B perturbation lags differently than predicted by its response to the A and B perturbations applied separately.

Acknowledgement: NIH EY08266

24.23, *3:00 pm* **Online vision of the hand supports accurate grasp performance in illusory contexts** Evan Cesanek[1] (evan_cesanek@brown.edu), Carlo Campagnoli[1], Claire Walker[1], Fulvio Domini[1,2]; [1]Department of Cognitive, Linguistic, and Psychological Sciences, Brown University, [2]Center for Neuroscience and Cognitive Systems@UniTn, Italian Institute of Technology

Grasping is a flexible human motor behavior coordinated on the basis of perceptual information about the structure of surfaces in reachable space. In two original experiments, we investigated the perceptual information supporting accurate grasp performance. Participants in these experiments reached-to-grasp target objects that were situated in illusory contexts under two perceptual conditions: a natural closed-loop condition with full visual feedback and a modified closed-loop condition which selectively prevented online vision of the hand. In natural closed-loop grasping in an illusory context, we found that the anticipatory opening between the forefinger and thumb (grip aperture) reflected the illusory perceptual size in early stages and the veridical physical size in late stages. Dynamic analysis of grip aperture scaling revealed a clear mid-flight correction, suggesting that additional information for motor control was made available during grasp execution. Based on this finding, we conducted a follow-up experiment in which we prevented online vision of the hand. In contrast to the natural closed-loop condition where maximum grip aperture (MGA) was tuned to veridical physical size, in the modified closed-loop condition we found that MGA was tuned to illusory perceptual size. This work focuses on the implications of these results for the perceptual control of action, arguing that they cannot be accounted for by explanations that posit specialized vision-for-action processes capable of extracting metrically accurate, Euclidean spatial information akin to a 3D depth map of the local environment. As an alternative, the results suggest that online control processes based on visual comparison of hand and target positions could support accurate grasp performance in illusory contexts.

24.24, *3:15 pm* **Automatic adjustments to grasping movements from unconscious visual information** Zhongting Chen[1] (u3001782@hku.hk), Jeffrey Saunders[1]; [1]Department of Psychology, University of Hong Kong

We investigated whether control of hand movements can be driven by visual information that is not consciously perceived. Previous studies have shown that subjects can make corrective responses to perturbations during hand movements even when they do not notice the perturbations. We tested whether movements can be affected by visual information that is not perceived at all, using backward masking to prevent conscious perception. Subjects performed reach-to-grasp movements toward 2D virtual objects that were projected onto a rigid surface. They were instructed to touch the projection surface at the locations that they would use to pick up the object. On perturbed trials, the target object was briefly shown (33 ms) at an orientation that was ±20° from the original orientation, followed by a 200 ms mask. Perturbations were triggered when the index finger was 20 cm away from the target. After the mask, the original target reappeared and remained visible until completion of movement. Thus, the task did not require any response to the perturbations. Unperturbed trials were identical except that the orientation of the target remained constant. None of the subjects reported noticing the masked perturbations, and a follow-up test found that half of the subjects could not reliably discriminate the perturbations even when trying. Despite the lack of awareness, the brief views of the rotated targets caused detectable changes in the grip axis during movement. Approximately 200 ms after perturbation onset, the grip axes in perturbed trials began to rotate in the direction of the target rotation, reaching a maximum deviation of 1.2° after another 200 ms. These biases were corrected during the final movement, so that the final grasp axes were not significantly different across perturbation conditions. The results demonstrate that visual information can affect control of hand movement even when it is not consciously perceived.

Acknowledgement: supported by the Hong Kong Research Grants Council, GRF 753211H

24.25, *3:30 pm* **Evidence for a functional and anatomical dissociation in the use of size constancy for perceptual report and goal-directed grasping** Robert Whitwell[1,2,3], Irene Sperandio[4], Gavin Buckingham[5], Philippe Chouinard[6], Melvyn Goodale[2,3,7]; [1]The Graduate Program in Neuroscience, The University of Western Ontario, London, Canada, [2]The Department of Psychology, The University of Western Ontario, London, Canada, [3]The Brain and Mind Institute, The University of Western Ontario, London, Canada, [4]School of Psychology, University of East Anglia, Norwich, UK, [5]Department of Psychology, Heriot-Watt University, Edinburgh, UK, [6]School of Psychological Science, La Trobe University, Melbourne, Australia, [7]The Department of Physiology and Pharmacology, The University of Western Ontario

On a moment-to-moment basis, we experience the visual world as permanent and unchanging despite the fact that the retinal image size of objects in the scene change with changes in viewing distance. After all, to the 'naked eye', the real size of objects rarely changes over short time scales and our visual system faithfully delivers this experience in terms of visual object-size constancy. Arguably, visual size constancy operates during prehension as well: objects can vary in retinal image size at different positions within reachable space and yet the visuomotor system codes grasping movements on the basis of the target's real size. Previous evidence from our laboratory, however, suggests that visual size-constancy for perception and for goal-directed grasping are not unitary. Here, we demonstrate conclusively that visual size constancy for perception and for grasping are functionally and anatomically dissociable. We tested a cortically blind patient, MC, who has large bilateral lesions encompassing almost the entire occipital lobe. We first demonstrate that MC's verbal and manual reports of target size depend entirely on retinal image size. Next, we show that despite MC's reliance on retinal image size for explicit reports of target size, her grasps are tuned to trial-to-trial changes in the real size of the targets – even when their retinal image size remain constant. Critically, for both perceptual report and grasping, the targets were presented at eye level in the absence of any environmental cues. We conclude that MC's spared size-constancy for prehension depends on the dorsal visual pathway's privileged access to shifts in horizontal gaze angle and/or accommodation to calibrate her grasps.

24.26, *3:45 pm* **Humans maintain probabilistic belief states when tracking occluded objects** Matjaz Jogan[1] (mjogan@sas.upenn.edu), Alan He[2], Alexander Tank[3], Alan Stocker[1]; [1]Department of Psychology, University of Pennsylvania, [2]Department of Bioengineering, University of Pennsylvania, [3]Department of Statistics, University of Washington

Humans are quite accurate in tracking moving objects whose trajectories are occluded. An intuitive sense for the laws of physics (so-called "intuitive physics") allows us to predict the future position of a dynamic object based on initial information about its motion. Recent experimental results suggest that these predictions reflect the outcome of a probabilistic inference process based on noisy observations and an accurate physics model of the world. However, it remains unknown whether humans mentally track and update i) an estimate or ii) a full probabilistic description of the object position (belief state). We designed a set of psychophysical experiments to specifically distinguish the two hypotheses. Subjects were first asked to predict the collision location of a moving object with a hidden wall. The trajectory of the object was occluded and subjects were only given the object's initial motion and an acoustic signal at the precise time of collision. Subjects exhibited clear biases in their location estimates that indicated that they were performing probabilistic inference using prior expectations over speed and location. Subjects then repeated the experiment receiving, however, an additional spatial cue about the hidden wall location. By introducing different levels of uncertainty associated with this cue we expected subjects to assign different relative weights in combining the cues if they were maintaining full belief states while tracking. More specifically, by measuring subjects performance for each cue alone we were able to individually predict optimal behavior and verify whether it matched subjects' actual behavior. We found that subjects' behavior was indeed well predicted by a Bayesian belief state model that optimally combined cues across space, time, and object motion. Our results suggest that humans maintain and update full belief states when predicting object trajectories.

Acknowledgement: Office of Naval Research

24.27, *4:00 pm* **Depth modulations for reaching across superior parietal lobule** Patrizia Fattori[1] (patrizia.fattori@unibo.it), Kostas Hadjidimitrakis[2], Giulia Dal Bo'[1], Annalisa Bosco[1], Rossella Breveglieri[1], Claudio Galletti[1]; [1]Dept. Pharmacy and Biotechnology, University of Bologna, Italy, [2]Dept. Physiology Monash University, Melbourne, Australia

Single cell recordings in the awake monkey have so far neglected the depth dimension of visuomotor transformations for reaching. In the few cases where depth has been taken into account, direction has been left apart. The coexistence of depth and direction information for reaching requires further studies, as usually our reaching movements in real life occurr by changes in the distance and laterality of our hand positions in peripersonal space. Here, we investigated how reach depth and reach direction interact at single cell level in two areas of superior parietal cortex (SPL): area V6A and PEc, located caudally in the SPL, in a region of the posterior parietal cortex medial to area MIP/PRR. Two macaque monkeys performed a fixation-to-reach task in 3-dimensional space, toward foveated targets located at different distances and lateralities. We analized the spatial tuning of about 200 neurons per area in several phases of this delay reaching task: target fixation, early and late delay period, movement and holding times. We found that depth and direction signals influenced jointly a large number of neurons in both areas in all epochs of the task considered, with PEc showing more independent processing of depth and direction, especially before the arm movement onset. In PEc, the effect of direction was more prevalent than depth before reaching execution while the reverse was true for depth. In V6A, depth and direction similarly influenced neural activity for the entire trial. These findings suggest the involvement of both areas in visuospatial and action representations in 3D peripersonal space, with a caudo-rostral trend from a joint processing of depth and direction signals for eye position and reach execution in V6A to an encoding of depth related mostly to arm movement in PEc. These data reflect a rostro-caudal trend similar to that observed in human fMRI studies.

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Development

Saturday, May 16, 5:15 - 6:45 pm
Talk Session, Talk Room 1
Moderator: Rowan Candy

25.11, *5:15 pm* **Vergence Sensitivity in 5-10 Week-Old Infants**

Eric Seemiller[1] (eric.seemiller@gmail.com), T. Candy[1]; [1]Indiana University School of Optometry

Introduction Fine motor alignment of the two eyes is necessary for appropriate binocular experience, yet in adults it appears that binocular processes are responsible for fine motor alignment. There is substantial evidence that infants start to respond to binocular retinal disparity (a primary cue for motor alignment) at 3-5 months of age. However, rudimentary eye alignment is possible from birth and matures with age. How does eye alignment develop in the absence of adult-like binocular processes? Here we investigate the sensitivity of vergence eye movements in 5-10 week old humans to a target moving in depth, while addressing the possible influence of accommodation. Methods Infants (5-10 weeks) and adult controls viewed a naturalistic movie stimulus on a screen that moved sinusoidally in depth at three different amplitudes (1.0, 0.5 and 0.25 MA) at 0.1 Hz. A photorefractor measured horizontal eye position and refractive status at 25 Hz. FFTs provided the amplitude spectra of both vergence and accommodation responses for comparison with the stimulus spectrum. Signal plus noise : noise ratios (SNRs) were calculated by dividing the response at the stimulus frequency by the mean of the adjacent frequencies. Results Vergence SNRs were significantly different from 1 (signal + noise equals noise) at even the smallest amplitudes tested (mean SNR = 2.10; p =0.03). suggesting that infants of 5-10 weeks could generate a vergence response to a full cue stimulus moving in depth at 0.25 MA (~30 minutes of disparity) Accommodation responses were only significant for the two larger amplitudes (mean SNRs = 2.84, 1.47; p = 0.04, 0.03). Adult SNRs were all significant for accommodation and vergence ($p < 0.002$). Discussion Infants make vergence responses to 0.25 MA stimulus movements at least one month prior to the documented onset of disparity sensitivity. Implications for development of eye alignment will be discussed.

Acknowledgement: NIH(R01EY14660, P30EY019008)

25.12, *5:30 pm* **Characterizing Perceptual Alternations During Binocular Rivalry in Children**

Amanda Beers[1] (beersam@mcmaster.ca), Michael Slugocki[1], Terri Lewis[1], Allison Sekuler[1], Patrick Bennett[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Although binocular rivalry has been examined thoroughly in young adults, we know relatively little about its developmental trajectory. To address this issue, we created a child-friendly task, in which we presented pairs of orthogonal, oblique sine wave gratings to 7-, 9-, 11-year-olds, and young adults (mean = 21.25 years). Stimulus size (diameter = 1.4 or 4.4) and contrast level (0.2 or 0.8), factors with well-known effects on rivalry in young adults, varied across trials. On each trial, participants recorded their alternations among percepts (each of the two exclusive, mixed, and fading/other) with a handheld button box. To measure accuracy of reported percepts, we intermixed pseudo-rivalry with experimental trials. For experimental trials, dependent measures included the average duration and proportion of time participants reported viewing each type of percept. Children spent a significantly greater proportion of time viewing exclusive percepts and less time viewing mixed percepts compared to young adults, a finding that provides evidence against the prediction of increased mixed percepts in children (Kovacs & Eisenberg, 2005). Sequential patterns of alternations between percepts also varied between children and young adults. For example, the proportion of return transitions increased from childhood to adulthood, specifically for low contrast conditions. Average durations for exclusive percepts did not differ significantly across age groups, contrary to previous reports suggesting faster alternation rates in children (Kovacs & Eisenberg, 2005; Hudak et al., 2011). Average durations for mixed percepts were shorter in children compared to young adults. No differences were observed between 7-, 9-, and 11-year-olds for any dependent measure. These are the first reports of several characteristics of binocular rivalry in children, specifically measures of mixed percepts and sequential transitions.

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25.13, *5:45 pm* **A short period of visual deprivation at birth triggers long-lasting crossmodal reorganization of the occipital cortex in humans**

Olivier Collignon[1] (olivier.collignon@unitn.it), Giulia Dormal[2], Adelaide de Heering[3], Franco Lepore[2], Terri Lewis[3], Daphne Maurer[3]; [1]Centre for Mind/Brain Science (CIMeC), University of Trento, Italy, [2]Centre de Recherche en Neuropsychologie et Cognition (CERNEC), Université de Montréal, Canada, [3]Visual Development Lab, Department of Psychology, Neuroscience and Behaviour, McMaster University, Canada.

The study of sensory deprivation is a striking model to reveal the role experience plays in sculpting the functional architecture of the brain. Here we used functional Magnetic Resonance Imaging to characterize brain responses to auditory stimuli in 11 adults who had been deprived of all patterned vision at birth by dense congenital cataracts in both eyes until they were removed surgically at 9 to 238 days of age. When compared to a control group with typical vision, the cataract-recovery group showed enhanced auditory-driven activity in two focal bilateral visual regions (the superior occipital gyrus and the cuneus) classically considered retinotopic. The crossmodal activation of occipital regions correlated neither with visual acuity nor with the duration of deprivation in the cataract-recovery group. A combination of dynamic causal modeling with Bayesian model selection indicated that this auditory-driven activity in the occipital cortex was better explained by direct cortico-cortical connections with primary auditory cortex than by subcortical reorganizations. These results demonstrate that a short period of visual deprivation during the early sensitive period of brain development leads to enduring large-scale crossmodal reorganization of the brain circuitry typically dedicated to vision.

Acknowledgement: This research was supported in part by the Quebec Bio-Imaging Network 'pilot project' grant (FL, OC), the Canadian Institutes of Health Research (FL), the

25.14, *6:00 pm* **Deficits in integration of global motion and form in noise is associated with the severity and type of amblyopia.**

Mahesh Joshi[1] (Mahesh.Joshi@gcu.ac.uk), Anita Simmers[1], Seong Jeon[1]; [1]Vision Research Group, Department of Vision Sciences, Glasgow Caledonian University

Motion and form processing along the functionally differentiated dorsal and ventral stream is reported to be abnormal in amblyopia; however limitations in previous stimuli have made analogous comparison of the outputs from these two streams difficult. In the current study, we characterise both functions in amblyopia using equivalent stimuli for fine global motion and orientation discrimination in the presence of noise. Anisometropic (n = 6) and strabismic (n = 6) amblyopes, and 12 visually normal subjects monocularly estimated the mean direction of motion of random dot kinematogram (RDK) and orientation of Glass pattern (Glass), whose directions/orientations were drawn from normal distributions with a range of means and variances that served as external noise. Two levels of noise were tested to obtain direction/orientation discrimination threshold in the

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absence of noise then threshold variance at the multiples of the direction/orientation threshold. For all subjects the thresholds for Glass were higher than RDK. The direction/orientation thresholds were higher for amblyopic eye (AE) in the strabismic group compared to the fixing eye (FE) and normal observers (NE) but not for anisometropic group. The MANOVA for the strabismic group revealed significant effect of both eyes ($p < 0.01$) and stimulus type ($p < 0.01$) but no interaction ($p > 0.1$), with thresholds significantly higher for the AE than both FE and NE (ps < 0.05) on pairwise analysis. The MANOVA for the anisometropic group showed no significant effect of eyes ($p > 0.1$) but a significant effect of stimulus type ($p < 0.001$) with no interaction ($p > 0.1$). Our results show a deficit in motion and form perception only in subjects with dense strabismic amblyopia, irrespective of noise levels. The thresholds will be modelled to parse out the influence of local and global processing mechanisms in the respective streams.

25.15, *6:15 pm* **Visual cortex of congenitally blind individuals responds to symbolic number** Shipra Kanjlia[1] (skanjli1@jhu.edu), Connor Lane[1], Lisa Feigenson[1], Marina Bedny[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University

Numerical processing is considered to be a highly visual capacity. Like other early visual features, numerosity is susceptible to visual adaptation. Numerosity-selective neurons naturally emerge in the dorsal visual stream of monkeys. Math abilities are predicted by both visual numerical estimation abilities and visuospatial abilities. Math calculation also activates the intraparietal sulcus (IPS), which responds to visual numerosity. Do numerical processing abilities depend on visual experience? We asked whether the cortical circuits involved in numerical processing develop normally in individuals who are blind from birth. While undergoing fMRI, 17 blind and 19 sighted participants heard pairs of equations (e.g. X-2=5, X-4=3) and judged whether the value of "X" was the same. Equations were either simple (single-digit, e.g. X-2=7) or complex (double-digit, e.g. X-12=17). In a control task, participants judged whether pairs of sentences had the same meaning. In a second experiment, participants heard syntactically simple and complex sentences and answered yes/no questions about them. Just as in sighted individuals, the IPS in blind individuals responds more to math than sentences and is sensitive to math complexity. In blind individuals the typical IPS activity extended posteriorly into "visual" occipital cortex. We found responses to auditory number symbols in the anatomical territory of dorsal V1 to V3. The response profile of this "visual" number area was similar to the IPS: 1) it responded more to math than sentences 2) was sensitive to math difficulty and 3) was not sensitive to syntactic complexity. We find that blind individuals develop typical IPS responses to number. This suggests that numerical representations in the IPS are not tied to visual processing abilities. Blind but not sighted individuals also activate "visual" cortical areas during numerical tasks. Together with prior data from our lab, these results suggest that higher cognitive functions expand into deafferented visual cortex of humans.

25.16, *6:30 pm* **The causal link between magnocellular-dorsal pathway functioning and dyslexia** Simone Gori[1,2] (simone.gori@unipd.it), Aaron Seitz[3], Luca Ronconi[1,2], Sandro Franceschini[1,2], Andrea Facoetti [1,2]; [1]Developmental and Cognitive Neuroscience Lab, Department of General Psychology, University of Padua, Padova 35131, Italy, [2]Developmental Neuropsychology Unit, Scientific Institute "E. Medea", Bosisio Parini, Lecco 23842, Italy, [3]Department of Psychology, University of California – Riverside, Riverside, CA, USA.

Impaired auditory-phonological processing is widely assumed to characterize dyslexic individuals. However, the magnocellular-dorsal (MD) pathway deficit theory, while controversial, has long been argued to play an important role in developmental dyslexia. The debate has centered on the critique that the visual MD deficit found in individuals with developmental dyslexia could just be a consequence of an impoverished reading experience. Here, we employ a comprehensive approach that incorporates all the accepted methods required to test the relationship between the MD pathway and developmental dyslexia: (i) a comparison with reading level controls, that are younger controls who read at the same level as the dyslexics (Experiment 1); (ii) a prospective-longitudinal approach, in which MD functioning was measured in pre-readers and a correlation then established with the future reading development (Experiment 2); and (iii) two remediation studies, in which the MD pathway is specifically trained and reading improvement is established (Experiment 3 and 4). The results of all the four experiments point strongly in the direction of a causal relationship between MD deficit and developmental dyslexia. Since an MD dysfunction can be diagnosed much earlier than a reading and language disorders, our findings pave the way for low resource-intensive, early prevention programs that could drastically reduce the incidence of reading disorders.

Face Perception: Flexible coding

Saturday, May 16, 5:15 - 6:45 pm
Talk Session, Talk Room 2
Moderator: Tamara Watson

25.21, *5:15 pm* **Face-selective areas sensitive to motion are also selective to human voice** Jonathan Oron[1] (oronjon1@mail.tau.ac.il), Galit Yovel[1,2]; [1]Sagol School of Neuroscience, Tel Aviv University, [2]School of Psychological Sciences, Tel Aviv University

Human perception must deal in many cases with dynamism. In face processing dynamism conveys rich social information including facial expression, eye gaze and mouth movements. To examine the response to dynamism within the neural face-processing system, we first identified several face-selective regions using a dynamic face localizer. In addition to the "core" face network, which includes the OFA, FFA and pSTS-FA, the dynamic localizer revealed two additional face areas – the anterior Superior Temporal Sulcus (aSTS-FA) and the Inferior Frontal Gyrus (IFG-FA). A few recent electrophysiology studies in monkeys and neuroimaging studies in humans have shown that areas in the STS and IFG are responsive to voices suggesting a common mechanism for the processing of dynamic visual and auditory information from faces. To assess this predication, we presented subjects with dynamic stimuli of mute faces and audio clips of human speech. Our results show no significant response to human speech in the OFA and FFA while the pSTS-FA, aSTS-FA and IFG-FA showed a significant response to human speech. To further assess whether these areas are selective to human voices we examined their response to human vs. non-human auditory stimuli. The pSTS-FA, aSTS-FA and IFG-FA showed a significantly higher response to human auditory stimuli. In conclusion, our data suggest a clear distinction between two face-selective pathways - the ventral face-selective network including the OFA and FFA, encoding uni-modal, static form information and the dorsal network including the pSTS-FA, aSTS-FA and IFG-FA, encoding dynamic multimodal information. These findings are inconsistent with the prevalent neural model that defines the pSTS-FA as part of the core face system and instead suggest a clear functional distinction between the pSTS-FA, which is part of a separate network that additionally encodes vocal information, and the OFA and FFA, which represent the visual aspects of a face.

25.22, *5:30 pm* **Seeing faces with your ears activates the left fusiform face area, especially when you're blind** Paula Plaza[1] (paulaplazakin@gmail.com), Laurent Renier[2], Anne De Volder[2], Josef Rauschecker[1]; [1]Laboratory of Integrative Neuroscience and Cognition Department of Neuroscience, Georgetown University Medical Center, Washington, DC, U.S.A. , [2]Institute of Neuroscience, Université Catholique de Louvain, Belgium.

Restoring vision in blind people is an important goal and can be achieved in certain cases, for instance by performing cataract surgeries in children. However, reconnecting the visual system alone is not sufficient; the visual cortex needs to be rewired. In order to fully appreciate visual information, a mental representation of the world needs to be created. Here we are presenting fMRI data from the visual cortex of blind people when they were perceiving faces, houses, and geometric shapes encoded into sounds by means of a sensory substitution device (SSD). Specifically, we focused on selective visual brain areas related to this perception: the fusiform face area (FFA), the lateral occipital complex (LOC) and the parahippocampal place area (PPA). Each area was identified in sighted subjects under visual conditions using a functional localizer consisting of pictures of famous persons, visual 2-D geometric shapes and real houses. Then, region-of-interest analyses were performed on the data acquired in both Congenitally Blind (CB) and Sighted Control (SC) subjects when the SSD was used to discriminate schematic drawings of faces, geometric shapes and houses. Our results indicate that the left LOC was activated under all three conditions in both groups, while the left FFA was activated in CB subjects selectively during the SSD-face discrimination condition. No significant brain activity was found in the PPA in CB or SC subjects at the group level. The specific recruitment of the FFA during the perception of sound-encoded faces in CB subjects shows that they can extract visual information from sound-encoded objects and such perception activates the appropriate module in the visual cortex. Our study also represents new evidence about the developmental constraints on functional specialization in the absence of visual inputs.

Acknowledgement: NEI

25.23, *5:45 pm* **The resilience of face recognition to early life stress**
Laura Germine[1,2,3] (lgermine@fas.harvard.edu), Erin Dunn[1,2], Katie McLaughlin[4], Jeremy Wilmer[5], Jordan Smoller[1,2]; [1]Center for Human Genetic Research, Massachusetts General Hospital, [2]Department of Psychiatry, Harvard Medical School, [3]Department of Psychology, Harvard University, [4]Department of Psychology, University of Washington, [5]Department of Psychology, Wellesley College

Individuals vary substantially in their ability to recognize faces, and these differences affect social functioning. But which aspects of nature and nurture impact face recognition? Early life stress is a likely candidate, as adverse childhood environments impact the development of many major cognitive, social, and affective functions. At the same time, evidence from twins suggests that variation in face recognition ability is due primarily to variations in genes and not environments. Here, we use a combined individual differences and epidemiological approach to directly assess whether variations in early life stress are linked with face recognition ability. We define early life stress as exposure to one of 25 forms of common childhood adversity before the age of 18. In approximately 4,000 adults, we show that face recognition ability is not significantly associated with variations in early life stress (including neglect, socioeconomic deprivation, physical abuse, and sexual abuse). Complex emotion perception ability, on the other hand, was reduced among individuals with a range of early life stress experiences. Our findings indicate that face recognition ability is uniquely resilient to variations in early life stress and childhood environment, thus ruling out domain general and process general accounts of the impact of early life stress on cognitive development.

25.24, *6:00 pm* **Investigating the face inversion effect in adults with Autism Spectrum Disorder using the fast periodic visual stimulation paradigm**
Buyun Xu[1] (xubuyun@uvic.ca), James Tanaka[1]; [1]Department of Psychology, University of Victoria

Fast periodic visual stimulation (FPVS) is a powerful method for investigating the brain activity underlying human face processing. Previous studies have shown that FPVS provides a reliable index of the face inversion effect (FIE) (Liu-Shuang et al., 2013) and individual differences in face recognition ability (Xu et al., 2014). In the current study, the FPVS method was used to compare the discrimination of upright and inverted faces of 6 adults with Autism Spectrum Disorder (ASD) and 6 age-matched typically developed (TD) control participants. A repeated face stimulus (A) was presented at a frequency of 6Hz (F) for a 60-second block with a different oddball face (B, C, D) interspersed at every 5th cycle of presentation (F/5=1.2Hz) (i.e., AAAABAAAACAAAAD....). Faces within each 60-second block were presented either in their upright or inverted orientations. It is hypothesized that the 6Hz response reflects sensitivity to stimuli belonging to the generic face category whereas the 1.2Hz oddball response indicates sensitivity to a particular individuated face. The results showed that the repeated face stimuli produced an enhanced EEG signal at the fundamental 6Hz frequency and its harmonics (12Hz, 18Hz, etc.) with the largest activation found at medial-occipital electrode sites. Both the ASD and TD groups showed the FIE in which upright faces elicited a greater EEG amplitude than inverted faces. At the 1.2Hz frequency and its harmonics (2.4Hz, 3.6Hz, etc.) , participants in the TD group showed the FIE where a greater signal was generated by the upright oddball face than the inverted oddball face. In contrast, participants in the ASD group exhibited the same EEG response to the upright and inverted oddball face. The lack of the FIE to the individuated oddball face in the ASD group is consistent with the behavioral findings indicating that adults with ASD have difficulty discriminating individual faces.

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25.25, *6:15 pm* **Uncertainty and bias in estimation of the sex and age of faces**
Tamara Watson[1] (t.watson@uws.edu.au), Yumiko Otsuka[2], Colin Clifford[2]; [1]School of Social Sciences and Psychology, University of Western Sydney, [2]School of Psychology, UNSW Australia

Prior expectation may influence our perception of people at the first meeting. For example, it has been shown that we are more likely to categorise a person as 'male' or to estimate their age as closer to our own. This could be due to perceptual effects and/or cognitive response bias. Here we use a forced choice task to reduce cognitive influence and a Bayesian modelling approach to estimate perceptual biases inherent in our decisions about the sex and age of faces. Two identities were presented to participants simultaneously, both of the same age or sex. One face was presented for 1000msec while the other was presented for either 250ms or 500ms (more/less uncertainty). Participants were asked to indicate which face appeared more male/female (n=40) or younger/older (n=20). The proportion of trials on which the briefer stimulus was chosen as more male/older indicated that under conditions of increasing uncertainty participants were more likely to respond 'male' and 'older'. For both judgements this is consistent with the operation of a Gaussian prior with a peak towards male and older faces and with the prior becoming more influential under conditions of increased uncertainty. This finding was supported by the results of a rating task. Here uncertainty was induced by jittering the phase spectrum of the face images. The equivalent shift in the rating of the noiseless version of each face that would be required to match the ratings of the phase jittered faces was also consistent with a Gaussian prior with a peak towards male and older faces. This demonstrates a biased expectation, operating at a perceptual level, that faces will be male and older. As this effect is not due to cognitive response bias, it represents a true inaccuracy in the experienced percept which we anticipate will be impenetrable to cognitive control.

Acknowledgement: This research is supported by an Australian Research Council grant to CWGC and TLW (DP150100516)

25.26, *6:30 pm* **Visualizing the Spatiotemporal Dynamics of Neural Representations of Individual Face Identities**
Mark Vida[1] (vidamd@mcmaster.ca), Marlene Behrmann[1]; [1]Department of Psychology, Carnegie Mellon University

Individual face identities are represented in the human brain by spatially distributed patterns of neural activity (e.g., Nestor et al., 2011). We investigated the spatiotemporal dynamics of this representation. An adult human viewed well-controlled color photographs of 91 male face identities (two expressions and 104 trials per identity), while brain activity was recorded with magnetoencephalography (MEG). For 47 time points 10-470 ms after stimulus onset, and two regions-of-interest (ROIs) commonly implicated in face processing (right and left posterior fusiform gyrus [pFG]), we used linear SVM classification to measure neural discrimination of all possible face pairs, across facial expression. We then used multidimensional scaling to identify statistical dimensions underlying the neural discrimination data. For each dimension and time point, we constructed a "classification image" (CI), which displays visual information captured by the dimension. CIs were constructed by computing the difference between weighted averages of faces on each side of a given dimension, and then applying a permutation test to isolate statistically significant pixels. Across all face pairs, left and right pFG displayed the best classification performance at 180-200 ms. For both ROIs, the proportion of significant pixels in the CIs was highest at around 200 ms, with smaller peaks at around 100 and 350 ms. Hence, information about face identity was captured most clearly at around 200 ms. Pixel-wise correlations between CIs for the two ROIs were small to moderate (r range = -.03-.28), with correlations peaking at around 200 ms. This pattern suggests that left and right pFG carry partially overlapping information about face identity, with the greatest overlap at around 200 ms. Together, these results suggest that visual information about face identity is represented maximally, but not exclusively, at around 200 ms in pFG, and that the spatial properties of the information represented differ between left and right pFG.

Acknowledgement: University of Pittsburgh/UPMC Presby seed fund for MEG research

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Eye Movements: Perception and neural mechanisms

Saturday, May 16, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

26.3001 The long and short of it: Size influences saccadic and pursuit behavior for objects moving in depth.

Helen Clark[1] (hclark@waikato.ac.nz), John Perrone[1]; [1]School of Psychology, The University of Waikato, Hamilton, New Zealand

A size-speed illusion has been demonstrated for trains and cars approaching from the side whereby the longer trains are judged to be moving slower than shorter cars (Clark, Perrone & Isler, AAP, 55, 2013). We have also shown that this size-speed effect could be caused by observers saccading to, and tracking a point further from the front of longer objects, compared to shorter objects (Clark & Perrone, VSS, 2014). However it is currently unknown which visual aspect of the approaching objects instigates the change in eye movement behavior. Findlay (Vis Res., 22, 1982) measured saccades made toward two static squares separated horizontally and presented in the near periphery. He found that saccadic landing position was determined by the gap between the two squares. These findings were based on stationary stimuli but may provide insights into our size-speed effect and explain why observers look further from the front of long objects moving in depth thus generating slower pursuit velocities compared to short objects. We therefore tested Findlay's theories with motion-based stimuli. Eye position and velocity were recorded as the observers judged the relative speed of two sequentially presented pairs of lines approaching from the periphery. Each pair in the sequence varied in the gap separation between lines (5.8° vs 2.2° deg). Results showed gap spacing had a significant effect on saccadic behavior; saccades landed further from the front line for large gaps than for small gaps. This is consistent with the static Findlay effect and the saccadic behavior observed with trains and cars. We also tested pairs of lines with different amounts of linear perspective but no significant differences were found in average eye position. These findings suggest that it is the length of objects in motion, rather than their perspective characteristics that determines saccadic landing positions and hence the perceived speed of the object.

26.3002 Sensorimotor adaptation of size perception.

Cécile Eymond[1] (cecile.eymond@gmail.com), Céline Paeye[1], Marianne Duyck[1], Patrick Cavanagh[1], Thérèse Collins[1]; [1]Laboratoire Psychologie de la Perception, Université Paris Descartes, CNRS UMR 8242

Sensorimotor adaptation is the process by which new associations between movements and their perceptual effects are learned. Previous work reported that the visual system learns associations between peripheral (coarse) and foveal (highly defined) images of objects to achieve feature constancy across eye movements (e.g., Cox et al., 2005). Here we investigated the ability to learn perceptual associations between peripheral and foveal object size across saccades. In a pre-adaptation phase, participants made saccades to a peripheral disk. During these saccades this disk was replaced with a bigger or smaller disk. Participants had to decide whether the post-saccadic (foveal) disk was bigger or smaller compared to the pre-saccadic (peripheral) disk. For each participant, we defined the critical size change that led to 75% correct performance. In the following 30-min adaptation phase, subjects made saccades to the peripheral disk. During the saccade, the disk was modified by the critical size change measured individually. The post-adaptation phase was identical to the pre-adaptation phase except that adaptation trials were interleaved to maintain the level of adaptation. Preliminary results on 5 participants showed a significant shift of the PSE after adaptation in the direction of the adapted size change. For example, after adapting to a small-to-large trans-saccadic size change, the post-saccadic target had to be slightly larger than the pre-saccadic target to appear as matched in size, while objects that did not change size during the saccade were seen as slightly shrinking. This suggests that a new trans-saccadic correspondence of object size was learned and that perhaps, like the trans-saccadic correspondence of object position (saccadic adaptation), the trans-saccadic correspondence of object size and other features might be adaptable.

Acknowledgement: This research was supported by an ERC grant to P.C.

26.3003 Perisaccadic changes in perceived heading and their neural correlates

Jan Churan[1] (jan.churan@physik.uni-marburg.de), Dirk Hofmann[1], Philipp Hesse[1], Markus Lappe[2], Frank Bremmer[1]; [1]AG Neurophysik, Philipps-University Marburg, [2]Institute of Psychology, Wilhelms-University Münster

Visual perception across eye-movements is not veridical. As an example, saccadic eye-movements modulate the perceived location of a briefly flashed stimulus leading to a perceptual compression of space. During everyday-life eye movements occur also during navigation through an environment, thereby challenging the perception of self-motion direction (heading). Here we asked if saccades influence also the perceived heading in humans. We found a perisaccadic compression of perceived heading and aimed to identify a neural correlate of this new perceptual phenomenon in the animal model (macaque monkey). Human subjects were presented brief (40ms) visual sequences simulating self-motion across a ground-plane (random dots) in one of five different directions during fixation or perisaccadically. After each trial the subjects had to indicate their perceived heading. Eye-movements were monitored by an infrared eye-tracking system. During fixation perceived heading was not perfectly veridical but shifted centripetally. In saccade trials performance was very similar to fixation trials for motion onsets long (>100ms) before or after a saccade. Around the time of the saccade, however, perceived heading was strongly compressed towards the straight-ahead direction, being equivalent to a compression of heading space. Precision of behavioral judgments was not modulated perisaccadically. In search for a neural correlate of the perceptual effect, recordings were performed in two dorsal stream areas of two macaque monkeys (areas MST and VIP, respectively). In a first step, we aimed to decode self-motion direction from population discharges of both areas. Heading could be decoded veridically during steady fixation and during tracking eye-movements. During saccades, however, decoded heading was compressed towards straight-ahead. We conclude that saccades compress not only perceived space, but also perceived heading. This newly described perceptual phenomenon could be based on the visual processing in cortical areas being responsive to self-motion information. Functional equivalents of both areas have been previously identified in humans.

Acknowledgement: Supported by DFG-CRC/TRR-135/A2

26.3004 Time course of the P300 Eye-Fixation Related Potential during the visual search for a target embedded in natural scenes

Hélène Devillez[1], Emmanuelle Kristensen[1], Nathalie Guyader[1], Bertrand Rivet[1], Anne Guérin Dugué[1]; [1]GIPSA-lab, Grenoble-Alpes University and Grenoble National Institut of Polytechnic

The Event Related Potential P300 has been intensively studied for over forty years (Polish, 2012). It is elicited at each updating of the stimulus representation, reflecting a cascade of cognitive processes engaging attentional and memory mechanisms. This potential is a positive component, appearing 300ms after stimulus onset, with maximal amplitude in centro-parietal regions. This study is mainly concerned by the analysis of the appearance and evolution of the P300 elicited by the onset of successive fixations recorded during a visual search using an ecological experimental paradigm. This goal is achieved through the co-registration of electroencephalographic (EEG) and eye-tracking (ET) signals. EEG and ET signals were recorded for thirty-four observers when exploring natural scenes during 5 sec to answer if a target object was or not present. To solve the main difficulty due to overlaps between the observed Eye Fixation Related Potentials (EFRP) elicited by consecutive fixations, we have used a new methodology based on the xDawn algorithm (Rivet, et al.; 2009). From each trial, a temporal window of 2s centered on the first fixation inside the Region of Interest (target). This duration was chosen to include five consecutive fixations (two before the first entrance, and two after). The fixations were tagged depending to their rank and position (inside/outside) the ROI. Neural activities were modelled as a cumulative response of specific latent responses elicited by each fixation with the corresponding onset. After xDawn estimation, the topographic maps have shown a potential identified as the P300 component elicited by the visual input through the consecutive fixations landed on the ROI. This result confirms previous studies but has been obtained for the first time on ecological paradigm thanks to the

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co-registration of EEG and ET signals and a new methodology to denoise potentials from overlaps of potentials elicited by consecutive fixations.

Acknowledgement: This work was supported by a grant from the ANR project

26.3005 Eye Gaze Position before, during and after Percept Switching of Bistable Visual Stimului

Celia Gagliardi[1] (gagliard@bu.edu), Arash Yazdanbakhsh[1]; [1]Vision Laboratory, Center for Computational Neuroscience and Neural Technology, Boston University, Boston, Massachusetts

A bistable visual stimulus, such as the Necker Cube or Rubin's Vase, can be perceived in two different ways which compete against each other and alternate spontaneously. Percept switch rates have been recorded in past psychophysical experiments, but few experiments have measured percept switches while tracking eye movements in human participants. In our study, we use the Eyelink II system to track eye gaze position during spontaneous percept switches of a bistable, structure-from-motion (SFM) cylinder that can be perceived to be rotating clockwise (CW) or counterclockwise (CCW). Participants reported the perceived direction of rotation of the SFM cylinder using key presses. Reliability of participants' reports was ensured by including unambiguous rotations. Unambiguous rotation was generated by assigning depth using binocular disparity. Gaze positions were measured 50 – 2000 ms before and after key presses. Our pilot data show that during ambiguous cylinder presentation, gaze positions for CW reports clustered to the left half of the cylinder and gaze positions for CCW reports clustered to the right half of the cylinder between 1000ms before and 1500ms after key presses, but no such correlation was found beyond that timeframe. These results suggest that percept switches can be correlated with prior gaze positions for ambiguous stimuli. Our results further suggest that the mechanism underlying percept initiation may be influenced by the visual hemifield where the ambiguous stimulus is located.

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26.3006 How transsaccadic predictions shape the perception of shape

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Introduction. Human vision is characterized by consistent shifts between fixations and saccadic eye movements. With each saccade, internal object representations change their retinal position and spatial resolution which raises the question as to how extra-foveal perception is affected by upcoming saccadic eye movements. Recently, we suggested that saccades are accompanied by a prediction of their perceptual consequences—i.e., the foveation of the target object (Herwig & Schneider, 2014, Journal of Experimental Psychology: General). Accordingly, extra-foveal perception should be biased toward previously associated foveal input. Up to now, effects of transsaccadic feature prediction on extra-foveal perception have been exclusively reported for surface features (i.e., color and spatial frequency) which are known to play an important role in establishing object correspondence while moving the eyes. In the present study, we tested whether also the extra-foveal perception of visual shape is partly based on predicted postsaccadic foveal input. Methods. Sixteen participants in an eyetracking experiment first underwent a 30 min acquisition phase, where, unnoticed by most participants, one out of two objects systematically changed its shape during saccades. In the following test phase, participants had to judge the shape of briefly presented peripheral saccade target objects. Results. Peripheral saccade targets were perceived as less curved for objects which previously changed from more circular in the periphery to more triangular in the fovea compared to objects which did not change during acquisition. Likewise, shapes were perceived as more curved for objects which previously changed from triangular- to circular-like. Conclusion. This result indicates that the extra-foveal perception of shape is specifically biased toward previously associated postsaccadic foveal input. Thus, extra-foveal perception seems to depend not solely on the current input but also on memorized experiences enabling predictions about the perceptual consequences of saccadic eye movements.

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26.3007 Effects of Simulated Scotomas on Pre-saccadic Fixation Durations

Harold Greene[1] (greenehh@udmercy.edu), James Brown[2]; [1]University of Detroit Mercy, [2]University of Georgia

Altitudinal scotomas from visual cortex injuries are rare, and upper visual field (UpVF) scotomas are rarer than lower visual field (LoVF) scotomas. Simulation of scotomas provides insight on adaptive behavior in defective visual fields. For example, fixation durations increase in the presence of simulated peripheral-surround scotomas. While useful, peripheral-surround scotomas do not address functional specialization in specific visual field areas. Electrophysiological and functional data suggest that processing of visual information below fixation (i.e., LoVF) is typically superior to processing of information above fixation (i.e., UpVF). An exception is the case of the saccadic system, where an UpVF bias is evident for pre-saccadic fixation durations (PSFDs) in visual search tasks. PSFDs are briefer when the ensuing saccade is directed upwards. Generally, the LoVF is biased towards global/sensory detection processing near the body, and the upper visual field is biased towards local/saccadic checking of distant objects. Here we examined how an UpVF/LoVF scotoma affects PSFDs. The superiority of LoVF processing suggests a LoVF scotoma may indiscriminately prolong PSFDs. However, given the specialization of the UpVF in saccadic behavior, a LoVF scotoma may be expected to prolong PSFDs only for downward-bound saccades. Eye movements were monitored as observers engaged in visual search with either no scotoma (N=12), an UpVF scotoma (N=12), or a LoVF scotoma (N=12). Scotomas blocked the entire UpVF or LoVF, 2 deg from the current fixation point. PSFDs associated with saccades directed within 90 deg visual field bins were compared. Contrast analyses revealed a vertical field asymmetry for each task, such that PSFDs were briefer for saccades directed upwards than downwards. Importantly, while the UpVF scotoma prolonged PSFDs only for upward-bound saccades, the LoVF scotoma prolonged PSFDs for both upward- and downward-bound saccades. The results demonstrate the importance of LoVF processing, even in a saccadic task.

26.3008 Saccade adaptation and saccadic suppression of displacement

David Souto[1,2] (ds572@le.ac.uk), Karl Gegenfurtner[1], Alexander Schütz[1]; [1]Department of Psychology, Justus-Liebig-University Giessen, Germany, [2]School of Psychology, University of Leicester, United Kingdom

When an error is injected to saccade endpoints by displacing the target midflight during saccades, observers typically adjust their saccade amplitudes on later trials to reduce landing error. Since target displacements are much harder to see during a saccade than during fixation (termed "saccadic suppression of displacement"), it is often assumed that observers are unaware of the manipulation for typical displacement amplitudes. Different conceptions of saccade adaptation predict different effects of target visibility on learning rates. One states that when displacements are less likely to be seen the error is attributed to the motor system instead of the external world and learning should be faster. Another one gives no role to visual error attribution itself, but predicts that learning rates are a function of the uncertainty of the visual error and the uncertainty in the visuomotor mapping. In the latter case learning rates should increase with the visibility of the target. We tested the effect of target visibility on learning rates by measuring saccade adaptation towards targets of different contrasts (10 and 100%). The target was 12 degrees of visual angle (dva) from the fixation point and was displaced 1.5 dva backward during the adaptation phase. On the same session we measured psychometric functions for discriminating between forward and backward target displacements. Learning, indexed by the time-constant of exponential fits, was slower for observers who had higher perceptual thresholds, favoring the signal uncertainty account.

Acknowledgement: Alexander von Humboldt fellowship (DS)

26.3009 Saccadic compression in natural scenes

Maria Matziridi[1] (Maria.Matziridi@psychol.uni-giessen.de), Karl Gegenfurtner[1]; [1]Department of Psychology, Justus-Liebig-University Giessen

Stimuli that are briefly presented around the time of a saccade tend to systematically be misperceived in a wrong location. In the total absence of visual references, this mislocalization reveals a uniform shift in the direction of the saccade. When visual references are available, a spatial compression of the stimuli's apparent locations towards the saccade target location or the endpoint of the saccade is revealed. A lot of research has been devoted on the role of visual references on perisaccadic compression, using a broad range of abstract stimuli on uniform backgrounds. We wanted to test whether saccadic compression also occurs when viewing natural scenes, making saccades between different objects contained in the scene. We presented an image of a natural scene with ample visual references, and asked participants to make a saccade from a fixation object to a target object, both of which were part of the natural scene. Around the time of the saccade, another object of the scene (previously absent) was briefly flashed. It could be presented at one of five possible horizontal and three possible vertical locations. Participants were asked to localize it by

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touching the screen at its perceived location. The results show a strong compression around the time of the saccade. We compared this finding with a control condition, where participants performed the same task without the references of the natural scene, but only with the fixation, target and flashed objects presented on a blank screen. The magnitude of compression was similar in the two conditions. Our results indicate that the numerous landmarks contained in the natural scene do not aid in the correct localization of a briefly presented flash around the time of a saccade.

26.3010 **Contributions of Eye Movement Transients to Spatial Vision** Michele Rucci[1,2] (mrucci@bu.edu), Martina Poletti[1], Jonathan Victor[3], Marco Boi[1]; [1]Department of Psychological & Brain Sciences, Boston University, [2]Graduate Program in Neuroscience, Boston University, [3]Brain and Mind Research Institute, Weill Cornell Medical College

Background: Under natural viewing conditions, fast relocations of gaze (saccades) separate brief periods of "fixation", in which microscopic eye movements continually occur. It is well known that the visual system is highly sensitive to temporal transients, and we have previously shown that fixational instability equalizes the amplitude of the luminance modulations to the retina over a broad range of spatial frequencies (Kuang et al., 2012). However, little attention has been paid to the visual consequences of the natural alternation between macroscopic and microscopic eye movements. How does this recurring sequence of transients affect spatial vision and its dynamics? Methods: We investigated this question by combining three different approaches: spectral analysis of the spatiotemporal input signals to the retina, neural modeling of the responses of retinal ganglion cells, and psychophysical experiments with precise control of retinal stimulation during normal eye movements. Results: We show that saccades and fixational drift yield temporal modulations with highly different spatial distributions. Whereas drift equalizes power across spatial frequency, as previously reported, saccadic transients lead to power at low spatial frequencies. In a model based on the responses of simulated retinal ganglion cells, the transition between these two spectral distributions yields specific predictions regarding the dynamics of contrast sensitivity: fixational eye movements enhance sensitivity to high spatial frequencies, while saccades mainly contribute to vision at low spatial frequencies. Measurements of contrast sensitivity with controlled retinal input show that elimination of saccadic transients and fixational modulations selectively affects sensitivity at low and high spatial frequencies, respectively. Conclusions: These findings suggest that the interplay between saccadic and fixational eye movements results in a coarse-to-fine dynamics of visual perception within each intersaccadic interval.

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26.3011 **Contrast sensitivity of microsaccade rate signature** Chris Scholes[1] (chris.scholes@nottingham.ac.uk), Neil Roach[1], Marcus Nyström[2], Paul McGraw[1]; [1]School of Psychology, University of Nottingham, NG7 2RD, Nottingham, UK, [2]Humanities laboratory, Lund University, Helgonabacken 12, 22362, Lund, Sweden

During periods of steady fixation, individuals make small ballistic eye movements (microsaccades) at a rate of around 1-2 per second. Presentation of a visual stimulus triggers a biphasic modulation in microsaccade rate – an initial inhibition followed by a period of elevated rate and a subsequent return to baseline. The magnitude and latency of this characteristic 'rate signature' have previously been shown to change with large manipulations of stimulus contrast (Rolfs et al., 2008). Here, we examine the contrast sensitivity of the rate signature and its relationship to individuals' psychophysical detection thresholds. Observers were required to fixate on a central dot, while large Gabor patches (SF = 0.33 c/deg; 11.8 deg. full-width/half-height) of varying contrast were presented briefly (12 ms), centered on fixation. On a subset of trials within each run, observers were cued to discriminate the orientation of the Gabor (±45°). Binocular eye position was recorded at 500Hz using an Eyelink-1000 and microsaccades were identified using criteria described by Engbert & Kliegl (2003) and Engbert (2006). Data were obtained for seven observers at 11 contrast levels; each observer completed at least 900 passive trials per contrast. Analysis of passive trials revealed statistically reliable rate signatures across a range of contrasts. For each observer, oculometric functions were constructed from changes in the magnitude and/or latency of the rate signature, or using pattern classification techniques. Resulting estimates of contrast sensitivity approached those obtained psychophysically. These findings indicate that stimulus-induced modulations of microsaccade rate are highly sensitive to absolute contrast. As a consequence, the rate signature could provide a novel means of quantifying visual sensitivity without the need for observers to make a stimulus judgment.

26.3012 **A unified network model for microsaccade and macrosaccade generation** Ruobing Xia[1] (ruobing_xia@brown.edu); [1]Department of Neuroscience, Brown University

Featured by small amplitude and involuntariness, microsaccade shows similar profiles with normal saccade (macrosaccade) otherwise. For instance, despite the stochastic nature of microsaccade generation, its frequency and direction can be regulated by covert attention. Recent studies suggested that microsaccade generation might share the same circuit with macrosaccade. However, whether and how these two motor types are processed remains unclear. With this question, we built a continuous attractor network model to simulate both microsaccade and macrosaccade generation. In this network, neurons with various spatial preferences (from -90° to 90°) were organized in a one-dimensional axis, whose activity controlled the timing and target of saccades using a threshold mechanism. The recurrent connection pattern contained two components: a homogeneous pattern where connection weights decrease monotonically with the distance between neighboring neurons, which produced continuous attractor properties in the network; and a clustered connection pattern between neurons tuned to foveal regions, which built a point attractor so as to provide a tendency of keeping fixation. Additionally, a global inhibition mechanism was used to maintain stability and to generate competition between potential saccadic targets. In the simulation, each neuron received a small Poisson-noise input, and a peripheral visual input was present to a group of neurons to mimic the cueing effect in a covert attention task. We found that, while large visual input induced macrosaccades directly, microsaccades could be generated from noisy foveal activities. Interestingly, a small visual input would not lead to macrosaccades, but might bias the foveal activity indirectly due to the continuous attractor properties, and thus influence the frequency and direction of microsaccades. The simulation successfully replicated the signature of microsaccade distribution in covert attention experiments, indicating that this model could be used as a potential solution for explaining the attentional effect on microsaccade and unifying the microsaccade and macrosaccade generation.

26.3013 **Characterizing ocular drift and tremor: contributions to the retinal input** Hee-kyoung Ko[1] (heekko@gmail.com), Donald Snodderly[1], Murat Aytekin[2], Martina Poletti[2]; [1]Department of Neuroscience, Institute for Neuroscience, and Center for Perceptual Systems, University of Texas at Austin , [2]Department of Psychological and Brain Sciences, Boston University

When we view a scene, saccades separate brief periods of fixation during which the information is acquired and processed. Mounting evidence indicates that the retinal motion introduced by fixational drift enhances fine detail, but physiological studies have not analyzed its effect. Responses of visual neurons to natural images are generally studied as if the eye is stationary during fixation. One reason for this situation is the challenge of measuring ocular drift with high accuracy and precision. Here we assess precision and resolution of two eyetracking systems, an eye coil (Remmel labs EM6) and a dual-Purkinje image eyetracker, (DPI v.6), to support neural and psychophysical studies of natural images with high precision during drift periods. We examined these systems noise with a model eye and eye coil mimicking the signal from a real eye. The impact of system noise on the measurements was characterized. The optimized eye coil system with a bandpass of 0-320 Hz had an RMS noise level of 0.18′~0.27′, and the slow drift over a period of 7 min was 0.52′ ± 0.16′ (N=10). The RMS noise level of a DPI eyetracker was of 0.35′ for both the horizontal and the vertical axes, and the slow drift over a period of 10 min was 0.7′ ± 0.20′ (N=6). By comparing the power spectrum of the system noise with ocular drift recorded from human subjects and a monkey, we determined the optimal filter to characterize drift speed. We also identified a high frequency tremor that varied between 50 and 100 Hz. Our results across the humans and the monkey consistently showed that ocular speed during fixation is much faster than previously thought, and tremor is sometimes larger than expected. These results can facilitate the development of standard procedures for optimizing study of the dynamics of microscopic ocular motion.

Acknowledgement: NSF IOS-0843354

26.3014 **Signal-Detection Analysis of Neural Impairment using Oculomotor Assessment** Dorion Liston[1,2] (dorion.b.liston@nasa.gov), Leland Stone[1]; [1]NASA Ames Research Center, [2]San Jose State University

Various types of brain disorders affect visuomotor processing and generate characteristic patterns of deficits in oculomotor behavior (e.g., Leigh & Zee, 2006). Whereas current clinical tests that assess static foveal acuity, perimetry, and contrast sensitivity provide early indicators of visual pathology, the oculomotor system may also provide sensitive and reliable signals that

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can be used to detect disease onset and track the severity of functional impairment. Methods. We developed a 15-minute test that derives a ten-element vector of metrics from the oculomotor responses to direction-and-speed randomized radially moving stimuli, including pursuit initiation and steady-state tracking, as well as direction-tuning and speed-tuning metrics (Liston & Stone, JOV, in press). Using this task, we collected data from a baseline population of normal observers (N=41) and a few observers with retinal pathology (glaucoma N=2; retinitis pigmentosa N=1, sampled twice over an interval of 17 months). For each metric, we normalized the raw measurements into a standard normal distribution. For a given pathology, we defined the oculomotor "disease vector" as the distance between the average vector for a patient population and the mean of the normal population. The inner product between a disease vector and the vector from any individual patient yields a linear detection metric of the severity of their impairment or their "impairment index". Results. For two glaucoma patients tested, we observed significant impairment in one observer (index: 2.27; $p< 0.05$), but not in the other (index: 0.70; $p>0.05$). For our single retinitis pigmentosa patient, we observed significant impairment at both time points (indices: 2.28 and 3.86, $p< 0.05$ and $p< 0.01$) with the index changing significantly over time ($p< 0.01$, bootstrap test). Conclusions. Using a multi-dimensional performance vector computed using our oculomotor assessment test, "disease vectors" and "impairment indices" can be constructed to characterize, detect, and track the progression of visuomotor pathology.

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26.3015 **Spatial phase dependence in motion mechanisms serving Ocular Following Responses**

Andrew Isaac Meso[1] (andrew.meso@univ-amu.fr), Guillaume S Masson[1]; [1]Institut de Neurosciences de la Timone, CNRS/Aix-Marseille Université

The fast, reflexive Ocular Following Response to large field motion (OFR) is thought to be driven by low level motion energy computation. When moving images contain broadband spatial frequencies, localised interactions between them can result in features like edges. Spatial phase invariant motion energy models should remain agnostic to such features. Here, we tested that assumption considering OFR as highly sensitive to contrast and total energy. We sought to create well controlled phase-varied stimuli to probe differences in the eye speed of human volunteers recorded with a video eye tracker over a 250ms task epoch from stimulus onset. We exploited Phase Congruency (PC): a dimensionless measure of the localised alignment of sinusoidal luminance components at different scales. PC is proportional to local luminance energy, normalised by the sum of the local amplitudes of the separate composite frequencies, making it awkward to compute and susceptible to noise. We used dynamic luminance noise textures as stimuli and exploited published PC estimation methods implemented with appropriately adjusted filters and sensitivity parameters (Morrone & Burr, 1988, Proc.Roy.Soc.B 235:221-245; Kovesi, 2000 Psych. Res 64:136-148). We ranked 250 stimulus cases based on PC repeating this to build a test bank of 2-6 octave bandwidth stimuli. Parameterised movies running from low to high phase coherence were used in an OFR task with trials containing motion at 24deg/s preceded by a centralising saccade. For the narrower (2 octave) bandwidth there was no difference in eye traces over the 250ms. Stronger responses for high-PC stimuli emerged after 140ms for images with over 3 octaves of bandwidth, relatively late in a computation with an 80ms latency from onset. The early 60ms is consistent with motion energy computation; phase sensitivity emerges later possibly from a dynamic accumulation of broadband signals necessary for the neural implementation of a separate motion feature sensitive process.

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26.3016 **A Computational Model to Study the Dynamics of Updating of Remembered Visual Targets During Rapid and Slow Eye Movements**

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After an intervening eye movement, or saccade, humans and animals are able to localize previously perceived visual targets (spatial updating). Although efforts have been made to discover the mechanism underlying spatial updating, there are still many unanswered questions about the neuronal mechanism of this phenomenon. State space model is an effective method for modeling dynamical systems and it can represent the internal behaviour of these systems. Therefore, we developed a state space model for updating target-related spatial information in gaze-centered coordinates. We considered three types of input in our proposed model: 1) an efference copy signal, inspired by motor burst in SC, 2) an eye position signal, found in LIP, VIP, MT and MST areas and 3) visual topographic maps of visual stimuli, located in SC. To model the internal neuronal behaviour of the system, we developed a radial basis function neural network (RBFNN) which can be trained with an Extended Kalman filter method. This RBFNN represents the state space and we can obtain a topographic map of the remembered target in its hidden layer. From our proposed model, the output obtained is the decoded location of the remembered target. To explore the internal mechanism underlying the updating process, we trained this model on a double-step saccade-saccade or pursuit-saccade task. After training, the receptive fields of state-space units replicated both predictive remapping during saccades (Duhamel et al. Science 1992) and continuous eye-centered updating during smooth pursuit (Dash et al. Current Biology, in press). In addition, during trans-saccadic remapping, receptive fields also expanded (to our knowledge, this predicted expansion has not yet been reported in the published literature). In the future, we plan to incorporate this framework within a more comprehensive model of trans-saccadic integration of both spatial and feature information, and use this framework to construct a physiologically plausible model.

Acknowledgement: NSERC Discovery Grant and the NSERC CAN-ACT CREATE Program

26.3017 **A common cortical detection mechanism for perception and movement**

Alex White[1] (alex.white@bccn-berlin.de), Martin Rolfs[1]; [1]Bernstein Center for Computational Neuroscience & Department of Psychology, Humboldt University Berlin

Visual input is shared by many perceptual, cognitive, and motor functions. We can study the architecture of the brain by determining when these streams of sensory processing diverge. We took this approach to investigate two fundamental perceptual and motor functions: visual detection and microsaccadic inhibition. Microsaccades are small, spontaneous eye movements that occur during attempted fixation. They are briefly and reflexively inhibited following the onset of a visual stimulus. Does microsaccadic inhibition rely on the same detection mechanisms as conscious perception, or an independent, possibly subcortical processing stream? Observers fixated a small point and detected a Gabor stimulus flashed briefly on a random half of trials. We measured perceptual sensitivity (d'), and oculomotor sensitivity for the same stimulus, derived from the drop in microsaccade rates following stimulus onset. In a first experiment, we found that foveal contrast thresholds for perceptual and oculomotor responses were very similar. In fact, microsaccades were inhibited if and only if the observer reported seeing a stimulus, even when no stimulus was present. This finding suggests a strong link between perception and oculomotor control: they share a source of internal noise. We then used orientation-specific adaptation to determine whether the signal triggering microsaccadic inhibition goes through visual cortex. In two experiments using foveal and peripheral targets, respectively, each trial began with several seconds of adaptation to a flickering grating. The target Gabor, flashed after the adaptor on 50% of trials, either had the same (adapted) or the orthogonal (unadapted) orientation. Consistent with classic phenomena known to rely on orientation-selective cortical neurons, perceptual sensitivity was reduced for the adapted orientation. Oculomotor sensitivity followed the same pattern: microsaccadic inhibition was less pronounced for the adapted than the orthogonal orientation. We conclude that even the most reflexive oculomotor responses rely on the same cortical detection mechanisms as perception.

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26.3018 **Lights, camera, action – CUT! How film cuts influence eye movements**

Esther Wu[1, 2], Fook-Kee Chua[2], Shih-Cheng Yen[1, 3]; [1]Singapore Institute for Neurotechnology (SINAPSE), National University of Singapore, [2]Department of Psychology, National University of Singapore, [3]Department of Electrical and Computer Engineering, National University of Singapore

When watching a movie, viewers are likely to find a cut from one shot to another more jarring if the two shots differed by only a small margin compared to two very different shots. According to Walter Murch, the small change may not be sufficient to compel viewers to re-evaluate the scene, but sufficient to indicate that something has changed. One interpretation is that the failure to detect a global context change, and the detection of a local change produce discomfiture. In the current study, we conducted two experiments that examined how abrupt scene transitions affected eye fixation patterns. Pairs of natural scene images were presented such that the first scene was shown for several seconds before a blank screen appeared for

15 ms during a fixation, followed by the second scene. In a subset of trials, the first scene was re-presented after the blank screen. In Experiment 1, we observed a shift of the eyes towards the scene center in the first saccade following the transition. This shift was greater when the scene changed, but was present to a smaller degree when the scene remained the same, suggesting rapid identification of global context changes before the first saccade. In Experiment 2, we varied the magnitude of scene changes by presenting pairs of scenes that overlapped to different degrees horizontally. At very small levels of scene change (1%), there were no changes in the shift of the eyes to the center, indicating a failure in detecting a global context change. At larger levels of scene change (>10%), the shift to the center increased significantly. Our results suggest that the detection of a global context change may be required to trigger a re-evaluation of the scene, and explains the discomfort when local changes are not accompanied by global context changes.

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Attention: Neural mechanisms

Saturday, May 16, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

26.3019 Attentional modulation interacts with orientation anisotropies in contrast sensitivity. Ilona Bloem[1,2] (im.bloem89@gmail.com), Taryn Janati[1], Sam Ling[1,2,3]; [1]Department of Psychological & Brain Sciences, Boston University, [2]Center for Computational Neuroscience and Neural Technology, Boston University, [3]Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, The Netherlands

The magnitude of attentional modulation in the LGN has recently been shown to depend on stimulus orientation, whereby oblique orientations yield larger attentional effects than cardinal orientations – a pattern of effects that is absent in visual cortex (Ling, Pratte & Tong, 2013). Here, we examined what impact, if any, this orientation-based anisotropy in subcortical attentional modulation may have on behavior. To do so, we first established the effect of stimulus contrast on the strength of the orientation sensitivity, by mapping the contrast psychometric functions for oblique and cardinal orientations. Participants performed a fine orientation discrimination task on a grating (4°; 7 cpd) varying in contrast from trial-to-trial, oriented either cardinally (0° or 90°) or obliquely (45° or 135°) at fixation. Results revealed a robust oblique effect, consistent with a multiplicative attenuation of contrast responses for oblique orientations. Next, we evaluated how orientation interacts with attention by measuring the same psychometric functions while varying the attentional load. The low attentional load condition consisted solely of a fine orientation discrimination task at fixation, while the high attentional load condition consisted of participants performing the same orientation discrimination task, concurrent with a demanding RSVP task at fixation. Results suggest that attentional load affects the sensitivity for cardinal and oblique orientations differently. Specifically, while attentional load only marginally affects the contrast response function for cardinal orientations, both the response gain and sensitivity decrease when attentional load increases for obliques. In sum, the magnitude of the effect of attention on the contrast response function seems to depend on the orientation of the stimulus. This is consistent with previous neuroimaging findings, showing that attention seems to strengthen the orientation-selective responses for oblique orientations to a larger degree than responses for cardinals within LGN, suggesting that early attentional modulation may have a substantial impact on behavior.

26.3020 Mouse Saliency - a New Method for Low-Cost Large-Scale Attentional Data Collection Ming Jiang[1] (mjiang@nus.edu.sg), Shengsheng Huang[1], Juanyong Duan[1], Qi Zhao[1]; [1]Department of Electrical and Computer Engineering, National University of Singapore

Eye tracking is commonly used in visual neuroscience and cognitive science to answer related questions such as visual attention and decision making. We envision that bigger eye-tracking data can advance the understanding of these questions due to the inherently complex nature of both the stimuli and the human cognitive process. The scale of current eye-tracking experiments, however, are limited as it requires a customized device to track gazes accurately. Low-cost data collection with general-purpose webcams is not yet accurate enough, especially in uncontrolled environments. We present a new method to allow the collection of large-scale attentional data using a gaze-contingent multi-resolutional mechanism. Subjects can move the mouse to direct the high-resolutional fovea to where they find interesting in the image stimuli. The stimuli encoded the visual acuity drop-off as a function of retinal eccentricity. The mouse-contingent paradigm motivated mouse movements, to reveal interesting objects in the periphery with high resolution, similarly as humans shift their gazes to bring objects-of-interest to the fovea. The mouse trajectories from multiple subjects were aggregated to indicate where people look most in the images. The new paradigm allowed using a general-purpose mouse instead of an expensive eye tracker to record viewing behaviours, thus enabling large-scale attentional data collection. We propose a crowdsoucing mechanism to collect mouse-tracking data through Amazon Mechanic Turk, and a proof-of-concept dataset of 60 subjects "free-viewing" 10,000 images from the recent Microsoft COCO dataset. The crowdsourcing allowed us to easily collect and compare various data with different top-down instructions. Our results suggested that the large-scale mouse-tracking data were much more similar to the eye-tracking data than those predicted from the state-of-the-art computational saliency models. They were also shown to be a good source as ground truth for the evaluation of saliency algorithms.

26.3021 Contrasting Bottom-up Saliency and Top-Down Attention in the Early Visual Pathway Sonia Poltoratski[1,2] (sonia.poltoratski@vanderbilt.edu), Sam Ling[3], Frank Tong[1,2]; [1]Department of Psychology, Vanderbilt University, [2]Vanderbilt Vision Research Center, [3]Department of Psychological & Brain Sciences, Boston University

The visual system employs a sophisticated balance of attentional mechanisms: individuals can willfully guide attention to serve their goals, but still notice salient information in the environment outside of their current locus of attention. At its simplest, this saliency can be defined as a measure of feature contrast across the visual field, such that a local region that is unlike its surrounding context along one or more feature dimensions is deemed salient. Here, we used high-resolution fMRI at 7T to investigate whether the effects of bottom-up saliency and top-down voluntary attention operate independently or interactively in the human visual system, and to determine the stages of visual processing at which these mechanisms first emerge. We measured BOLD responses to a near-peripheral Gabor grating, presented among a field of other gratings. Depending on its orientation relative to the contextual patches, this stimulus patch could be either salient – for example, a vertically oriented Gabor patch amongst horizontal patches – or not salient, sharing all of its features with the surrounding context. To concurrently manipulate top-down attention, observers performed a demanding task that directed covert spatial attention to either the salient or non-salient patch. This design allowed us to directly compare the magnitude of BOLD responses to salient and non-salient items, and to attended and non-attended items. We found evidence of independent, additive effects of top-down attention and bottom-up saliency in retinotopic visual areas V1, V2, V3, and hV4. In contrast, fMRI response amplitudes in the lateral geniculate nucleus (LGN) showed significant enhancement due to top-down attention, but showed no evidence of reliable modulation by orientation saliency. We conclude that saliency representation emerges in feature-selective populations of neurons at early cortical stages of visual processing, and can be distinguished from independent effects of top-down spatial attention.

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26.3022 Structural and functional connectivity of visual and auditory attentional networks: insights from the Human Connectome Project David Osher[1] (osher@bu.edu), Sean Tobyne[2], Keith Congden[1], Samantha Michalka[2,3], David Somers[1,2,3]; [1]Psychological & Brain Sciences, Boston University, [2]Graduate Program for Neuroscience, Boston University, [3]Center for Computational Neuroscience and Neural Technology (CompNet), Boston University

Recent work in our laboratory has suggested that human caudal lateral frontal cortex contains four interleaved regions in each hemisphere that exhibit strong sensory-specific biases in attention tasks (Michalka et al, 2014). Two visually-biased attention regions, superior and inferior pre-central sulcus (sPCS, iPCS), anatomically alternate with two auditory-biased attention regions, caudal inferior frontal sulcus (cIFS) and the transverse gyrus intersection the precentral sulcus (tgPCS). These small regions were identified in fMRI studies in a small number of individual subjects. Here, we have investigated these regions and their putative networks by mining the WashU-Minn Human Connectome Project (HCP) dataset. We used data from the 482 HCP participants with both diffusion-weighted imaging and resting-state fMRI. We defined seed regions from our individual subject data in a task that contrasted auditory and visual spatial attention. Probabilistic activation maps were constructed and thresholded to generate ROIs. These ROIs served as seed regions for resting state and tractography analyses of the HCP dataset. Stronger functional connectivity was observed for the sPCS and iPCS than for tgPCS and cIFS with superior parietal lobule visual attention regions, and conversely stronger connectivity was observed for the tgPCS and cIFS than for sPCS and iPCS with superior temporal lobe auditory attention regions. A similar pattern was observed with tractography for all ROIs, except for tgPCS. We next analyzed the whole-brain connectivity patterns of these ROIs using a multivariate approach; we found that the modality of sensory-bias can be predicted well above chance in both hemispheres at a voxelwise scale (L:71%, R:80%), using only the connectivity pattern of an individual voxel. A long-term goal of this analysis is to develop reliable methods for identifying fine-scale brain networks in large population datasets, which could have important clinical applications. Our preliminary results reveal both successes and challenges of these efforts.

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26.3023 Cortical circuit for tracking dynamic object locations and identities

Lauri Oksama[1] (loksama@utu.fi), Lauri Nummenmaa[2], Jukka Hyönä[3]; [1]National Defence University, [2]Aalto University, [3]University of Turku

During real-world vision observers often need to attend and track several moving objects. Sometimes the objects also have different identities (such as individual players in a football game), thus the observer needs to bind the object identities to their movement trajectories to know where each object is currently located. It has been proposed that dynamic identity-location binding is based on serial attention shifting with the help of working memory (Oksama & Hyönä, 2008). However, the brain mechanisms supporting tracking of object locations (multiple object tracking; MOT) and their identities (multiple identity tracking; MIT) have remained unresolved. Here we reveal cortical circuits supporting MIT and MOT while viewing moving objects with distinct identities. Twenty-four participants tracked identities (MIT) or locations (MOT) of 0, 2 or 4 moving targets while their haemodynamic brain activation was measured with functional magnetic resonance imaging (fMRI). Concurrent eye tracking revealed that participants made more saccades in the MIT versus MOT condition. Both MIT and MOT tasks engaged similar components of the dorsal attention system, yet MIT task resulted in increased activity in frontocortical circuits supporting working memory and temporal areas involved in object recognition, as quantified on separate localizer scans. Additional activations were observed in intraparietal regions involved in attention shifting. Only the latter regions' activity was modulated by the number of saccades made during trials, suggesting that eye movements do not confound frontal and temporal responses. We conclude that MIT task relies on interactions between executive functions and ventral visual areas.

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26.3024 Post-stimulus alpha oscillations influence visual discrimination performance

Stephanie Nelli[1,2] (smnelli27@gmail.com), Sarah Fraley[2], John Serences[1,2]; [1]Neurosciences Graduate Program, [2]Department of Psychology

Visual attention allows organisms to more efficiently process behaviorally relevant stimuli. Several studies indicate that pre-stimulus alpha oscillations adjust the state of visual (Van Dijk et al 2008, Busch et al 2009, Mathewson et al 2009) and somatosensory (Haegens et al 2011) systems through top down attentional control (Capotosto et al 2009). Specifically, alpha band activity is involved in the engagement and disengagement of specific regions according to anticipated processing needs (Thut et al 2006), perhaps via an anticipatory desynchronization that regulates inhibition. However, most previous paradigms investigated the role of alpha oscillations during pre-stimulus attentional orienting, and did not address whether alpha is involved in mediating processing during decision making. In the current study, subjects participated in a 2AFC task in which they were asked to report the orientation of a temporally unpredictable and briefly flashed (~8 ms) orientated grating. The contrast of this grating was determined before the experiment for each subject to fix accuracy at 65%. Importantly, subjects were not cued to the possible stimulus location. As reported previously in the literature, behavioral performance was slightly lower on trials with higher parieto-occipital alpha power in the 200 ms before stimulus onset. However, logistic regression revealed that alpha power had the largest modulatory impact on behavior 200-700 ms post-stimulus, with lower alpha power predicting correct responses. This result suggests that alpha oscillations are involved in mediating information processing at multiple stages of visual perception.

26.3025 The footprint of spatial attention in V4 receptive fields

Alexandria Marino[1,2] (alexandria.marino@yale.edu), James Mazer[1,3,4]; [1]Yale Interdepartmental Neuroscience Program, [2]Yale Medical Scientist Training Program, [3]Yale Department of Neurobiology, [4]Yale Department of Psychology

Spatial attention modulates responses of visual neurons at virtually all levels of cortical processing. Studies of attentional modulation of neural selectivity for stimulus properties like orientation and contrast have found that directing attention into a V4 receptive field (RF) alters neuronal gain. Little, however, is known about how attention affects the spatial structure of V4 RFs. Nor do we know how, or even if, attentional modulation is constrained to neurons with RFs within the attentional focus (AF). To address these questions we recorded from V4 neurons in monkeys performing a spatiotopic attention task where they responded to targets appearing at a cued location in space. On alternating blocks of trials, the attended location was either in the lower or upper visual field. One of three fixation points was chosen at random on each trial to control the spatial relationship between the RF and AF. Ignored low contrast probe stimuli were displayed in and around RFs during trials. Neuronal responses to probe stimuli were used to characterize the spatiotemporal RF. Over half of V4 neurons showed significant attentional modulation (attend-in vs -out), with 70% of neurons showing facilitation and 30% suppression. We observed both multiplicative and additive modulatory effects. Interestingly, the sign of these effects were often in opposite directions. About half of the attentionally modulated neurons were modulated only when the RF fell inside the AF, consistent with behavioral performance. The remaining neurons were modulated even when the RF was located more than one diameter outside the AF, suggesting that at the neuronal level attention can spread beyond the AF, as defined by enhanced behavioral performance. Consistent with proposed ventral stream contributions to spatiotopic processing, we found activity in >70% of the V4 neurons studied was also modulated by gaze angle position, reminiscent of dorsal stream gain fields.

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26.3026 Rapid and Parallel Allocation of Attention to Shapes

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In real-world visual environments, many objects can appear simultaneously or in rapid succession and often guide attention based on features such as colour and shape. There is continuing debate as to whether attention is allocated in serial or in parallel; however, previous research by Eimer and Grubert (2014) used event-related brain potential (ERP) markers of attentional allocation to show that attention could be allocated rapidly and in parallel to new items. Since colour is known to be a particularly strong guiding feature (Wolfe, 2007), it is possible that this effect is unique to colour. The current research aimed to replicate these findings using targets defined by shape in order to generalise this attentional phenomenon. Participants were presented with trials containing two rapidly presented displays with a stimulus-onset asynchrony (SOA) that varied between conditions (10, 20 and 50ms). Each display contained one target shape and one distractor shape. Participants were instructed to compare the orientations of lines presented inside the target shapes. EEG data were collected from each participant and the N2pc ERP component was analysed as a marker for the deployment of attention to a location in the contralateral visual hemifield. As found by Eimer and Grubert, differences between N2pc onset latencies in each of the two displays closely matched the objective SOA in each condition, demonstrating that attention can also be allocated rapidly to new target objects when they are defined by shape, and two separate foci of attention can be maintained in parallel. These results suggest that the ability to maintain attention at one location whilst allocating it to a new location is not confined to colour, but may in fact be a phenomenon that exists also for other attention-guiding features.

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26.3027 Single trial decoding of visual attention from local field potentials in the primate lateral prefrontal cortex

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It has recently been shown that attention can be decoded from the spiking activity of ensembles of neurons in area 8A of the monkey lateral prefrontal cortex (Tremblay et al., 2015). As spikes are believed to reflect the output of a given brain region and local field potentials (LFPs) its input and local activity, we used a decoding approach to investigate the role of area 8A in visual attention. To do so, we used simultaneously recorded LFPs from chronically implanted multi-electrode arrays to decipher the target of visual attention. However, when attempting to decode the information content of an LFP signal, conventional filtering techniques (low-pass at 250 Hz) are insufficient in segregating spikes components from other LPF sources. Indeed, multiple studies have shown that spike waveforms recorded from the same electrode contaminate LFP signals above 80 Hz (Zanos et al., 2012), biasing the decoded information. Using a previously published spike removal algorithm (Zanos et al., 2011), we compared the decoding performances of spike-free LFPs and spiking data. Our results demonstrate that LFPs in the mid to high gamma range (> 80 Hz) offer comparable performance to spikes in decoding accuracy, while the lower frequencies are unreliable. We further show that the information content of high-frequency LFPs is entirely redundant with the one contained in locally recorded action potentials. These results first demonstrate that LFP signals can be used to decode the allocation of attention across the visual field. Secondly, recent work by Ray and Maunsell (2011) proposed that the higher LFP frequencies (> 80 Hz) reflect the neuronal firing around the electrode and are independent of lower gamma oscillations. This suggests that our decoding accuracy is only dependent on the local spiking activity of area 8A and not from its input, placing it as a potential source for attentional signals.

26.3028 **Attentional switching of connectivity between visual and memory systems** Natalia Córdova[1,2] (ncordova@princeton.edu), Alexa Tompary[3], Nicholas Turk-Browne[1,2]; [1]Princeton Neuroscience Institute, Princeton University, [2]Department of Psychology, Princeton University, [3]Department of Psychology, New York University

Attention amplifies neural responses within areas coding for goal-relevant information and also strengthens the coupling between these areas. This modulation has been found repeatedly in ventral visual cortex and linked to the behavioral effects of attention on perception. However, attention also has a powerful effect on learning and memory behavior, suggesting that such modulation may impact the medial temporal lobe (MTL) memory system. Here we investigated this possibility by examining how visual input into the MTL gets prioritized based on top-down attentional goals. In particular, we focused on two cortical structures, perirhinal cortex (PRC) and parahippocampal cortex (PHC), which project to the entorhinal cortex and hippocampus. These regions are thought to belong to different pathways, with PRC involved in face and object processing and PHC involved in scene and spatial processing. However, in addition to these static networks, we hypothesized that these regions would dynamically couple with ventral visual cortex depending on whether attention is directed to their preferred content — that is, visual cortex would be more coupled with PRC when attending to faces and with PHC when attending to scenes. To test this prediction, subjects were exposed to blocks of composite images containing both face and scene information, but attended to only one category. We measured background connectivity between PRC, PHC, and ventral visual cortex separately during the face and scene attentional states. Region-of-interest and voxelwise analyses revealed an interaction consistent with our prediction, with visual cortex coupling relatively more with PRC during face attention and PHC during scene attention. Interestingly, the degree to which attention modulated a voxel's connectivity was negatively correlated with the voxel's category selectivity — voxels with mixed selectivity had the most malleable connectivity. These findings suggest that attention determines which MTL structures receive the most input from ventral visual cortex.

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26.3029 **Controlled Attentional Suppression** Nancy Carlisle[1] (nancy.carlisle@gmail.com), Aleksander Nitka[1]; [1]School of Psychology, University of Leicester

When participants are given a cue about the color of distractors in an upcoming array, they are faster to find a target then when no distractor cue is given (Arita, Carlisle, & Woodman, 2012). While the benefit of this cue is not as large as the benefit for a cue that indicates the color of the target, it indicates participants can engage in active suppression of a specific color features. However, other evidence suggests that participants may first need to attend to the distractor color in order to suppress it, a 'search and destroy' mechanism (Moher & Egeth, 2012). In this study, we used the N2pc ERP component to evaluate the conflicting proposals from these two explanations. We used an array that contained 6 items of one color in the left visual hemifield, and 6 items of another color in the right visual hemifield. Participants were provided with a neutral cue (color will not appear in array), a negative cue (color will be distractor), or a positive cue (color will be target). The active suppression hypothesis predicts the cued distractors will be avoided in the negative cue condition, leading to an N2pc toward target features. The search and destroy hypothesis predicts the cued distractors will first be attended, leading to an N2pc toward the cued distractors. We found no evidence of an N2pc toward the cued distractors, in contrast to the prediction of the search and destroy hypothesis. Both the positive and negative cues led to N2pcs toward the target color. The latency of the N2pc response was much faster for the positive cue condition, leading to an interaction of early vs. late window and cue type. Overall, these results show that in some conditions participants can actively avoid a cued distractor feature, suggesting the possibility of active attentional suppression.

26.3030 **Using the N2pc to compare the timing of attentional shifts to categorical and featural targets.** Chloe Callahan-Flintoft[1] (ccallahanflintoft@gmail.com), Brad Wyble[1]; [1]Department of Psychology, Pennsylvania State University

When a target is presented on one side of a visual display, EEG will record a brief negativity from posterior locations on the contralateral scalp about 200ms after target onset. This component, called the N2pc, is thought to reflect the deployment of attention towards the target. The present study contrasted the N2pcs produced by targets defined by feature or by category. Participants viewed two RSVP streams with a 150ms SOA. The distractors were black letters and the targets were either red letters (differing from distractors in feature) or black digits (differing in category). Trials either had one target or two (T1 and T2), with T2 always presented immediately after and on the same side as T1 in all possible combinations of target types. The presentation of the target(s) was followed by another string of distractors and subsequently participants were asked to report what targets they had seen. We found that the N2pc onset was later when T1 was defined by category (digit) versus feature (red letter). From this we predicted that the delay in the localization of attention from a category target would delay the subsequent encoding of that target, such that participants would swap the T1 and T2 in their report more often whenever the first target was specified by category rather than feature. The behavioral data confirmed this prediction. Additionally, in an unexpected finding, the lowest accuracy in reporting both targets involved a categorical T1 (slow localization) followed by a featural T2 (fast localization). This arrangement may have caused the attentional processes evoked by the two attentional sets to collide, thus producing less efficient encoding of the targets from the RSVP stream. The reverse order (feature followed by digit) produced much higher accuracy.

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26.3031 **Cerebellar Contributions to Visual Attention and Visual Working Memory Revealed by Functional MRI and Intrinsic Functional Connectivity** James Brissenden[1] (brissend@bu.edu), Emily Levin[1], David Osher[1], Maya Rosen[1], Mark Halko[2], David Somers[1]; [1]Boston University, Department of Psychological and Brain Sciences, [2]Harvard Medical School and Beth Israel Deaconess Medical Center

The study of cerebellum function has been traditionally limited to the motor domain. Recent research, however, has begun to characterize the cerebellum's role in cognition (see Schmahmann, 2010) and has demonstrated intrinsic functional connectivity between cerebral cortical networks and distinct cerebellar regions (Buckner et al., 2011). Here, in two separate fMRI experiments, we investigated whether cerebro-cerebellar connectivity of dorsal attention network (DAN) predicts cerebellar activation during visual attention and visual working memory (VWM) task performance. In experiment 1 (N=8), subjects performed a multiple-object tracking task. In experiment 2 (N=9), subjects performed a VWM change detection task using oriented bars. Memory load was varied across blocks (set size: SS0, SS1, or SS4). Both experiments employed resting-state functional connectivity analysis using cortical network seeds (Yeo et al., 2011) to parcellate cerebro-cerebellar networks in individual subjects. In experiment 1, a region-of-interest analysis revealed a robust attentional effect within cerebellar regions functionally connected to the cortical DAN ($p < .01$). Conversely, cerebellar regions functionally connected to the cortical default mode network (DMN) showed reliable deactivation ($p < .001$). In experiment 2, contrasting SS4 with SS0 and SS1 resulted in a similar pattern of competitive interaction between cerebellar nodes of the DAN and DMN. Load-dependent activation spatially corresponded with cerebellar DAN

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nodes (SS4–SS0: p< .005; SS4–SS1: p< .0001) and load-dependent deactivation was observed within cerebellar DMN nodes (SS4–SS0: p< .005; SS4–SS1: p< .0005). Across both experiments the strength of intrinsic functional connectivity, with either the cortical DAN or the cortical DMN, significantly predicted the response of individual cerebellar voxels (Experiment 1: r_{DAN} =.67, r_{DMN} =–.71; Experiment 2: r_{DAN} =.60, r_{DMN} =–.56). Our results indicate that cerebellar nodes of the DAN contribute to network function across a diverse range of attentive and working memory conditions.

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26.3032 **Whole-brain, sub-second data collection for task-evoked fMRI studies using simultaneous multi-slice/multiband acquisition** Stephanie McMains[1] (smcmains@fas.harvard.edu), R. Matthew Hutchison[1,2], Ross Mair[1,2]; [1]Center for Brain Science, Harvard University, [2]Athinoula A. Martinos Center for Biomedical Imaging, Harvard Medical School, Massachusetts General Hospital

Slice-accelerated EPI using multiband (MB) RF pulses that allow for simultaneous multi-slice (SMS) acquisition of BOLD contrast images can significantly enhance the temporal and spatial resolution of fMRI by acquiring up to 8 non-contiguous slices at the same time, thus enabling whole-brain sub-second TRs. Here we studied visual cortex response at a variety of MB accelerations and TR reductions to investigate whether there were any costs associated with parameters that allowed for whole-brain, sub-second data collection at 2mm resolution. 6 subjects were scanned (3.0T Siemens Tim Trio) with a 32-ch head coil while subjects performed a fixation task and blocks of flashing checkerboards were presented to alternating visual fields. BOLD scans were acquired at 3mm and 2mm isotropic resolutions, a max TR of 3s, and MB accelerations of 0 (conventional BOLD sequence), 1, 4 and 8 (Siemens WIP 770A). Beta and t-statistics were extracted from regions localized in visual cortex. With a TR of 3s, there were 91 timepoints, while for TR= 1.25/0.75/0.7s, there were 184/307/328 timepoints. There were no significant differences in betas for any parameters, or in t-statistics for levels of MB when holding the TR constant. Shortening the TR increased t-statistics significantly. This advantage was reduced when temporal autocorrelations in the noise were modeled. An event-related study was also conducted for 2mm voxels to compare 3s TR (MB1) versus 750ms TR (MB8). Betas were larger for the MB8 scans, likely due to improved characterization of the hemodynamic response, even though stimulus onset was jittered to the TR. The results suggest that whole brain coverage with high spatial and temporal resolution can be achieved using SMS with little to no cost in terms of BOLD signal sensitivity, as measured by betas and t-statistics, even though time-series SNR decreased significantly at high MB factors.

Object Recognition: Parts and features

Saturday, May 16, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

26.3033 **The Role of Color and Spatial Frequency in Perceptual Expertise Training** Tim Curran[1] (tim.curran@colorado.edu), Matthew Mollison[1], James Tanaka[2], Lisa Scott[3]; [1]Department of Psychology and Neuroscience, University of Colorado Boulder, [2]Department of Psychology, University of Victoria, [3]Department of Psychology, University of Massachusetts

Recent research with bird experts indicates that their subordinate-level categorization of species is influenced by image color (Hagen et al., 2014) and spatial frequency characteristics (Hagen et al., 2015). The present research sought to examine how these same characteristics influenced learning and subsequent discrimination of species in novice participants trained at the subordinate species level (e.g., "Nashville Warbler" vs. "Wilson's Warbler"). Six training days included unaltered images (color congruent, all spatial frequencies) of 10 species of birds. During the pre- and post-training tests, images were manipulated to examine the influence of color (congruent, incongruent, or grayscale) or spatial frequency (all frequencies, high spatial frequencies above 8 cycles/image (cpi), or low spatial frequencies below 8 cpi) during a serial species-matching task. Results suggest that, prior to training, congruent and incongruent color did not differ and generally improved discrimination relative to grayscale images. Presumably these pre-training effects reflect the importance of color in part segmentation for novices. However, after training, participants performed best with congruent colors relative to the incongruent and grayscale images. These findings highlight the importance of color knowledge in correct subordinate-level identification. Unlike color, the effects of spatial frequency did not change with training. Training improved performance for all image types. However, accuracy before as well as after training was ordered: all special frequencies > high spatial frequency > low spatial frequencies. In general, post-training results were similar to real-world bird experts who perform best with congruent colors and all spatial frequency images, and who rely on high spatial frequencies more than low spatial frequencies for discrimination. The present results suggest that color congruency effects were dependent on learning, whereas the effects of spatial frequency did not change with learning.

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26.3034 **The roles of structure-based and function-based action knowledge in object recognition** Ye Liu[1] (liuye@psych.ac.cn), Long Ni[1], Xiaolan Fu[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences

In recent years, a growing body of research has shown that action knowledge is an important part in the representation of object concepts and plays a role in the recognition of manipulable objects (Lin, Guo, Han, & Bi, 2011; Matheson, White, & McMullen, 2014). Action knowledge of manipulable objects regards how an object could be grasped, moved, and used. Further evidence from neuropsychological and brain imaging research has suggested that there are two kinds of action knowledge: function-based and structure-based action knowledge (Bub & Masson, 2013). Structure-based action refers to grasping an object and moving it, and function-based action refers to functionally using an object. Both types of action knowledge could be activated automatically during object processing, and they are independent of each other functionally and neuroanatomically (Bub & Masson, 2013; Jax & Buxbaum, 2010). However, their respective roles in object recognition is still unclear. In the present two experiments, static action pictures (Experiment 1) and dynamic action videos (Experiment 2) of structural versus functional hand gestures were used as primes to examine their respective roles in the recognition of manipulable target objects. Experiment 1 found that structural and functional hand gestures could facilitate the naming of manipulable objects to the same extent. However, Experiment 2 found that the prime effect of functional hand gestures on the naming of manipulable objects was much stronger than the effect of structural hand gestures. The findings indicated that both function-based action and structure-based action knowledge did play important roles in object recognition, but the facilitation effect of dynamic function-based action was more significant. The present research provided further evidence for the role of the dorsal pathway in object recognition that previously considered subserved only by the ventral pathway, and the distinction between the two action systems: "Grasp" and "Use" systems.

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26.3035 **The effect of familiar and unfamiliar context in peripheral object recognition** Derrick Schlangen[1] (dschlang@fau.edu), Elan Barenholtz[1]; [1]Psychology Department, College of Science, Florida Atlantic University

Previous research on peripheral recognition has largely concerned artificial stimuli (e.g., letters or gratings) shown in isolation or in an uninformative context (e.g. surrounded by flankers). Under these conditions, recognition abilities decline rapidly with eccentricity due to crowding and a decrease in visual acuity. Under typical viewing conditions, however, the larger contextual scene in which an object appears may carry high levels of information about the identity of the object, particularly if the environment is familiar. This contextual information may serve to improve recognition ability in the periphery. To examine this potential role of context and familiarity, we tested participants' ability to identify pictures of objects across the visual field. A wide variety of objects were used as target objects. On each trial, participants maintained fixation on a point while a photographed object in the periphery was cued by a flashing dot. The task was to identify the cued object. Fixation was moved progressively closer to the target until it could be successfully recognized. Using this technique, we compared performance when the object was shown within its entire contextual scene vs. when the image of the object was isolated. In addition, we compared performance when the contextual scene was familiar to the participants vs. when it was unfamiliar. The same set of objects, shown at the same eccentricities, was used across the three conditions (Familiar Context, Unfamiliar Context, No Context). Results showed an effect of contextual condition, with successful

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recognition in the Familiar Context condition at dramatically higher eccentricities than in the Unfamiliar Context condition (~20 degrees), which, in turn yielded higher eccentricities than in the No Context condition. Overall, these findings demonstrate that contextual information—and particularly a familiar context—allows for recognition of objects even in the far periphery, despite the constraints imposed by crowding and lowered acuity.

26.3036 Object-based perception of orientation in the Ternus-Pikler display Andreas Wutz[1] (andreas.wutz-1@unitn.it), David Melcher[1]; [1]CIMeC, Center for Mind/Brain Sciences, University of Trento

Early visual processing is based on orientation-selective receptive fields in a retinotopic reference frame. Perception of visual features over longer time scales, exceeding this fast feedforward encoding, has been demonstrated to involve object-based, rather than only retinotopic coordinates (Fracasso et al., 2010; Boi et al., 2011). For example, non-retinotopic encoding has been found using the Ternus-Pikler (T-P) apparent motion display in which object identity is mapped across the object motion path given the inter-stimulus interval (ISI) is sufficiently long (Boi et al., 2009). Here, we report evidence that feature integration over time can involve an object-based frame of reference, even for the perhaps most paradigmatic example of retinotopically defined features: orientation. We presented observers with repeated series of T-P displays, in which the perceived rotation of Gabor patches depended on the combination of Gabor orientations in either retinotopic or object-based coordinates across display frames. We report that the frequency of perceived retinotopic rotations linearly decreases with increasing ISI between T-P display frames. For very short ISIs (< 50 ms) perceived rotation is strongly biased towards retinotopic processing but on longer time scales (exceeding ISIs around 100 ms) the rotation percept appears ambiguous or predominantly non-retinotopic for individual observers. In addition to these temporal factors, we show that in perceptually ambiguous T-P displays (constant ISI; 200 ms) the perceived rotation can be strongly biased towards either retinotopic or non-retinotopic integration based on object grouping. Cueing either static spatial object position or apparent motion resulted in robust element- or group motion percepts, respectively, and the frequency of retinotopic vs. non-retinotopic rotation reports depended strongly on the perceived object matching. Our results indicate that temporal integration of even basic, low-level visual features like orientation can be biased towards non-retinotopic processing in order to support the perceived constancy of objects in motion.

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26.3037 The canonical upright in the representation of object orientation Miles Hatfield[1], Emma Gregory[2], Michael McCloskey[3]; [1]Johns Hopkins University, Department of Cognitive Science, [2]Johns Hopkins University, Department of Cognitive Science, [3]Johns Hopkins University, Department of Cognitive Science

Some objects are mono-oriented, possessing a canonical or "preferred upright" orientation (Palmer at al., 1981; Jolicoeur, 1985). The implications of canonical orientations for theories of object recognition have been widely discussed (Rock, 1974; Tarr & Pinker, 1989; Ghose & Liu, 2013), but it remains unclear how "canonical" orientations fit into a theory of object orientation representation. How does the orientation representation for an object differ in canonical versus non-canonical orientations? Eight "horizontal" and 8 "vertical" objects (Fig. 1) were each presented in 16 different orientations (canonical and non-canonical) (Fig. 2). On each trial, participants (under working memory load) viewed an object in a "target" orientation and subsequently attempted to select the target from an array of that object in 16 different orientations. In previous research with poly-oriented (no preferred orientation) objects (Gregory and McCloskey, 2010), participants often selected the object primary-axis (OPA) reflection of the target: an "OPA error" (Fig 3a). We predicted that if the "uprightness" of a mono-oriented object is specifically encoded, OPA errors should be affected by canonical orientation: for canonically-oriented vertical targets, an OPA error maintains "uprightness" (Fig. 3b); for a canonically-oriented horizontal target, an OPA error would result in an "upside-down" orientation (Fig. 3c). Indeed, OPA errors were modulated by an Object type (vertical vs. horizontal) X Orientation (canonical vs. not) interaction ($F(1,13) = 16.70$, $p< .05$): for vertical objects, OPA errors were equally common for canonical and non-canonical targets ($t(13) = .16$, n.s.); for horizontal objects, they were significantly reduced for canonical targets ($t(13) = 4.01$, $p< .05$) (Fig. 4). Participants apparently represent the "uprightness" of a stimulus, thereby avoiding otherwise common errors that contradict this representation. These results suggest that the canonical orientation of an object affects not just the cognitive processes underlying object recognition but also those involved in representing spatial information.

26.3038 Invariant object recognition enhanced by object persistence Mark Schurgin[1] (maschurgin@jhu.edu), Jonathan Flombaum[1]; [1]Psychological and Brain Sciences, Johns Hopkins University

The same object can look different to an observer because of changes in viewpoint, lighting, and other parameters. This makes object recognition that is invariant to viewing condition a staggering challenge. It has been suggested that spatiotemporal association can support invariant learning; combining information gained during distinct encounters can improve one's estimates of an object's true features. But spatiotemporal association is insufficient; one needs to know whether spatiotemporally close encounters include the same object. We hypothesized that spatiotemporal association should therefore be constrained by the rules of object persistence, the object physics thought to make up core knowledge in infants and known to guide online perception of token identity. We tested this hypothesis with an incidental-encoding paradigm followed by a recognition test. During each encoding trial a single object appeared twice, via an apparent motion manipulation, in a way that made it look like encounters with two distinct individuals (discontinuous motion) or that made it look like two encounters with the same individual (continuous motion). Participants then judged test objects each as old, similar, or new. Signal detection measures of recognition were used to compare performance as a function of motion continuity. In Experiment 1, encoding involved encounters with an object embedded each time in independent noise. In Experiment 2, encoding occurred without noise, but test images were embedded in varying degrees of noise. And in Experiment 3, each encoding encounter included the object oriented differently, with old objects at test appearing at a third, never-before-seen orientation. (Additional control and extension experiments were run as well). In all three experiments, objects encountered through continuous motion were recognized significantly better than objects encountered through discontinuous motion. These results demonstrate how invariant object learning is supported by constraints from object physics that control the online perception of token identity.

26.3039 Object dissimilarities in visual search: the whole is equal to the sum of parts RT Pramod[1,2] (pramodrt@ece.iisc.ernet.in), Sripati Arun[2,1]; [1]Department of ECE, Indian Institute of Science, Bangalore, India, [2]Center for Neuroscience, Indian Institute of Science, Bangalore, India

A fundamental question in vision science is whether objects can be understood in terms of their parts. If the whole is the sum of parts, it suggests that dissimilarities between whole objects can be explained using dissimilarities between their constituent parts. Here we set out to investigate this problem by studying dissimilarity relations in a set of abstract objects. We measured perceived dissimilarity by asking subjects to find the oddball item in a visual search array. The reciprocal of the time taken by humans to find one object among homogeneous distracters was taken as a measure of dissimilarity between the two objects. In Experiment 1, we created two-part objects joined by a stem. Each side of the stem could be occupied by one of seven parts, resulting in a total of 49 objects. Subjects performed searches involving all possible 1,176 pairs ($49C_2$) of these objects. We then asked whether these search dissimilarities could be explained using a smaller set of 21 ($7C_2$) part-part dissimilarities. Our main finding is that dissimilarities between a pair of objects is a linear sum of the dissimilarities between every pair of their constituent parts ($r = 0.88$, $p < 0.0005$). Thus, for objects AB and CD, their overall dissimilarity is a linear sum of the dissimilarities between AC, BD, AD, BC, AB and CD. In Experiment 2, we confirmed that this result holds for three-part objects ($r = 0.90$, $p < 0.0005$). The only systematic deviation between observed and predicted dissimilarities was for searches involving symmetric objects. For pairs of symmetric objects, the predicted and observed dissimilarities were tightly correlated but offset by a fixed amount. This suggests that symmetry confers an additional but fixed distinctiveness to objects. Taken together, our findings reveal a surprising and systematic linear rule by which objects are related to their parts.

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26.3040 Faster than the speed of rejection: Object identification processes during visual search for multiple targets Michael Hout[1] (mhout@nmsu.edu), Hayward Godwin[2], Steven Walenchok[3], Joseph Houpt[4], Stephen Goldinger[3]; [1]Department of Psychology, New Mexico State University, [2]School of Psychology, University of Southampton (UK), [3]Department of Psychology, Arizona State University, [4]Department of Psychology, Wright State University

When engaged in a visual search for two targets, participants are slower and less accurate in their responses, relative to their performance when searching for singular targets. Previous work on this "dual-target cost" has

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primarily focused on the breakdown of attention guidance when looking for two items. Here, we investigated how object identification processes are affected by dual-target search. Our goal was to chart the speed at which distractors could be rejected, in order to assess whether dual-target search impairs object identification. To do so, we examined the capacity coefficient, which measures the speed at which decisions can be made, and provides a baseline of parallel performance against which to compare. We found that participants could search at or above this baseline, suggesting that dual-target search does not impair object identification abilities. We also found substantial differences in performance when participants were asked to search for simple versus complex images. Somewhat paradoxically, participants were able to reject complex images more rapidly than simple images. We suggest that this reflects the greater number of features that can be used to identify complex images, a finding that has important consequences for understanding object identification in visual search more generally.

26.3041 **Shape recognition: convexities, concavities and things in between** Gunnar Schmidtmann[1] (gunnar.schmidtmann@mcgill.ca), Ben Jennings[1], Frederick Kingdom[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University

Previous studies on shape recognition have drawn different conclusions regarding the importance of specific object features, such as convexities, concavities and intermediate points. Some studies found evidence for a predominant role of convexities, whereas others favored concavities or intermediate parts. However, most studies have employed familiar objects or simple geometric shapes not necessarily containing curves (polygons) as their stimuli. Here we present a novel set of shapes with well-defined convexities, concavities and points between convexities and concavities. The shapes were composed of the sum of three different radial frequency (RF) components with random phases, segmented to remove all but variable lengths of contour centred on the feature of interest. Observers were required to match the segmented test shape to one of two subsequently presented whole-contour re-scaled test shapes. Observers were never presented with the same shape twice. Results show that for short (dot-sized) segment lengths, performance was significantly higher for convexities than for either concavities or intermediate points. For the convexities, performance remained constant as a function of segment length, and although performance improved with segment length for concavities and intermediate points, it only reached convexity performance at the largest lengths tested. No significant differences between concavities and intermediates were found. We present a model by which positions of convexities are extracted and connected to form shape primitives (polygons) that are matched to the test shapes. These results indicate that these closed shapes are encoded from the positions of convexities, rather than from the positions of either concavities or intermediates.

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26.3042 **Mapping eye movements in 3D: Preferential fixation of surface curvature minima during object recognition in stereo viewing.** Charles Leek[1] (e.c.leek@bangor.ac.uk), Stephen Johnston[2], Filipe Cristino[1]; [1]School of Psychology, Bangor University, Bangor, UK, [2]School of Psychology, Swansea University, Swansea, UK

The recognition of 3D object shape is a fundamental issue in vision science. Although our knowledge has advanced considerably, most prior studies have been restricted to 2D stimulus presentation that ignores stereo disparity. In previous work we have shown how analyses of eye movement patterns can be used to elucidate the kinds of shape information that support the recognition of multi-part 3D objects (e.g., Davitt et al., JEP: HPP, 2014, 40, 451-456). Here we extend that work using a novel technique for the 3D mapping, and analyses, of eye movement patterns under conditions of stereo viewing. Eye movements were recorded while observers learned sets of surface-rendered multi-part novel objects, and during a subsequent recognition memory task in which they discriminated trained from untrained objects at different depth rotations. The tasks were performed binocularly with or without stereo disparity. Eye movements were mapped onto the underlying 3D object mesh using a ray tracing technique and a common reference frame between the eye tracker and 3D modelling environment. This allowed us to extrapolate the recorded screen coordinates for fixations from the eye tracker onto the 3D structure of the stereo-viewed objects. For the analysis we computed models of the spatial distributions of 3D surface curvature convexity, concavity and low-level image saliency. We then compared (fixation) data – model correspondences using ROC curves. Observers were faster and more accurate when viewing objects with stereo disparity. The spatial distributions of fixations were best accounted for by the 3D surface concavity model. The results support the hypothesis that stereo disparity facilities recognition, and that surface curvature minima play a key role in the recognition of 3D shape. More broadly, the novel techniques outlined for mapping eye movement patterns in 3D space should be of interest to vision researchers in a variety of domains.

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26.3043 **Structural, not spectral, representation of shape in lateral occipital complex** Haluk Tokgozoglu[1] (htokgoz1@jhu.edu), Anthony Sali[2], Brian Anderson[2], Steven Yantis[2], Charles Connor[3]; [1]Department of Computer Science, Johns Hopkins University, [2]Department of Psychological and Brain Sciences, Johns Hopkins University, [3]Solomon H. Snyder Department of Neuroscience, Johns Hopkins University, Zanvyl Krieger Mind/Brain Institute

Neural recording studies in monkeys have shown that shape representation in high-level ventral pathway cortex (including inferotemporal cortex or IT) is structural: ensembles of neurons encode shapes as spatial configurations of structural fragments. The putative homologue for IT in the human brain is the lateral occipital complex (LOC), which is defined by differential responses to intact and scrambled object photographs. Here, we used fMRI to test whether shape representation in human LOC is similarly structural, or is better explained by spatial frequency tuning, which has been the standard quantitative model for shape sensitivity in human cortex. Our stimuli were letter-like combinations of medial axis fragments (straight and curved line segments). Stimuli were presented in random order while subjects performed a one-back shape-matching task. We used a generalized linear model (GLM) to estimate the response pattern of each LOC voxel across stimuli. We parameterized the stimuli as combinations of medial axis fragments, defined by their curvatures, orientations, and object-relative positions. For each voxel, we used stepwise regression to fit a structural tuning model that explained stimulus responses in terms of sensitivity to component fragments. Model complexity was limited to components that explained at least 5% additional variance. Typical models comprised 3–6 components and explained 45–65% of the response variance across stimuli. In contrast, comparable spectral models, based on components from a Gabor wavelet pyramid decomposition of the stimuli, typically explained only 5–15% of the response variance. The explanatory power of the structural models suggests that LOC represents shapes as configurations of structural components. These results also support the homology between human LOC and monkey IT, where neural mechanisms of shape coding can be studied in detail.

26.3044 **Feature fragments and evidence accumulation in object and face perception** Maxim Bushmakin[1,2] (mbushmak@indiana.edu), Thomas James[1,2]; [1]Department of Psychological and Brain Sciences, Indiana University, [2]Cognitive Science Program, Indiana University

Recognition and identification of objects is ubiquitous in the daily lives of human beings, yet despite its importance we still do not understand how visual information arriving at the retina is processed by the human visual cortex (and the rest of the brain) in such a fast and flexible manner. There is a large body of neurophysiological work with non-human primates showing that certain neurons in the posterior and middle regions of the inferior temporal gyrus (area TE) respond preferentially to specific features of objects. Further studies exploring the brain's response to a large set of objects decomposed into simpler shapes led a number of researchers to suggest that part of TE was organized in column-like structures with all neurons in a column having preferential tuning for specific shapes. Assuming that object features are presented similarly in humans, the current study aimed to discover the features of objects and faces that produce the fastest and most accurate categorization responses. Participants viewed many single fragments selected from random locations in images of a set of objects and attempted to classify the fragment based on object category. Accuracy and reaction time measures were analyzed using a sequential sampling framework, specifically Drift Diffusion and Linear Ballistic Accumulator models (Brown & Heathcote, 2008; Ratcliff & Rouder, 1998). Modeling results showed that the variability in reaction times across features was accounted by the rate of perceptual evidence accumulation, which is dependent on the amount of information in the fragment. The current study represents a fundamental step toward evaluating the functional organization of the human ventral visual stream within a feature-based theoretical framework.

26.3045 **Correlating Beauty and Two Measures of Pleasure** Lauren Vale[1] (lauren.vale@nyu.edu), Gernot Gerger[2], Helmut Leder[2], Denis Pelli[1]; [1]Psychology Dept. and Center for Neural Science, New York University, [2]Faculty of Psychology, University of Vienna

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When you look at your beauty and I look at mine, do we have the same feeling? Kant (1764) and Santayana (1896) say that the experience of beauty is pleasure, with qualifications. So we measure pleasure. Observers use Google Images to find an image that is beautiful to them. The observer is asked to look at that image and rate pleasure by continually adjusting the spread of two fingers to track the decaying pleasure they feel from the image. We record both the finger spread rating (on smartphone screen using our emotiontracker.net) and facial muscle activity (fEMG, facial electromyography of M. corrugator supercilii and M. zygomaticus major). We find a high correlation between the feeling of beauty (or liking) and fEMG and finger-rating responses. The rating correlation is 80% until 90 s after stimulus offset. This consistent finding across observers suggests that the two physiological responses, one overt and the other automatic, both track the pleasure of beauty.

26.3046 Is the Visual System Tuned to Perceive Ratios in Bodies?

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Men reportedly have a strong preference for women's bodies with a waist-to-hip ratio (WHR) of 0.70. Based on the well-established relationship between women's WHR and fecundity, this preference has been interpreted to reflect sensitivity of the human visual system to perceive a physical signal of fertility and mate potential. However, the bulk of research supporting this claim did not use ecologically valid stimuli nor systematically vary the WHR within the normal range in the population, which is between 0.67-0.80 for adult fertile women. Here, we hypothesized that if the WHR is truly a visual signal used to identify potential fertile partners, men should be able to detect differences in WHR within this normal range in realistic female bodies. Furthermore, given that a woman's WHR decreases by approximately .01-.015 during the luteal phase of the menstrual cycle, men might also be able to identify such minute changes in WHR. To address these questions, exclusively heterosexual young men and women performed a preference task and a visual discrimination task on images of a woman's body and pairs of parallel line stimuli. The WHR and ratio between line stimuli systematically varied by .01 from .66-.90. Men and women participants exhibited different patterns of preferences for the body, but not line, stimuli. In contrast to previous findings, men preferred a wider range of WHRs between 0.66-0.82. Women had much sharper preferences that were focused on WHRs between 0.66-0.71. Men and women both had great difficulty discriminating ratios at the fine-grained level in the discrimination task; however, they were more accurate at detecting these differences in WHRs than in ratios between line stimuli. These findings indicate that the visual system may be biased to detect minute variations in ratios within bodies, like it does within faces, which may provide important social information about conspecifics.

26.3047 Holistic Processing of Body Postures

Catherine Reed[1] (clreed@cmc.edu), Daivik Vyas[1], Alison Harris[1]; [1]Claremont McKenna College

Although research supports the idea that faces are processed holistically, less evidence exists for the holistic processing of bodies. The body has more degrees of freedom, making it a challenge to distinguish between holistic and configural processing via traditional tests of holistic processing (e.g., the composite effect). Here, we test for the holistic processing of body postures using a stereoscopic manipulation to create either the percept of a whole body occluded by a set of bars or segments of body floating in front of a background. Despite having identical low-level properties, only the first stimulus is perceived holistically due to filling-in via amodal completion. These stimuli were presented in a modified version of the whole-versus-part superiority paradigm (Tanaka & Farah, 1993) in which subjects were asked to identify body parts either in isolation or within the context of a body. In line with previous results for faces, our current data suggest that recognition performance was better for body parts in the whole-body condition, relative to isolated parts and for conditions where the body was perceived to be whole behind the bars. Additionally, it appears that the whole-part difference is greater for stereoscopic conditions where the body is perceived to be intact behind the bars rather than as floating body segments. These findings support the idea that bodies, like faces, can be processed in a holistic manner, laying the groundwork for further research using this paradigm.

26.3048 Relationships between eating disorder tendency and body imaged-related size perception

Moe Nagahata[1], Miki Onoda[2], Eiichi Mito[2], Masamitsu Harasawa[3], Hiroshi Ishikane[1,2]; [1]Graduate School of the Humanities, Senshu University, [2]Department of Psychology, Senshu University, [3]Science & Technology Research Laboratories, Japan Broadcasting Corporation

The excessive concern for body shape is considered as one of the most powerful risk factor for eating disorders (EDs). Previous studies reported that patients with EDs showed body image disturbance and speculated that the disturbance might be derived from distorted visual perception or visual memory of body images. It has been suggested that patients with EDs overestimated their own body in visual memory. However, it is not clear whether the tendency of EDs affects the perception of human body. We investigated the relationships between ED tendency and characteristics of body image-related size perception. Undergraduate female students participated in the experiment. The participants were divided into two groups by their ED tendency using the subscale of Eating Disorder Inventory-91 (EDI-91). They were asked to adjust the length of the horizontal line segments of the standard stimulus to fit to the length of comparison stimuli, the horizontal line segments which were superimposed on a human body pictures or a rectangular. The comparison stimulus and the standard stimulus were simultaneously presented on a LCD side by side. The comparison line segments were positioned over the waist of body picture or the center of the rectangle. Three types of body pictures were used; underweight, normal weight and class-2 obesity. The ratio of the reported length of the comparison stimulus to the standard stimulus was analyzed using mixed repeated measures ANOVA. The results showed that 1) all participants overestimated the length of the line segment superimposed on the human body pictures against to the line segments over the rectangles, 2) participants with higher EDI-91 score perceived the line segments over the obese body picture longer than participants with lower EDI-91 scores did. These results suggest that ED tendency should affect body picture perception.

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26.3049 Gun-Embodiment Biases on Object Perception are Unaffected by Prior Experience

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Object perception is influenced by a number of non-visual factors. One factor relates to embodied cognition: objects are more likely to be identified as the object held and used to respond. For example, observers are more biased to see guns when they also hold and respond with a gun than when they respond with a neutral object. In the current experiments, we tested whether prior experience with guns modifies this gun-embodiment bias. Gun owners and video game players participated in the experiments. Gun owners were just as biased as novices to perceive guns as present, and the bias was similar regardless of whether a real gun or a toy gun was used. Video game players, on the other hand, only showed the bias when they responded with a real gun but not with a toy gun. The results suggest that the same object can be embodied in different ways. However, once the object is embodied, its influence on object perception is stable and fixed, rather than flexible and malleable.

Acknowledgement: National Science Foundation

Color and light: Neural mechanisms

Saturday, May 16, 2:45 - 6:45 pm
Poster Session, Pavilion

26.4001 Hyperspectral Evolution of Trichromatic Response Filters

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Anatomical and perceptual findings suggest that color perception is a skill shared among the vast majority of organisms with advanced visual systems. Animals who possess it tend to exhibit better performance in a wide array of high and low level visual tasks such as segmentation and object identification. While most vertebra possess only dichromatic vision, humans and several other higher primates are trichromatic. The advantages of trichromatic vision have been studied extensively across a variety of tasks, and are quite apparent while comparing average trichromatic humans to their dichromatic "color-blind" counterparts. Such studies often focus on the performance gains trichromatic vision provides for tasks such as foraging, distinguishing between edible and non-edible plants, and even social interaction (where differentiation between different shades of skin pigmentation is advantageous). These studies may then proceed to claim that the spectral tuning of primate retinal pigments has evolved in order to optimally perform such tasks. Although studies indicate that small mutations in the genes encoding retinal pigments may produce large shifts in their peak response frequency - the retinal pigments of many higher primates share similar spectral sensitivities, despite environmental and behavioral differences between them. Therefore we examine the hypothesis that these pigments evolved to optimize a more general tasks, namely differentiating between spectra, rather than excel in a particular visual task. In this study standard evolutionary computation methods are employed over a large data-set of real-world spectral samples to discover optimal trichromatic filters for spectral differentiation. When simple, naturally plausible, constraints are applied (such as smoothness or an approximately Gaussian response curve) we find that human-like response profiles emerge naturally as optimal detectors. This strongly suggests that human and primate cone pigments are not only tuned to excel in specific visual tasks but rather are evolutionary optimized for differentiation between commonly occurring natural spectra.

26.4002 How does the neural retina process optical blur? Insights from emmetropization.

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Introduction Optical blur is potentially important for visual perception, but how the retina processes blur remains unclear. We know from studies of emmetropization (where a postnatal eye normally adjusts its growth to achieve good focus) that the retina detects both the presence and sign of blur (hyperopic defocus: eye too short, myopic defocus: eye too long), and that it can do this independently of the rest of the central nervous system. What optical cues does it use? The retina could use longitudinal chromatic aberration (LCA), but the sparsity of short wavelength-sensitive ("blue") cones should make it impossible for the retina to use spatial resolution to determine the degree to which blue images are in focus. We propose that the retina uses the temporal flicker in blue as an animal moves itself and its eyes as a proxy for image sharpness. Methods Four groups (n=3 per group) of tree shrews (a diurnal cone dominated mammal closely related to primates) were exposed binocularly to either steady or flickering red (628nm) or blue (464nm) light for 14 hours a day from 11 to 25 days after eye opening. The pattern of flicker approximated the natural temporal pattern on the back of the retina as an animal moves both its eyes and itself. Results Compared with normal eyes, both steady (+3.8D) and flickering red light (+6.4D) powerfully arrested eye growth. Flickering blue light produced significant myopia (–4.5D), but steady blue light was much less myopiagenic (–0.9D). Conclusion These results are consistent with the neural retina using LCA to regulate eye growth during development, and with temporal flicker being used as a proxy for spatial image focus for blue light. Does the retina shares this information with the brain via retinal ganglion cells?

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26.4003 Cortical Responses to Real and Illusory Surface Colors

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In addition to the dominant wavelength of light reflecting off an object, our brain uses other visual cues to assign color to surfaces in the visual field. For example, boundaries of an area provide contextual clues to an object's color. Simply outlining the shape of an object on a piece of paper can produce a strong figure ground effect, delineating the enclosed area as the figure and outside area as the background. Furthermore, a strong illusory color can be seen when an area is outlined twice with two adjacent and differently colored lines. Under certain conditions, the enclosed region can adopt a hue similar to that of the inner line while the background often adopts a complimentary color. This illusion has come to be known as the watercolor effect by vision scientists. We have studied this illusion using the visual evoked potential and compared the electrical recordings to behavioral responses. By exchanging an image of the illusion with an image of a control stimulus at a rate of 4 Hz, a large 2 Hz response is elicited concurrent with the appearance of the induced color during every other image presentation. When two control conditions are exchanged, only a large 4Hz component is present. However when physical color is inserted into one of the controls, a measurable 2Hz component is produced. It remains to be determined which cortical areas in the color processing stream respond to the illusory color and in what order (e.g. feedback vs. feed forward). Consequently, we are currently using high density EEG to look at cortical activation, comparing activation elicited by illusory colors with activation elicited by real colors. In these studies, we are attempting to characterize the temporal and spatial distribution of the neurological basis for the sensation of induced color.

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26.4004 fMRI activation of LGN and visual cortex under photopic, mesopic and scotopic luminance levels

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We investigated whether the fMRI BOLD response in the visual pathway depends on the light adaptation level. Twelve normal-sighted participants (4 males, 8 females; age 21-41 years) with functional magnetic resonance imaging (fMRI) were measured under scotopic, mesopic and photopic luminance levels. The visual stimulation consisted of a 30-degree radial checkerboard stimulus flickering at 8 Hz. The stimuli were presented in a block design (12 s stimulation, 12 s baseline). Photopic, mesopic and scotopic luminance levels were achieved by applying 2 to 6 neutral density filters (transmission 13%) resulting in a maximal luminance of 43 (photopic), 0.73 (mesopic) or 0.01 (scotopic) cd/m2, respectively. Dark-adapted subjects reported a Purkinje-shift in perceived colors under mesopic conditions and the total absence of color perception under scotopic conditions. fMRI measurements were conducted using a 3T scanner (Siemens Allegra). Functional images were acquired with a T2*-weighted gradient echo planar imaging sequence (TR=2s, TE=30 ms, FA=90°) consisting of 34 transverse slices (voxel size = 2.5 x 2.5 x 2.5 mm; FoV=160 x 160 mm). Data analysis was performed with SPM8. Images were normalized to the Thalamus Atlas (Krauth et al., 2010, Neuroimage, 49, 2053-2062). ROI-analysis was conducted on the atlas-based magno (M) - and parvocellular (P) voxels of the LGN. A 2 (hemispheres) x 3 (luminance levels) x 2 (M/P ROIs) repeated-measurements ANOVA was conducted on the percent signal changes in the BOLD signal for the LGN. Results show a significant main effect of luminance level (decreasing BOLD response with decreasing luminance; $p < .001$) and a significant interaction between luminance condition and ROI (M/P; $p = .001$). In agreement with an earlier study (Hadjikhani & Tootell, 2000, Human Brain Mapping, 9, 55–63), in retinotopically defined V1 we found no activation in the projection zone of the fovea for the scotopic luminance level.

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26.4005 Chromatic visual evoked potentials using customized color space

John Erik Vanston[1] (jvanston1206@gmail.com), Michael Crognale[1]; [1]Psychology Department, University of Nevada - Reno

Chromatic visual evoked potential (cVEPs) and psychophysics are often used to characterize isolated color or cone-opponent systems for various purposes. Retinal inhomogeneities across the visual field can introduce color shifts and luminance artifacts to uniform, large-field stimuli. It may be useful, therefore, to design customized stimuli that correct for the retinal inhomogeneities of observers. We created large-field stimuli equated across the visual field for luminance and hue shifts using psychophysical methods. We also evaluated the effects of applying corrected stimuli on the waveform of the cVEP. Five subjects viewed full-field onset stimuli. Stimuli comprised a field of gabor patches composed of colors modulated along nominal LM- and S-axes; in some conditions, colors of the gabor patches were customized using psychophysical settings made by the observer, such that axis contrasts were perceptually equated by suprathreshold contrast matching, and individuals' tritan axes were determined using the minimally distinct border technique. Stimuli were equated for luminance by flicker photometry. Isoluminance and tritan directions were determined across five levels of retinal eccentricity, including foveal and extrafoveal regions. cVEPs were recorded using both nominal and customized stimuli. Equating stimuli for perceptual salience and adjusting S-axis stimuli to modulate along an individual's tritan axis did not have a strong effect on the waveform of the chromatic VEP. Compared to responses using normal tritan stimuli, responses for "individual" tritan stimuli differed little in latency and only moderately in amplitude. Nonetheless, waveforms for both types of S-cone stimuli were different from those of LM-cone stimuli in latency and amplitude. Many psychophysical techniques (e.g. threshold measurement) are sensitive to small changes in luminance and chromaticity and would benefit from utilizing an observer-specific color space and stimuli adjusted for retinal inhomogeneity. However, the cVEP appears to be robust to retinal inhomogeneity, likely due in part to cortical magnification.

26.4006 The psychophysicist's microscope: weak stimuli reveal neuron-like response properties

Alan Freeman[1], Gloria Luo-Li[1], David Alais[2]; [1]School of Medical Sciences, University of Sydney, [2]School of Psychology, University of Sydney

Aims. 1. The visual contrast-response function in human subjects typically has low gradient at low contrast. This is inconsistent with signal detection theory, and we therefore aimed to measure precisely the contrast-response

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function at low contrast. 2. Recently published work shows that light decrements are detected sooner than increments. We aimed to see whether this observation held at low contrast. Methods. Visually normal adult humans were briefly presented with horizontal grating patches. The gratings were raised-cosine in form so that each presentation provided either an increment or decrement in luminance. Either the left or right half of the grating patch was shown and subjects indicated which half had been shown. Stimuli were randomly timed, and response correctness and reaction time were recorded. Results. There was a small range of contrasts, centred on zero, at which contrast sensitivity was indistinguishable from zero. Neurons in primary visual cortex have a resting membrane potential well below threshold (Tan et al., Nature, 509, 226): we propose that the contrast sensitivity plateau indicates the minimum contrast required to depolarise these neurons to threshold. Further, reaction times at low contrast were about 50 ms shorter for contrast decrements than for increments. This corresponds well with recently published work showing that off-dominated cortical neurons have shorter latencies to decrements than do on-dominated neurons to increments (Komban et al., Neuron, 82, 224). Conclusion. Low-contrast measurements reveal behaviour that appears to reflect the properties of single neurons in primary visual cortex.

26.4007 **Comparison of fMRI measurements in LGN and Primary Visual cortex with visual deficits in Glaucoma** Sophie Wuerger[1] (s.m.wuerger@liverpool.ac.uk), Joanne Powell[1], Anshoo Chaudhoury [1], Laura Parkes[2]; [1]University of Liverpool, [2]University of Manchester

Experimental primate glaucoma demonstrates that the retinal ganglion cell (RGC) loss is associated with atrophies in the lateral geniculate nucleus (LGN) and the primary visual cortex (V1). The purpose of our study was to determine whether, in glaucoma patients, selective behavioural deficits in the three main visual pathways (magnocellular, parvocellular, koniocellular) are associated with selective changes in the neural activity in LGN and V1. A POAG group (n=20) and a matched control group (n=20) were examined using the following tests: Visual field loss was assessed using standard automated perimetry (SAP); the Cambridge Colour Vision test (CCT) was used to assess colour deficiencies; visual thresholds along the three cardinal directions of colour space were measured (achromatic; red-greenish; lime-violet). For a subset of the participants (n=9 in either groups), functional Magnetic Resonance Imaging (fMRI) was used to obtain BOLD signals in the LGN and V1 in response to supra-threshold modulations along these three cardinal directions. We report the following results: (1) There are significant visual threshold differences between patients with Glaucoma and controls, in particular along the yellowish-violet (YV) cardinal direction. (2) The average BOLD signal in primary visual cortex (V1) is lower in the Glaucoma group compared to the control group. High thresholds along the yellowish-violet colour direction are associated with low V1 activity. (3) In contrast, the BOLD signal in the LGN is higher in Glaucoma patients compared to the controls. Within the Glaucoma group, more severe visual field defects are associated with higher LGN activity. In conclusion and contrary to our expectations, the LGN signal is increased in glaucoma patients compared to the controls. We speculate that this may reflect feedback from primary visual cortex.

Acknowledgement: UK & EIRE Glaucoma Society

26.4008 **Binocularly matched luminance contrast reduces sensitivity to between-eye but not within-eye differences in hue and saturation** Ben Jennings[1] (ben.jennings@mcgill.ca), Frederick Kingdom[1]; [1]Mcgill Vision Research, Department of Ophthalmology, McGill University

Detection of between-eye differences in both hue and chromatic contrast (saturation) were measured using dichoptically superimposed colour patches. Sensitivity was found to be highest at isoluminance and decreased with the addition of task-irrelevant spatially contiguous binocular (i.e. same in both eyes) luminance contrast. However, when the members of each dichoptic pair were presented side-by-side on the screen and thus both viewed with the same eye, the luminance contrast had no effect on the detection of their differences. If the effect of the luminance contrast was simply to dilute, or 'desaturate' the chromatic signals we would expect thresholds to increase for the within-eye as well as the between-eye (dichoptic) conditions. We suggest that binocular luminance contrast reduces the interocular suppression between dichoptic colours, causing the dichoptic colours to blend and as a result render their differences harder to detect. Our hypothesis is that binocularly matched luminance contrast promotes the interpretation that disparate colours are nevertheless part of the same object, and we term this the "object commonality hypothesis".

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26.4009 **Independence of color and shape processing in the ventral visual pathway of humans and macaques** Rosa Lafer-Sousa[1,2] (rlaferso@mit.edu), Nancy Kanwisher[1,3], Bevil Conway[1,2,3]; [1]Brain and Cognitive Science Department, MIT, [2]Neuroscience Program, Wellesley College, [3]McGovern Institute for Brain Research

To what extent are color and shape processed independently of each other in the ventral visual pathway? Color is sometimes assumed to be just another stimulus feature for object recognition. On this view, there is a computational advantage to multiplexing color and shape processing. But the importance of color can sometimes be distinguished from shape: color signals a person's emotional state, independent of face features; similarly, color provides independent information about fruit's edibility (bananas ripen, green to yellow, without changing shape). We asked whether distinct regions are sensitive to color and shape by scanning 13 humans and 2 rhesus monkeys with fMRI while they viewed full-color or achromatic movie clips of faces, objects, scenes, bodies, or scrambled objects. We defined color, face, place, and shape-selective regions within each subject, and measured the response magnitude of each region to the ten conditions in independently acquired data. We confirmed the existence of three color-biased regions in humans, and determined that none of these regions showed an interaction of color preference with stimulus category; moreover, two of the color-biased regions showed no higher response to intact versus scrambled objects, suggesting these regions code color independent of shape or stimulus category. Furthermore, shape-biased cortex (LO) did not show a bias for colored objects, providing a double dissociation of color and shape processing. Consistent with our previous report on responses to static stimuli in monkeys, a preliminary analysis of monkey data obtained using movie clips suggests that color-biased regions in inferior temporal cortex (IT) are no more responsive to intact than scrambled shapes, and that IT shape-selective regions are less sensitive to color compared to the color-biased regions. Taken together, these data support a dissociation of color and shape processing at certain stages of the visual-processing hierarchy in both humans and monkeys.

Acknowledgement: NIH, NSF, Whitehall Foundation

26.4010 **Selective noise masking of L and M cone stimuli: unipolar tests reveal theoretically significant asymmetries** Timothy Shepard[1] (timmyshepard@gmail.com), Rhea Eskew Jr.[1], Comfrey McCarthy[1], Nicole Ochandarena[1]; [1]Psychology, Northeastern University

In an important study, Hansen & Gegenfurtner (2013) showed that chromatic masking noise placed near the corners of detection contours in the $\Delta L/L$, $\Delta M/M$ plane of cone contrast color space can produce selective masking. Rather than being indicative of the existence of large numbers of mechanisms, as they suggested, we (Eskew & Shepard, 2013) demonstrated that this result could be accounted for by a model with a very limited number of mechanisms. Both studies used bipolar test stimuli that contain equal and opposite chromatic contrasts. The symmetry of such stimuli enforces symmetry on the threshold contour and the model fit that can obscure the presence of asymmetric mechanisms—ones that do not form pairs with equal and opposite cone weights. Unipolar mechanisms like this can act as if there were more mechanisms than actually exist, since different mechanisms can detect the two poles of bipolar stimuli independently (Eskew, 2009). Here, for the first time, we report that detection contours for unipolar stimuli in the LM plane may be asymmetric when masking noise is added near the corners of the detection contour. Thresholds for stimuli comprised of nearly equal L and M increments are, for almost all observers, higher than the thresholds for the corresponding stimuli comprised of nearly equal L and M decrements. There are also differences in the cone contrast weights for the R and G mechanisms (responsible for the long flanks of the detection contour), differences that predict selective masking, as we previously reported, without requiring large numbers of mechanisms. A plausible physiological reason for these asymmetries will be discussed. A very limited number (4 to 6) of unipolar, asymmetric mechanisms may be able to account for all the bipolar and unipolar test detection contours.

26.4011 **Treating Color Vision as a Sensory Integration Problem: Application of Nonlinear Integration and Amplification Mechanisms to Chromatic Brightness and Yellowness** Vincent Billock[1] (billock.3@osu.edu); [1]College of Optometry, Ohio State University

Saturday PM

Information integration occurs at every sensory level and some distinctions between levels seem arbitrary. For example, rattlesnakes have two separate visual systems, one for optical information transduced by photoreceptors and one for infrared stimuli transduced by heat-gated trigeminal neurons. This is traditionally a sensory integration problem and I've modeled it as a binding problem (Billock & Tsou, JCNS, 2014), but how is integration of visible and infrared light really different from integration of wavelength selective mechanisms in human color vision? This idea is explored by applying neural synchronization and amplification models (developed for visual/infrared integration in rattlesnake and visual/auditory interactions in cat) to understand broadening and amplification of spectral sensitivity in chromatic brightness and yellowness. Nonlinear interactions in these models amplify weak sensory signals much more than strong signals – in sensory integration this is the famous Principle of Inverse Enhancement. Chromatic Brightness: Chromatic brightness is broader in spectral sensitivity than luminance and is generally modeled as a nonlinear combination (e.g., a vector sum) of hue and luminance, but this is problematic on neural grounds. Alternatively, chromatic brightness spectral sensitivity modeled as a nonlinear amplification of luminance conforms better to sensory integration's Principle of Inverse Enhancement than do most sensory integration data! Yellowness: The spectral sensitivity of the yellow lobe of the y-b hue opponent channel is not a linear transformation of cone spectral sensitivities, but usually shows a nonlinear amplification of L-cone signals when M-cone signals are present, often manifesting as a strong spike of sensitivity near 570 nm. I modeled this amplification by substituting L+M- and M+L- neurons for the visual and auditory inputs in Billock & Tsou's (JCNS, 2014) sensory integration model. The model creates a spectral sensitivity spike near 570 nm that is strongly dependent on stimulus intensity, a prediction suitable for psychophysical testing.

26.4012 **Correlation between chromatic sensitivity and higher order color vision functions in Asperger Syndrome but not in high functioning autism**

Elaine Zachi[1] (elainez@usp.br), Thiago Costa[1,2], Mirella Barboni[1], Dora Ventura[1]; [1]Experimental Psychology Department, Institute of Psychology, Sao Paulo University, Sao Paulo – Brazil, [2]Cognitive Neuroscience Laboratory and Developmental Disorders Program, Center for Health and Biological Sciences, Mackenzie Presbyterian University, Sao Paulo – Brazil

The assumption that Asperger Syndrome (AS) and high functioning autism (HFA) are quantitative manifestations of the same disorder today remains somewhat controversial. The purpose of this study was to examine possible correlations between chromatic sensitivity and visual perception/memory for complex detailed colored stimuli in AS and HFA patients and controls. Ten patients with AS, 9 patients with HFA, and 12 controls were tested. The participants were 6 to 19 years old and had normal or above-average intelligence according to the Raven Matrices Test. University's hospital psychiatrists made the diagnosis based on DSM-IV criteria. Short-term memory for colored stimuli was assessed with the Delayed Matching to Sample test (DMS) from the CANTAB battery. Color discrimination was measured using the Cambridge Colour Test (CCT). AS participants performed significantly better than the other groups in delayed perceptual matching (Kruskal-Wallis ANOVA, $p < 0.05$). Higher DMS total scores were significantly correlated with lower thresholds for protan ($r_S = -0.75$), deutan ($r_S = -0.86$), and tritan ($r_S = -0.81$) axes and with narrow areas of the MacAdam ellipses ($r_S = -0.89$) among patients with AS. Correlations between CCT values and DMS scores were not statistically significant for HFA participants and controls. Color vision losses (defined according to previous data from our Laboratory - Ventura et al., 2003) were found in 20% (2/10) of the patients with AS and in 44% (4/9) of the HFA group. Chromatic sensitivity seemed to influence the performance in a task that integrates color vision discrimination and complex processes including perception and memory in the AS group. The results corroborate the superior detailed information processing in Asperger Syndrome. This study supports a different profile of interaction between sensory and high-order cortical functions in AS and HFA.

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Binocular Vision: Mechanisms of binocular interaction

Saturday, May 16, 2:45 - 6:45 pm
Poster Session, Pavilion

26.4013 **Interocular contrast gain control plus monocular luminance gain control can explain binocular luminance summation**

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Interocular contrast gain-control (interocular-CG) was first used to model binocular phase combination (Ding & Sperling 2006), and later modified to explain both phase and contrast combination in binocular vision (Huang et al 2010, Ding et al 2013). In the present study, we demonstrate that, by adding monocular luminance gain-control (monocular-LG), the interocular-CG model can also explain binocular luminance summation. Luminance disks were used as stimuli. The target luminance was either increased by 1, 2, 4, 8, 16 cd/m2 against a darker background (0, 2, 4, 8, 16 cd/m2) or decreased against a lighter background (4, 8, 16 cd/m2). Experimental trials consisted of two stimulus intervals, one with a standard luminance which was identical in the two eyes, and the other with a test luminance presented to both eyes. The interocular ratio of the test luminance varied from trial to trial. The observer's task was to judge which interval had the higher luminance increment or decrement. Consistent with previous studies, we found that binocular luminance summation behaves very differently depending on the background luminance. Fechner's paradox was observed on the equal-luminance-increment contour with the dark background (0 cd/m2), while an apparent winner-take-all phenomenon was observed on both increment- and decrement-contours with the light background (16 cd/m2). Using one set of model parameters, 3 parameters for monocular-LG and 3 parameters for interocular-CG, the combined model provides a unified explanation of binocular combination of both luminance increments and decrements over a large range of luminance input (reduced-chi-square = 2.35). Combined with previous studies on phase (Ding & Sperling 2006), contrast matching (Huang et al 2010, Ding et al 2013), contrast discrimination (Ding et al 2013), stereovision (Hou et al 2013), and second-order stimuli (Zhou et al 2014), we conclude that the interocular-CG can provide a unified explanation of binocular combination for multiple binocular tasks.

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26.4014 **Luminance contrast thresholds in patients with amblyopia under monocular and dichoptic viewing**

Goro Maehara[1] (goro@kanagawa-u.ac.jp), Benjamin Thompson[2], Behzad Mansouri[3], Reza Farivar[4], Robert Hess[4]; [1]Kanagawa University, [2]University of Waterloo, [3]University of Manitoba, [4]McGill University

Purpose: We investigated whether simply opening the fellow eye triggers suppression of the amblyopic eye or whether stimulation of the fellow fixing eye is required for suppression. Methods: We measured luminance contrast thresholds either for the amblyopic eye or fellow fixing eye using a haploscope. A square frame was presented to each eye to aid binocular fusion. In experiment 1, two gratings appeared within diagonal quadrants (e.g. top-left and bottom-right) of one eye. The other eye was either occluded with an eye patch or viewed a black background. In experiment 2, two gratings appeared within the diagonal quadrants of one eye and another two gratings were shown to the opposite quadrants of the other eye. One pair of gratings were the targets to detect and the other pair were dichoptic maskers. Results and Discussion: A two-way ANOVA with factors of eye and patching was conducted on the thresholds from experiment 1. Although thresholds were significantly higher for the amblyopic eye than for the fellow fixing eye, the difference was relatively small. This could be due to the low spatial frequency of the gratings. The effect of patching and the interaction were not significant. That is, thresholds for the amblyopic eye were only minimally elevated when the eye patch was removed from the fellow fixing eye. On the other hand, the patients exhibited much higher thresholds when the dichoptic masker gratings were presented in experiment 2. These results suggest that just opening both eyes is not sufficient to elicit strong suppression of the amblyopic eye and that dichoptic stimulation is required to trigger suppression. Furthermore, the suppression was not confined to the quadrants that contained the masks but extended to the quadrants containing the targets. This suggests the presence of long-range suppressive interactions within the amblyopic visual cortex.

 See page 3 for Abstract Numbering System

26.4015 **Patterns of suppression mapping for strabismic and micro-strabismic observers.** Akash Chima[1] (akash.chima@anglia.ac.uk), Sarah Waugh[1], Monika Formankiewicz[1]; [1]Anglia Ruskin University

Strabismic amblyopes experience constant interocular suppression during habitual binocular viewing to avoid diplopia and confusion. We measured depth and extent of suppression across the visual field of strabismic and micro-strabismic observers using luminance-modulated (LM) and contrast-modulated (CM) noise stimuli. LM and CM noise ring stimuli extended across 24 deg of the visual field. Nine strabismic observers made forced-choice judgements about the strength of a dichoptically presented sector that was positioned systematically around the rings within the stimulus field. Suppression for both LM and CM stimuli was assessed as CM stimuli have revealed greater depths of suppression in normal eyes with inter-ocular blur differences and may be more sensitive to true binocular disruption, such as in strabismus. Both strabismics and micro-strabismics showed deeper suppression for CM than LM stimuli ($p< 0.05$). Suppression was central or combined with a broader horizontal hemispheric asymmetry, depending on the stimulus used. A significant positive correlation was found between amblyopia (inter-ocular visual acuity difference) and suppression depth ($r\sim+0.70$); stereo-acuity level and suppression depth were negatively correlated ($r\sim-0.85$). Unlike inter-ocular blur suppression, the mapping procedure in strabismic observers revealed more localised regions of suppression, indicating selective suppression mechanisms. CM stimuli revealed greater levels of suppression than did LM stimuli in observers with degraded binocularity. Suppression can therefore be more sensitively measured and monitored by combining stimulus types during diagnosis and treatment of amblyopia.

26.4016 **The effects of eccentricity and separation on interocular positional judgements in amblyopia** Zahra Hussain[1] (zahra.hussain@nottingham.ac.uk), Ben Webb[1], Paul McGraw[1]; [1]Psychology, University of Nottingham

Positional judgements are distorted in the central and peripheral visual field of amblyopic subjects. We have previously shown that bisection and alignment of spatially separated targets is more impaired near the fovea than in the periphery. Here, we examined whether the pronounced central deficit is due to foveal presentation per se, or due to the smaller separation of targets at smaller eccentricities. Observers performed a two-dimensional free-localization task along three axes (diagonal, horizontal and vertical). Each positional judgement comprised simultaneous bisection and alignment of a comparison stimulus relative to a target stimulus, using the central fixation cross as a reference. Target eccentricity (1 - 7 deg) and target-comparison separation (0.76 - 13 deg) were varied independently. The stimuli were broadband dots viewed dichoptically and the fixation cross was viewed by both eyes. Visually normal and amblyopic observers were tested. We calculated the precision (standard deviation) and bias (mean displacement) of responses as a measure of performance in all conditions. For normal observers, performance declined with eccentricity, and showed a modest dependence on stimulus separation at each eccentricity. Conversely, amblyopic observers showed a larger dependence on stimulus separation than on eccentricity: Although performance of amblyopes was poorer in the central visual field compared to the periphery (consistent with previous findings), performance was disproportionately worse at small stimulus separations at all eccentricities. These results suggest the presence of interocular interference for spatially proximal stimuli throughout the near-peripheral visual field in amblyopia. The strength of interocular suppression in amblyopia may depend less on visual field position than on the distance between competing stimuli viewed by both eyes.

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26.4017 **Age-related changes in accommodation predict perceptual tolerance to vergence-accommodation conflicts in stereo displays** Simon Watt[1] (s.watt@bangor.ac.uk), Louise Ryan[1]; [1]School of Psychology, Bangor University, Wales, UK

Conventional stereoscopic imagery presents conflicting stimuli to vergence and accommodation. With sufficient conflict, vergence-accommodation coupling causes inaccurate responses in one or both systems, impairing stereoscopic depth perception, or preventing it altogether. We examined tolerance of stereo depth perception to stimuli presented in-front-of and behind the screen, and examined factors that might predict it, including phoria, and decreased ability to accommodate with age (presbyopia). We characterised accommodation of observers aged 20 to 68 years using the slope of the linear portion of their stimulus-response functions. We also measured phoria, AC/A and CA/C ratios, visual acuity, and motor fusion limits. We determined a 'zone of good stereo' for each observer around screens at 1.3, 0.7, and 0.1 dioptres. We first measured their stereoacuity at each distance, using a random-dot-defined sinusoidal corrugation in depth (2-AFC task). These data were used to specify a no-conflict stimulus (coincident with the screen surface) for each observer for which performance was 90% correct. Adaptive staircases then controlled the stimulus position in-front-of and behind the screen to determine the point at which stereo performance was reduced by a criterion amount, yielding boundaries of the 'zone of good stereo'. Tolerance of stereo depth perception to vergence-accommodation conflict was related to accommodation ability. The 'zone of good stereo' was largest for presbyopes. In younger observers phoria was predictive of the symmetry of the zone, as reported for discomfort in stereo displays (Shibata et al., 2011). These results are counter to the belief in the stereo industry that older viewers are more affected by stereo viewing than younger viewers. They are consistent instead with the idea that presbyopes are better matched to viewing stereoscopic imagery because their normal behaviour is to vary vergence with fixed accommodation. The results are relevant for optimising stereo hardware and content for different audiences.

26.4018 **Sensory eye dominance varies within the visual field** Kevin Dieter[1] (kevin.dieter@vanderbilt.edu), Randolph Blake[1,2]; [1]Vanderbilt Vision Research Center & Dept. of Psychology, Vanderbilt University, [2]Department of Brain & Cognitive Sciences, Seoul National University

Binocular combination of monocular inputs transpires within cortical neurons that vary in ocular dominance, owing to developmental and experiential influences that govern the strengths of innervation from the two eyes1. Accordingly, binocular experience may vary within the visual field due to regional imbalances that impact effective signal strengths from the two eyes. Rather than having a single dominant eye, people may have regional differences in sensory eye dominance (SED)2,3. Using binocular rivalry, a competitive phenomenon with dynamics sensitive to the stimulus strength of competing monocular images, we mapped patterns of SED in observers' visual fields. Observers tracked perceptual alternations while dichoptically viewing dissimilar monocular stimuli imaged at various visual field locations. Results reveal that the relative predominance of the two eyes can vary widely across the visual field, with some locations promoting equal balance and others strongly biased toward one eye (see Figure). Results were reliable across sessions ($r=0.55$, $p< 0.0001$), especially for regions of strong SED imbalance (locations with >10% difference in predominance on both runs, $r=0.70$, $p< 0.0001$). Importantly, SED appears to function like a reduction in effective contrast for the weaker eye – the amount of balancing contrast required by the weaker eye to equate predominance for the two eyes is closely predicated by the magnitude of SED imbalance ($r=0.85$, $p< 0.01$). These results indicate that SED relies on local mechanisms that are idiosyncratic within the visual fields of typical observers. Such naturally occurring variability in the effective contrast contributed by the two eyes may have widespread impact on binocular functions such as stereopsis, where contrast imbalances produce impaired stereoacuity. Within a subset of observers tested, stereopsis is indeed impaired in regions of the visual field with pronounced SED. Continuing investigations are exploring the impact of regional inter-ocular contrast variations on other binocular functions.

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26.4019 **Using the symmetry of false matches to solve the correspondence problem** Cherlyn Ng[1] (cherlyn.j.ng@gmail.com), Bart Farell[1]; [1]Institute for Sensory Research, Syracuse University

Sensing stereoscopic depth requires that image points be binocularly matched. Therein lies the correspondence problem: how are true matches distinguished from false ones? Conventional algorithms select true matches on the basis of correlated features and adherence to natural statistics, while rejecting false matches as noise. We propose here an alternative that uses the signals present in false matches to delineate the true solution. When visualized in a Keplerian array, binocular matches are symmetrically reflected about an axis that represents a potential solution. Surface properties such as slant and curvature are encoded the transformation that describes how one-half of the matches reflects across the symmetry axis onto the other. To implement this strategy, we convolved left and right images with Gaussian kernels of various standard deviations (spatial frequencies). We then produced Keplerian arrays by comparing filter responses across left and right spatial-frequency combinations. Responses that are minimally different across the eyes gave rise to regions of high symmetry; response position within the Keplerian array gave the location of a solution in space. Solutions possessing natural surface regularities consistently showed minimal differences for one left : right spatial frequency ratio, which is correlated with the local surface slant. As a result, combining responses within particular ratio families can distinguish true matches from false ones. True matches tend to be elongated and smoothly contoured, with symmetry preserved across all members of a ratio family from low to high spatial-frequency combinations. This approach is efficient; preprocessing is minimal since no feature extraction is involved. It can be implemented in machine vision to solve the correspondence problem for depth sensing algorithms. It is robust when tested against perfectly camouflaged surfaces in random dot stereograms and consistent with physiological data showing that false match signals are propagated to higher cortical areas along the dorsal pathway.

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26.4020 **Interactions among contrast, spatial displacement, and dichoptic viewing during binocular combination in global motion perception** Lanya Tianhao Cai[1,2] (tcai@sunyopt.edu), Alexander Yuan[1], Benjamin Backus[1,2]; [1]Graduate Center for Vision Research, SUNY College of Optometry, [2]SUNY Eye Institute

The percent coherence threshold in a random-dot kinematogram (RDK) global motion task depends on contrast and dot displacement. Does threshold also depend on whether signal and noise dots are presented to same or different eyes? We compared performance under three binocular viewing conditions in a 2AFC net motion discrimination task (up vs. down). In a 7 degree circular aperture at a 114 cm viewing distance, coherently moving signal dots and randomly moving noise dots were displayed to either eye entirely (“monocular”), or to the two eyes respectively (“dichoptic”), or mixed among the two eyes equally (“binocular”). Threshold percent coherence was estimated from a 3-down-1-up staircase procedure and converted to signal-to-noise ratio (SNR). Dot lifetime was strictly 2 frames at 30 Hz (2-frame motion), and the stimulus duration was 300 ms. Trials from different viewing conditions were randomly intermingled. We tested at two contrast levels (33%, 6%) and three displacements (0.04, 0.11, and 0.27 degree/frame) for a total of 3x2x3 = 18 viewing conditions. All 7 subjects had normal binocular vision. Five of our subjects replicated Seitz, Pilly, and Pack (2005), who reported that high luminance contrast was helpful when the displacement of dots was large, but harmful when small; however, two of our subjects showed little reduction in their high-contrast advantage even at the smallest displacement. Remarkably, dichoptic viewing was significantly better than monocular or binocular viewing at high contrast, and significantly worse at low contrast; this interaction was most dramatic for large displacements. We conclude that global motion mechanisms are variable within the population and that different pathways may operate to combine motion signals across the eyes depending on contrast.

26.4021 **Grouping of optic flow stimuli is driven by monocular information** Vivian Holten[1] (v.holten@uu.nl), Sjoerd Stuit[1], Frans Verstraten[1,2], Maarten van der Smagt[1]; [1]Division of Experimental Psychology, Helmholtz Institute, Utrecht University, The Netherlands, [2]The University of Sydney, School of Psychology, Australia

Binocular rivalry occurs when two dissimilar images are dichoptically presented, each to a different eye. Neighboring image-parts with similar features, such as motion or orientation, tend to be perceived together for longer durations than image-parts with dissimilar features, i.e. grouping occurs. Previous studies have shown that this grouping depends on a shared eye-of-origin to a much larger extent than on image content, irrespective of the complexity of a static image. Here, we address the question whether grouping of optic flow patterns is also primarily driven by monocular information. In addition, we examine whether parameters, such as optic flow direction, and partial versus full visibility of the optic flow structure, affects grouping durations during rivalry. For each eye, two apertures (diameter 1.0°) were presented above and below the fixation dot (diameter ~0.22°). Each aperture contained either optic flow (expansion or contraction) or incoherent motion. The speed of the dots of the optic flow pattern increased from center (0.086°/s) to periphery (1.49°/s). The dots were colored either white or black and observers had to track the color of the dots they perceived in the two apertures during 1 minute trials. The results show that, as for static images, grouping of motion information is primarily affected by its eye-of-origin. The motion direction of the optic flow pattern (i.e. the ‘image cue’) only affected grouping durations when full optic flow patterns were presented within each aperture. This effect was absent for partial optic flow parts that could be perceived holistically as a single optic flow pattern. These results suggest that grouping during rivalry is primarily driven by monocular information even for complex motion stimuli thought to rely on higher-level motion areas.

26.4023 **Ambiguous filling-in at the blind spot resolved through perceptual rivalry** Zhimin Chen[1] (mandychan@pku.edu.cn), Rachel Denison[3], David Whitney[2], Gerrit Maus[2]; [1]Department of Psychology, Peking University, China, [2]Department of Psychology, University of California, Berkeley, [3]Department of Psychology and Center for Neural Science, New York University

Visual stimulation at adjacent borders of the retinal blind spot leads to perceptual filling in: a bar reaching through the blind spot, for example, is seen as complete. When multiple stimuli are presented reaching through the blind spot, which stimulus is to be filled in remains ambiguous. This can be demonstrated in a novel illusion, the “jumping pen illusion”. Hold a strip of paper horizontally and view it monocularly so that part of it reaches through the blind spot. Then hold a pen (or another object) vertically behind the paper where it also spans the blind spot region. The pen appears to jump in front of the paper. The blind spot thus provides a unique opportunity to study the resolution of perceptual ambiguity in the absence of retinal input. Here we show that the visual system resolves ambiguity by alternating between unambiguous percepts in which one filled-in stimulus occludes the other. Using a haploscopic setup, we presented an orthogonal cross formed by two isoluminant bars of different colors only to one eye, with its intersection placed in the blind spot. Observers viewed this stimulus continuously for trials of 1 minute. They indicated with continuous key presses which of the two bars appeared in front of the other; no key press meant unsure. Observers readily perceived one bar in front of the other; only brief periods were associated with ‘unsure’ responses. Which bar was perceived to be in front was stochastically alternating, akin to other cases of perceptual rivalry. Distributions of perceptual dominance durations followed gamma distributions, as found for binocular and monocular rivalry (O’Shea et al., 2009). These results demonstrate a novel situation: perceptual competition between two illusory percepts. Further, they suggest that filling-in at the blind spot shares common features with other mechanisms that resolve perceptual ambiguity.

26.4024 **Common and shared mechanisms underlying the temporal dynamics of bi-stable perception** Teng Cao[1,3] (ctjspz@126.com), Lan Wang[1], Sheng He[1,2]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, Bejing, China, [2]Department of Psychology, University of Minnesota, Minneapolis, Minnesota, United States of America, [3]University of the Chinese Academy of Sciences - Beijing, China

There are many forms of perceptual bi-stability where perceptual experience alternates between two (sometimes even more) different images or interpretations. The alternation could happen between different images (e.g., binocular rivalry, monocular rivalry, stimulus rivalry), different viewpoint perspectives (e.g., the Necker cube), different surface depth assignments (e.g., 3D Structure-from-Motion), or different levels of perceptual organization (e.g., moving plaids vs. component gratings). These diverse phenomena seem to have different temporal dynamics, some with slow and others with fast alternating rates. One previous study (Suzuki & Grabowecky, 2007) discovered that in binocular rivalry the dynamics of perceptual switches was profoundly altered by perceptual experience, that there were within-trial slowdown and a long-term speeding of binocular rivalry switch when observers viewed the binocular rivalry repeatedly over many days. In this study, we investigated whether such an experience-induced change in perceptual dynamics is unique to binocular rivalry or is general to many forms of bi-stability, and in addition, whether there is transfer of this long-term speeding-up of switch rate from a trained form of bi-stable perception to other untrained forms. Over a 10-day period, in a paradigm similar to Suzuki and Grabowecky (2007), subjects viewed their individually assigned form of bistable stimuli for 12 trials a day, with each trial lasting 30 seconds separated by 2 minutes rests. Results show a consistent within-trial slowdown as well as a day-to-day long-term speedup for all types of bi-stable stimuli tested. In addition, there was evidence of transfer of the long-term speeding from trained to untrained types of bi-stable stimuli. Overall, these results indicate that there are common (e.g., adaptation) and even shared neural mechanisms underlying the temporal dynamics of different forms of bi-stable perception.

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26.4025 **Adapting the mechanism that initiates binocular rivalry**
Sucharit Katyal[1] (skatyal@umn.edu), Sheng He[1], Stephen Engel[1]; [1]Department of Psychology, University of Minnesota Twin Cities

When the two eyes receive different inputs, the visual system either fuses the images into one coherent percept, or engages in binocular rivalry. What neural computations decide between rivalry and fusion? If these computations compare opposing neural signals for fusion and rivalry, and adjusts their weights based on stimulus history, then adapting to either fusion or rivalry might bias the subsequent perception of an ambiguous, partially fusible stimulus towards the other state. Stimuli were constructed using 0.5 contrast orthogonal square-wave gratings (±45°; 0.7 cpd). There were two types of adapters: rivaling orthogonal gratings presented dichoptically, and fusible plaids (the sum of the orthogonal gratings) presented binocularly. The ambiguous test patterns were plaids where a different component grating in each eye was presented with reduced contrast (0.3). During each trial, subjects viewed the adaptor for 6 s followed by the ambiguous test for 8 s. Subjects pressed one of four buttons to report percepts of: +45 grating, –45 grating, piecemeal mixed, or fused plaid. For the rivalrous adapter, the test pattern was always initially perceived as a fused plaid and then began to rival after 6.24±0.44 s (SE; n=6). For the fused adapter, the test pattern began to rival much sooner, either immediately upon presentation, or shortly thereafter (3.25±0.27 s). Similar results were obtained regardless of whether the orientations of the rivalrous adapting gratings matched that of the higher or lower contrast component of each eye's test plaid. These results strongly suggest that adaptation affected an opponent neural mechanism that determines whether a stimulus fuses or rivals. This mechanism may depend upon the ocular opponency units proposed by a recent computational model of rivalry (Said & Heeger 2013).

Acknowledgement: NSF R01EB006433

26.4026 Traveling waves of dominance in motion-induced blindness

Dustin Cox[1] (dcox2013@fau.edu), Sang Hong[1]; [1]Florida Atlantic University

There is accumulated evidence supporting the idea that motion-induced blindness (MIB) and binocular rivalry (BR) may be mediated by a common mechanism(s). To test this hypothesis, we examined the spatiotemporal dynamics of perceptual switches in MIB. It is well known that perceptual switches occur in a traveling-wave-like fashion during binocular rivalry, meaning that a suppressed stimulus during BR regains its dominance locally and progressively expands its dominance over space and time. If MIB and BR share a common mechanism, their spatiotemporal dynamics should resemble each other. In each trial, observers viewed a MIB display consisting of a rotating grid of black crosses on a grey background and a static, segmented, white arc presented in the periphery within protection zones. Observers pressed and held a key once the entire arc completely disappeared from awareness due to MIB. Target reappearance was induced by briefly flickering a portion of the end of the arc right after it completely disappeared. Observers released the response key when a segment of the arc reappeared at a designated location. The target reappearance location was systematically varied in distance from the flicker pulse along the arc across trials. We found that the reappearance of the arc reached locations further from the flicker pulse with greater latencies, resembling the traveling-wave-like propagation of dominance observed in BR. Participants indeed reported that reappearance of the targets appeared to propagate in a wave-like manner along the arcs. Our results indicate that the suppressed targets in MIB regain visual awareness in a wave-like fashion similar to BR. The consistent spatiotemporal dynamics between BR and MIB indicates that both visual phenomena may be mediated by a common mechanism(s).

26.4027 Object-level grouping contributes to chromatic interocular-switch rivalry

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INTRODUCTION & PURPOSE: Chromatic interocular-switch rivalry (CISR) occurs when two equiluminant but chromatically rivalrous stimuli (e.g., one "purple" and one "green" circle) are presented separately to each eye, and then swapped interocularly several times a second (e.g., 3.75Hz). Instead of seeing the fused circle change color rapidly, the percept is a long-lasting color that alternates between the two presented chromaticities (Christiansen, D'Antona & Shevell, VSS2014). This study investigated whether object-level grouping contributes to the resolution of CISR when two separate rivalrous circles, one above the other, are viewed simultaneously. If so, then the probability of simultaneously perceiving two spatially separated circles having the same color would be greater than predicted from the independent probabilities of perceiving each circle of that color. METHODS: At each moment, two spatially homogeneous circles (one above fixation, one below) were presented to each eye at corresponding retinal locations. Each circle alternated over time between two equiluminant chromaticities along one of the cardinal color direction (either L/(L+M) or S/(L+M)). The time-average chromaticity was always equal-energy-spectrum (EES) "white". To determine the independent probabilities, percepts were measured during CISR with one spatially homogeneous circle in each eye (either above fixation or below, in separate runs). The task always was to report (via a gamepad) the color of the top circle and/or the bottom circle in the fused binocular percept. In separate runs, three different square-wave frequencies were tested: 3.13, 3.75 and 4.69Hz. RESULTS & CONCLUSIONS: The probability of simultaneously perceiving two circles of the same color was far greater than predicted from the independent probabilities of perceiving each circle alone with that color ($p < 0.01$ for each of 3 observers at each of the 3 temporal frequencies). Therefore, object-level grouping contributes to resolving chromatic interocular-switch rivalry. This influence from perceptual organization is a novel aspect of interocular-switch rivalry.

Motion Perception: Experience

Saturday, May 16, 2:45 - 6:45 pm
Poster Session, Pavilion

26.4028 The automaticity and timecourse of motion processing

Katherine Burnett[1] (k.e.burnett@hotmail.co.uk), Isabel Arend[1], Avishai Henik[1]; [1]Department of Psychology, Ben-Gurion University of the Negev

Because of its biological relevance, motion processing may be prioritized, or processed automatically. We tested this by combining shape and motion dimensions in the same task. An arrow pointing to the left or right contained a flowfield of left- or right-moving dots, and participants responded to either arrow direction or motion direction. A congruity effect was present for both tasks, indicating that arrow direction and motion direction are processed automatically. There was a significant Task X Congruity interaction, as the arrow direction produced a larger congruity effect on the motion task than the motion direction produced on the arrow task. Reaction time (RT) was faster for the arrow than the motion task, suggesting that the interaction may be due to the processing time associated with each task. We therefore analysed the RT distributions using a binning procedure. For the arrow task, a congruity effect was absent at short RTs. For the motion task, a congruity effect was seen across RTs. We proposed that arrow direction interfered more - and earlier - with the motion task because it was resolved more quickly. In order to test this proposal, we manipulated the stimuli. Firstly, we removed the arrow border to increase arrow direction RTs. Secondly, we increased the speed of motion to decrease motion direction RTs. Both manipulations altered the overall task RTs as predicted, but did not modify the timecourse of interference on the arrow task. A final experiment mixed the tasks into one pre-cued block, in which the Task X Congruity interaction was significant and the timecourse asymmetries remained. In conclusion, we present some evidence that motion processing is automatic. However, interference effects from motion processing are consistently seen later in the timecourse of a shape processing task, despite efforts to encourage similar processing speeds for the two dimensions.

26.4029 Location of the interaction between motion and form signals in motion-streak facilitation

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Introduction. Motion streaks are the smeared representation of a moving object produced by the response persistence of cortical cells. They can be treated as form cues by the visual system, and can facilitate motion processing (Geisler, 1999, Nature). Here we investigated where in the visual system this interaction between form and motion signals occurs. Two likely candidates are the local (V1) and global (V5/MT or MSTd) motion levels. Methods. We used a three-frame global-motion stimulus consisting of signal and noise dots. Strong or weak motion streaks were generated by moving a given dot in either the same direction or a different direction on each frame transition, respectively. There were three conditions: 1) No strong motion-streaks (No Streak); 2) Strong streaks on the signal (Signal Streak); 3) strong streaks on the noise (Noise Streak). Thresholds were the percentage of signal dots required to perform a 2AFC direction judgement. The Noise-Streak condition was designed to tap differences in the tuning of cells at the local- and global-motion levels. At the global-motion level, cells are tuned to particular signal directions, so motion streaks should enhance the motion response only when they are in that signal direction, so this would not occur in the Noise-Streak condition. At the local-motion level, each cell is tuned to the direction it is extracting, so if the form-motion interaction occurs here, the noise strength in the Noise-Streak condition would be enhanced. Results. Thresholds for the Signal Streak condition were the lowest (consistent with Edwards & Crane, 2007, VisRes) and thresholds for Noise-Streak condition were the highest. Conclusions. Strong streaks in Noise-Streak impaired motion extraction, consistent with those streaks enhancing the strength of those noise motion-signals. This finding supports the form and motion interactions in motion streak facilitation occurring at the local-motion level.

26.4030 Prediction of illusory motion direction from eye tracking data

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The perception of motion can be generated by modulating the contrast relationships among objects, backgrounds, and thin lines separating them (Gregory and Heard, 1983; Shapiro et al. 2005; and others). This motion can be called "illusory" since no elements in the image physically change location. Here we examine a variant of this type of motion to see the extent to which it produces eye movements and whether we can predict the direction of illusory motion by examining only the eye movement data. The stimulus consisted of a large mid-luminance colored diamond (visual angle 16 degrees) bordered by thin (0.07 deg) edges and surrounded by a background (19 deg). Both the edges and background modulated in luminance between light and dark at 2 Hz; due to differences in timing between these elements, the diamond appeared to move continously in one direction (up, down, left, or right, depending on condition) though the diamond itself did not change position (Flynn and Shapiro, 2012). An eye tracking camera (50 Hz, Cambridge Research Systems) mounted to a chin rest tracked the gaze of naive observers (n = 30) who were asked simply to "watch" the stimulus on a computer monitor. Each observer saw 50 3-second trials presented in ranomized blocks of 5 conditions (up, down, left, right, no motion). An analysis of the slope of the eye movements'change in position shows that observers' eye movements drift in the direction of perceived motion. Additionally, an anylsis of the eye postion following saccades shows that observers' gazes center around the leading edge of the stimulus in each motion condition. We conclude that illusions of motion appear to create reliable patterns of eye movements which resemble responses to real motion. Eye tracking data can be used to predict the direction of illusory motion perceived by the observer.

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26.4031 Sharing Displays and Data from Vision Science Research with Databrary

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Open data sharing is gaining increasing attention in many areas of scientific research and is a priority for research funding agencies. Databrary (databrary.org) is a web-based, digital data library specialized for storing and sharing video files and associated metadata. Vision scientists often present visual displays to observers and frequently collect gaze position, kinematic data, or other physiological recordings in conjunction with participants' viewing of the displays. In some cases, researchers collect identifiable video recordings of participants' visual exploration and other behaviors. Databrary is especially well suited for handling use cases involving dynamic displays, video recordings, and other behavioral data streams. Databrary has also developed policies to enable identifiable information to be shared with participants' permission. This presentation will describe the structure and features of the Databrary library and policies for access and sharing with special focus on the challenges and promises of data sharing in vision science.

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26.4032 Measuring the effect of internal motion of a moving Gabor on speed perception and smooth pursuit

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We have previously shown that internal motion of the vertical stripes within a laterally moving Gabor patch can cause subjective biases in overall speed perception in an occlusion paradigm (Hughes, Stevens and Tolhurst, 2012). Here, we extend this result with a two-alternative-forced-choice paradigm, where observers chose which of two stimulus intervals contained the faster moving Gabor patch; the patches in the two intervals differed in the internal movement of the stripes. A Gabor patch with drifting stripes is perceived to move faster than a non drifting standard if the stripes drift in the same direction as the overall direction of movement. Conversely, if the stripes drift in the opposite direction to the overall direction of movement, the patch is perceived to move slower. We show that this speed effect depends on the relationship between the stripe motion and the direction travelled; when the stripe motion is orthogonal to the overall patch movement, no directional speed bias is seen. Similarly, adding non-directional temporal flicker to the patch does not affect speed judgements. Finally, we show that there are differences in eye movements made to the different types of stimuli, with smooth pursuit being faster on average if the stripes are drifting in the same direction as the overall direction of movement compared to if the stripes are drifting in the opposite direction, which may be related to the differences in speed perception seen.

Acknowledgement: BBSRC/Dstl CASE studentship to AEH

26.4033 Illusory rotation and motion capture depend upon assignment of complex motion signals.

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When viewing the concentric circles, which consist of oblique components, the observers see illusory rotation of those circles by changing the viewing distance. If several additional elements were superimposed on the concentric circles, they will see the illusory rotation not only for the circles, but also for the superimposed elements (Ichikawa et al, 2006, Perception, 35, 933-946). This illusory rotation of the superimposed elements is caused by "motion capture". We examined the basis of the motion capture by changing the number of the superimposed elements (dots) when the rotation of the circles was generated by the Pinna illusion, which is generated by automatic size change of the stimulus on the display, or by apparent motion. A CRT display presented the inner and outer circles (14.3 and 17.2 deg in diameter) each that consisted of 72 oblique lines, which were tilted radially by 30 deg. The numbers of the dots ranged from 0 to 40. The viewing distance was fixed at 50 cm. In the Pinna illusion condition, the stimulus changed its size from 17.2 to 6.9 deg. In the apparent rotation condition, the inner and outer circles rotated to opposite direction by 10.0 deg and 6.0 deg, respectively. In the complex motion condition, the inner and outer circles, which consisted of 72 radial lines, rotated to opposite direction by 10.0 deg and 6.0, respectively, and changed its size from 17.2 to 6.9 deg. In the Pinna illusion and complex motion conditions, we observed the motion capture; the dots moved with the same direction as the rotation of the inner circle. However, in the apparent rotation condition, we observed the induced motion; the dots moved with the opposite direction to the rotation of the inner circle. These results suggest that the motion capture depends upon the assignment of complex motion signals.

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26.4034 Age-related changes in motion direction discrimination in the horizontal plane

Louisa Miller[1] (l.miller@abdn.ac.uk), Hannah Agnew[1], Karin Pilz[1]; [1]School of Psychology, College of Life Sciences and Medicine, University of Aberdeen

Motion perception, including determining the speed and direction of motion, has been found to deteriorate dramatically during healthy ageing. However, the extent to which ageing affects the discrimination of different motion directions is still unknown. Here, we investigated age-related changes in discriminating the direction of vertical and horizontal motion using random-dot kinematograms (RDK). In a first step, older (N = 16, >60 years) and younger adults (N = 27, 18-30 years) had to discriminate left/right (horizontal), or up/down (vertical) motion, with motion coherence at 100%. We determined stimulus duration individually for each participant with a minimum duration of 400ms. Stimulus durations did not differ significantly between age groups or motion directions. In a second step, using the same task with individually determined stimulus durations from step one, we measured motion coherence thresholds using the method of constant stimuli with stimulus coherences varying between 1% and 80%. Coherence thresholds did not differ significantly between groups but were significantly higher overall for vertical motion. In a third step, using individually determined stimulus durations and motion coherences, participants had to discriminate motion directions in a two-alternative forced-choice paradigm. Two RDKs were presented successively. In one RDK, dots moved either horizontally (right, 0°) or vertically (up, 90°), in the other RDK, dots moved diagonally between 1° to 25° degrees away from horizontal or vertical. Participants had to determine in which of the two RDKs the dots moved diagonally. Overall, accuracy improved with increasing angular deviations and was significantly higher in the vertical than the horizontal plane. Most interestingly however, older adults' performance dramatically deteriorated in the horizontal plane, whereas their performance in the vertical plane was similar to younger

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adults. These results show that healthy ageing differentially affects motion direction discrimination along the vertical and horizontal planes.

Acknowledgement: BBSRC

26.4035 Reference-Frame Selection in Motion Perception Haluk Ogmen[1,2] (ogmen@uh.edu), Mehmet Agaoglu[1,2], Michael Herzog[3]; [1]Department of Electrical & Computer Engineering, University of Houston, [2]Center for NeuroEngineering & Cognitive Science, University of Houston, [3]Laboratory of Psychophysics, Brain Mind Institute, EPFL

Motion is often perceived according to non-retinotopic reference-frames (e.g., Duncker's wheel; biological motion); however, how reference-frames are selected remains to be established. The stimulus consisted of two concentric arcs undergoing circular motion, with the same average angular-velocity, around the center of the display. The outer arc's (target) velocity was modulated by a sine-wave whereas the inner arc (reference) moved at a constant velocity, except in Experiment 4. Observers' task was to report (yes/no) whether the target reversed its direction of rotation at any point during its motion. The minimum velocity of the target at "50% yes" gave the point of subjective stationarity (PSS). PSS=0 indicates a retinotopic/spatiotopic reference-frame while a PSS equal to the average velocity indicates a motion-based reference-frame with perfect vector-decomposition. In four experiments, we varied the radial and the angular contour distances between the two arcs, the relative radial size of the arcs and the velocity modulation of the reference arc. The perception of motion was neither retinotopic/spatiotopic nor based on perfect vector-decomposition. The effect of the reference arc's motion on the perception of target arc's motion ("reference-frame effect") decreased with increasing radial and angular contour distances, while it was independent of the size-ratio and the absolute-level of velocity modulation. In assessing which metric would unify all of our findings, we considered (i) object-centered, (ii) object-nearest-contour, (iii) motion-centered, and (iv) motion-nearest-vector reference-frames. Our results reject the first three and strongly support the last one. In fact, when the data from all experiments were plotted against this metric, we found a simple linear relationship between the reference-frame effect and the distance defined by this metric. The selection of a reference-frame for motion perception can be explained by a field whose strength decreases linearly as a function of the distance between the nearest motion vectors.

26.4036 Temporal subsampling counteracts motion-related visual acuity loss in the near periphery Jonathan Patrick[1] (lpxjap@nottingham.ac.uk), Neil Roach[1], Paul McGraw[1]; [1]Visual Neuroscience Group, School of Psychology, University of Nottingham

While most of us rely on foveal (central) vision for high-resolution tasks, those with macular damage or disease must view the world peripherally. As a step towards making best use of available resolution capacity in such patients, we investigated methods of optimising the presentation of peripheral stimuli in healthy observers. Resolution thresholds were measured for Landolt C targets presented in the near periphery (10 degrees eccentricity). Observers were required to judge the orientation of the target (4 alternatives), which was either static or moving along an isoeccentric path at one of 5 speeds. Consistent with previous findings (Brown, 1972), we found that thresholds rose systematically as a function of target speed, indicating a motion-related loss in visual acuity. In an attempt to disrupt this effect, we subsampled the motion path, removing frames from the stimulus sequence. Interestingly, this manipulation dramatically reduced the impairment of acuity at high speeds, despite reducing the overall information within the stimulus. This effect persisted when the time-average contrast of smooth and sub-sampled paths were equated. Loss of acuity at high speeds is often attributed to shifts in the contrast sensitivity function to lower spatial frequencies (Burr & Ross, 1981). To explore this effect further, we measured contrast sensitivity for a 4c/deg Gabor patch using a similar task, motion paths and range of speeds. For smooth motion, contrast thresholds for orientation identification formed a non-monotonic function of speed, with a marked elevation around 10 deg/s. Subsampled motion paths, however, showed little speed dependence. For physically translating stimuli, the acuity loss for smooth paths and acuity preservation for subsampled paths at high speeds are not easily reconciled with speed-related shifts in contrast sensitivity. Our results suggest that temporal subsampling of visual input can improve peripheral acuity for moving targets.

Acknowledgement: Fight for Sight

26.4037 How fast can a baseball spin before an observer can't tell the direction of rotation? Arthur Shapiro[1] (arthur.shapiro@american.edu), Jonathan Newport[2], Bree DeVries[3]; [1]Department of Psychology, American University, Washington D.C., [2]Department of Physics, American University, Washington D.C., [3]Department of Computer Science, American University, Washington D.C.

In baseball, a pitcher throws a 3" ball toward a batter positioned 60.5 feet away. Shapiro et al (2009, 2011) hypothesized that a batter's perception of a pitch could be influenced by changes in the ball's retinal location (i.e., whether the batter views the ball centrally or peripherally). One question concerns whether a curveball spins too fast for a batter to discern the direction of spin. To address this question, we constructed a device in which a microcontroller spins a motor at rates up to 3000 rpm. A baseball rested on a driveshaft extending from the motor; an LCD shutter controlled the presentation duration (set at .6 sec); steady LED lights illuminated the ball. The observer viewed the ball from a distance of 140 cm (ball subtended 3.2 deg) and pressed one of two buttons to indicate the direction of perceived spin. Experiment 1: The ball was presented at rotation rates between 500 and 2500 rpm (40 trials in random order; half the trial were clockwise, half counter clockwise). Experiment 2: Similar set up, but on different sets of trials the observers viewed the ball either centrally or 10 deg in the periphery. Experiment 3: On different sets of trials the ball was positioned on the motor in a "2-seam" or a "4-seam" configuration. For all conditions, at rates up 1200 rpm, observers were typically correct 100% of the time, but near 2000 rpm, observers were typically at chance. Peripheral viewing and spin configuration had little effect on observer's ability to identify spin direction. Since an MLB curveball spins between 1400 and 1800 rpm, these pitches approach the limit of our perceptual resolution. The minor effect of peripheral viewing and spin configuration suggest, surprisingly, that our ability to perceive spin direction may be mediated by low spatial frequency channels.

26.4038 Human contrast normalization process operates on a local scale Boris Sheliga[1] (bms@lsr.nei.nih.gov), Christian Quaia[1], Edmond FitzGibbon[1], Bruce Cumming[1]; [1]Laboratory of Sensorimotor Research, National Eye Institute, National Institutes of Health

We quantitatively assessed the strength and extent of spatial summation in human Ocular Following Responses (OFRs). In Experiment 1 we used a pair of 1D sine wave gratings which both drifted horizontally in the same direction but whose vertical or horizontal spatial separation was manipulated. We compared the OFRs to the pair with responses recorded when each grating, comprising the pair, was presented in isolation. Overall, as the separation between the gratings increased, the interaction progressed from sub-linear summation towards pure summation and even facilitation (in 2 out of 3 subjects), confirming earlier observations (Quaia et al, 2012). Additionally, the strength of the suppressive interactions at each separation tested was considerably weaker in the horizontal than in the vertical stimulus configuration. In Experiment 2 we kept the pair's spatial separation constant while independently varying the contrast of each grating. For a fixed contrast of one grating ("conditioning grating") we described responses as a function of contrast in the other grating ("test") with a Naka-Rushton equation. Changing only Rmax in these fits as a function of contrast in the conditioning grating produced excellent fits. The changes in fitted response amplitude accounted for 92±4% of changes in observed OFR amplitude. Conversely, when only C_{50} was changed with conditioning contrast, the fits were poor and accounted for just 14±9% of changes in observed OFR amplitude. If the conditioning grating affected contrast normalization for the test changes in C_{50} should be expected. Thus, this pattern of results suggests that contrast normalization operates on a local scale.

26.4039 Similarities and differences in forward and reverse motion extrapolation Kevin Smith[1] (k2smith@ucsd.edu), Joshua Davis[2], Benjamin Bergen[2], Edward Vul[1]; [1]Department of Psychology, University of California, San Diego, [2]Department of Cognitive Science, University of California, San Diego

We often must not only extrapolate the future trajectory of objects (where will a thrown rock go?) but also extrapolate backwards in time (where did the rock flying by your head come from?). We matched forward and reverse extrapolation in two experiments to investigate similarities and differences between extrapolation directions. Forward and reverse extrapolation share biases and response time patterns across various trajectories, but reverse extrapolation is noisier. This suggests both forms of extrapolation share cognitive processes, and opens up further avenues of investigation into why reverse extrapolation is noisier. In Experiment 1, participants observed a ball moving either towards (forward) or away

Saturday PM

from (reverse) a semi-circular occluder, then a mark appeared on the outside of the semi-circle and participants indicated whether the ball would travel (forward) or came from (reverse) above or below this mark. 85% accuracy was maintained by dynamically adjusting the mark for each condition. Participants were slightly slower to respond when the occluder was larger ($F(2,32)=4.8$, $p=0.015$), but speed was unaffected by extrapolation type ($F(1,16)=0.4$, $p=0.56$). Reverse extrapolation was harder (greater offset thresholds: $F(1,16)=5.4$, $p=0.034$), though difficulty increased at the same rate over distance (no interaction: $F(2,32)=0.04$, $p=0.96$). These results suggest shared processing underlies both extrapolation directions, but do not differentiate whether reverse extrapolation is more biased or simply more variable. In Experiment 2, participants observed a ball in motion and indicated where on a line it would next cross (forward) or last came from (reverse). Each forward trial had a matched reverse trial with mirrored motion, so the line crossing would be identical. Systematic biases were nearly identical across extrapolation directions ($r=0.96$) but people were on average 30% more variable on reverse trials. This suggests that reverse extrapolation and forward extrapolation share biases, and that greater variability caused the increased difficulty in Experiment 1.

Acknowledgement: University of California, San Diego Interdisciplinary Collaboratory Fellowship

26.4040 **Confidence in the mind's eye** Morgan Spence[1] (morgan.spence@uqconnect.edu.au), Paul Dux[2], Derek Arnold[1]; [1]Perception Lab: School of Psychology, The University of Queensland, [2]Attention and Control Lab: School of Psychology, The University of Queensland

Humans intuitively evaluate their decisions by forming different levels of confidence. It has been established that decisional confidence and accuracy are well-correlated, but can also deviate. Understanding of the computations underlying confidence, and how these differ from computations that limit sensitivity, is lacking. Here we show that, for visual judgments concerning global motion direction, confidence and accuracy are separable because the variance associated with a sensory signal undermines confidence to a greater extent than it does sensitivity. Stimuli consisted of dots moving in a uniform distribution of directions about a mean test value. The critical manipulation was the range of different directions contained in a test stimulus. Before testing, we calibrated different stimuli to equate sensitivity in fine direction discriminations (left / right of vertical), by manipulating the offset of the average direction from the vertical decisional boundary. This calibration failed to equate confidence - despite constant levels of sensitivity, people were less confident when judging more variable direction signals. When we instead calibrated stimuli to equate confidence, people were more sensitive when judging more variable signals. These complementary results reveal a differential weighting of signal variance in computations that limit visual sensitivity and decisional confidence. This means that the precision of perceptual decisions, and levels of confidence in those decisions, rely on independent transformations of sensory input.

26.4041 **Contribution of the ventral visual pathway to Perception of Wriggling Motion Trajectory Illusion: an fMRI study** Ryosuke Tanaka[1] (tanaka@fechner.c.u-tokyo.ac.jp), Yuko Yotsumoto[1]; [1]Department of Life Sciences, The University of Tokyo

The neural substrate of the perception of visual motion has been generally attributed to so-called "dorsal visual pathway", which includes the Medial Temporal Visual Area (MT) and several parietal regions. Recent studies, however, have revealed that the perception of a global feature of visual motion can require contribution of visual areas outside the dorsal pathway, such as superior temporal sulcus and fusiform gyrus for perception of biological motion. When hundreds of dots move in straight trajectories and random directions without colliding, the trajectories are perceived as wriggling rather than straight. In the present study, we used this Wriggling Motion Trajectory Illusion to investigate the neural correlates underlying perception of the "wrigglingness." In the experiment, 16 subjects observed visually presented moving stimuli under two conditions in Siemens 3T MRI scanner. In both conditions, dots moved straight in random directions. In the wriggling condition, dots moved without colliding, eliciting wriggling perception. In the control condition, the moving dots were allowed to collide and were perceived to be moving straight. BOLD signal changes were compared between the wriggling and the control conditions. The results indicated that illusory perception of wrigglingness coincided with activations in the temporal areas including bilateral fusiform gyrus and right inferior temporal gyrus. Our results also suggest that activities in the ventral visual pathway could modulate perception of motion trajectory. We conclude that perception of WMTI is, like perception of biological motion, based on transformation of motion-defined shape by moving dots.

Acknowledgement: JSPS25119003

Visual Memory: Neural mechanisms

Saturday, May 16, 2:45 - 6:45 pm

Poster Session, Pavilion

26.4042 **Dissociation of Memorability and Memory Encoding in the Brain** Wilma Bainbridge[1] (wilma@mit.edu), Daniel Dilks[2], Aude Oliva[3]; [1]Department of Brain and Cognitive Sciences, MIT, [2]Department of Psychology, Emory University, [3]Computer Science and Artificial Intelligence Laboratory, MIT

Some images, upon first glance, are more easily remembered than others. Such memorability is highly consistent across people, and thus can be used as an image property for exploring the interaction of perception and memory. We conducted two fMRI experiments to investigate perception of memorable versus forgettable faces and scenes (controlled for possible confounds, including color, spatial frequency, emotion, attractiveness, objects). In Experiment 1 (N=16), participants viewed these images in a block design, while in Experiment 2 (N=16), another participant group viewed these images in an event-related design. Every image was completely novel and presented only once. In both experiments, participants performed an orthogonal image categorization task (i.e., male/female; indoor/outdoor), and were unaware of the experiments' memory-related nature. After scanning, the participants then completed an unexpected memory test. Visual perceptual regions of interest (e.g., fusiform face area, parahippocampal place area) were defined using independent functional localizers, while memory-related regions (medial temporal lobe, MTL) and attention-related regions (intraparietal sulcus, IPS; dorsolateral prefrontal cortex, DLPFC) were anatomically defined. In both experiments, we found significantly greater activation for the memorable than forgettable images in the visual perceptual regions and several MTL regions (perirhinal cortex, PRC; parahippocampal cortex, PHC; amygdala; anterior hippocampus). Further, this memorability effect was found regardless of whether the image was later remembered or forgotten, indicating a dissociation of memorability and subsequent memory. No memorability effect was found in early visual cortex, IPS, or DLPFC, indicating that this effect is not due to visual or attentional confounds. An additional multivariate analysis revealed significantly higher classification for memorable versus forgettable images in PRC. By contrast, activity for memory encoding (remembered versus forgotten images in the subsequent memory task) was only present in the PHC. These results indicate that image memorability may be a dissociable phenomenon from memory encoding, particularly within the PRC.

Acknowledgement: Funded by the DoD NDSEG Program to W.B. Thanks to the Athinoula A. Martinos Imaging Center at the McGovern Institute for Brain Research, MIT.

26.4043 **Understanding the nature of visual short-term memory representation in human parietal cortex** Katherine Bettencourt[1] (kcb@wjh.harvard.edu), Yaoda Xu[1]; [1]Department of Psychology, Harvard University

Recent work has shown that the human parietal cortex, in particular superior intraparietal sulcus (IPS), plays a central role in visual short-term memory (VSTM) storage. However, much remains unknown about the nature of these memory representations including whether they are similar or distinct from perceptual representations. Using fMRI multivariate pattern analysis (MVPA), it has been shown that VSTM representations in occipital cortex are highly similar to perceptual representations. Here, we tested whether the same would be true for VSTM representations in superior IPS. On the one hand, VSTM representations in superior IPS could simply be an extension of the sensory representations formed during perception. This would predict a high degree of similarity between VSTM and perceptual representations in this region. However, we have previously shown that VSTM representations in superior IPS, unlike those in occipital cortex, are robust to visual distraction. This suggests that the nature of VSTM representation in the two regions may differ, and that representations in superior IPS may be consolidated and thus, distinct from perceptual representations. In the present study, we had participants complete both a VSTM and perceptual task using face and gazebo stimuli. We then decoded between the two stimuli types both within a task and across the two tasks. To minimize any attention or memory effects in the perceptual task, participants performed a one back letter task at fixation. Pilot results showed decoding of both memory and perceptual information in

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superior IPS, and, importantly, successful cross decoding between the two tasks. This suggests that, just like in occipital cortex, VSTM information in superior IPS is represented in a similar manner to perceptual information.

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26.4044 Using MVPA to decipher neural correlates of visual sequence learning in the brain. Melanie Burke[1] (m.r.burke@leeds.ac.uk), Graham Barnes[2], Jacqueline Billington[1], Claudia Gonzalez[3]; [1]School of Psychology, University of Leeds, U.K., [2]Faculty of Life Sciences, Universty of Manchester, U.K. , [3]College of Health and Life Sciences, Brunel University, U.K.

Using top-down memory-driven information to guide actions is the common method for successful and efficient completion of most everyday activities. Many previous studies have demonstrated a role of the frontal and parietal cortices in top-down processing with a number of studies revealing attentional modulations and maintenance of neuronal activity during delays in these areas. These areas have been extensively studied in regards to explicit visual working mechanisms, but its role for motor learning is currently unclear. We have implemented a novel and equivalent saccade and pursuit sequence-learning paradigm inside an fMRI scanner to investigate how early motor learning is implemented in the brain and more specifically within this fronto-parietal network. To achieve this we used a multivariate analysis approach (MVPA) to a priori regions of interest (prefrontal, frontal and parietal cortices) to evaluate how patterns of activation within these areas change with increasing repetition i.e. during visuomotor learning. The results revealed patterns of activity within these areas that reflect early motor learning that is analogous to the dorsal attentional network, indicating an overlap in function for the fronto-parietal network in attention, working memory and early motor learning.

26.4045 Temporal Dynamics of Memory and Maintenance of Faces in Visual Cortex: An On-line TMS Study Kelsey Holiday[1] (kelsholiday@gmail.com), David Pitcher[1], Leslie Ungerleider[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health, NIH, Bethesda, MD 20892, USA

Electroencephalography and behavioural studies report that structural encoding of faces occurs for a short duration after stimulus presentation, as indexed by the right lateralized N170 component. Investigation of a prosopagnosic patient exhibited an absence of this component and disruption of face identification (Eimer, 2000). Based on this evidence, we hypothesized that the early mechanisms of face encoding would be more susceptible to cortical disruption than maintenance of face representations at later latencies. To test this, we used transcranial magnetic stimulation (TMS) to disrupt processing in the right occipital face region (rOFA). Participants performed a delayed match-to-sample task and indicated face identity changes with a button press. Double pulse TMS, separated by 100ms, was delivered during the inter-stimulus interval at one of three time latencies: early (150ms), middle (1700ms) or late (2900ms). Results revealed that TMS to rOFA impaired face-matching performance during the early application condition only, while TMS delivered during the middle and late latencies had no effect. These results demonstrate that TMS delivered over a face-processing area early after stimulus offset disrupts face consolidation. Furthermore, face memory in the rOFA is immune to this disruption during later phases of retention as demonstrated by the lack of an effect at the middle and late TMS delivery latencies. Planned studies will examine whether this early impairment is also evident in other functionally defined regions of extrastriate cortex.

Acknowledgement: NIMH

26.4046 Reconstructing the population dynamics of spatial priority in early visual cortex during working memory Masih Rahmati[1] (masih.rahmati@nyu.edu), Golbarg Saber[2], Clayton Curtis[1,2]; [1]Psychology & Center for Neural Sciences, New York University, [2]Center for Neural Sciences, New York University

The read-out of prioritized maps of space in frontal cortex is believed to provide the spatial feedback signals needed to bias activity in early visual cortex. These feedback signals can be spatially directed via a saccade plan. Maintaining a saccade plan in working memory, therefore, may evoke a pattern of activity in topographically organized population of neurons with a peak centered in the neurons with receptive fields that match the saccade goal. Here, we test for such population dynamics using a forward encoding model of the distributed patterns of fMRI activity in human visual cortex. First, using fMRI we measured neural activity in human visual areas V1, V2, V3, V3A/B, hV4 and IPS-0/1 while subjects maintained a planned saccade directed to or away from the location of a brief visual cue. Second, we mapped the retinotopic locations of memory-guided saccade cues within each visual area. Third, we developed a forward encoding model to reconstruct the neural population dynamics in early visual areas. In the forward model, we used a linear combination of outputs from a number of information channels (i.e., basis functions) to estimate each voxel's response to visual cues at a variety of retinal locations. We validated the model by successfully reconstructing both the locations of both remembered visual cues and prospective saccade goals based on fMRI responses during working memory delay periods. Our ability to build a forward model that reconstructs the locations of maintained representations allows us to make strong inferences about the population dynamics of topographic visual areas and how these dynamics are related to working memory storage. Moreover, these results show that the population activity in early topographic areas is sculpted by top-down feedback signals representing spatial priority.

26.4047 Involvement of visual cortex in a visual working memory task: Evidence from steady-state visual potential frequency tagging Nina Thigpen[1] (nthigpen@ufl.edu), Klaus Oberauer[2], Andreas Keil[1]; [1]University of Florida, [2]University of Zurich

Working memory, the short-term maintenance of behaviorally relevant information, has robustly been shown to engage prefrontal cortex and attentional control networks in hemodynamic and electrophysiological studies. Work in the animal model has provided converging evidence, but has also pointed towards involvement of sensory cortices. In line with these findings, several current models of working memory emphasize aspects of selecting and amplifying sensory representations of the task stimulus during retention. Progress in the empirical testing of these notions has however been prevented by methodological issues with quantifying sensory responses to concurrently presented or retained stimuli of a memory set. The present study addressed this problem with three experiments using a steady-state potential frequency tagging approach: EEG data were collected from 47 participants during a visual working memory task, with the orientation of two grating stimuli being the task-relevant dimension. After a retention interval, probe gratings were presented again, while phase reversing at two different fixed rates to elicit steady-state visually evoked potentials. Observers then made either a match/no-match decision or they manually set one probe grating at the remembered orientation. Results show an enhanced steady-state signal over visual cortical areas for stimuli being held in working memory, compared to non-matching stimuli. These data suggest that early visual neurons are actively involved in the process of working memory. Future work may use the visual electrocortical response as a reference signal for studying interactions among brain regions involved in working memory.

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26.4048 Load-Dependent Increases in Alpha-Band Power: Relevance to Sensory Cortex Excitability and Distractor Interference Andrew Heinz[1], Jeffrey Johnson[1]; [1]Department of Psychology, Center for Visual and Cognitive Neuroscience, North Dakota State University

Studies exploring the role of neural oscillations in cognition have revealed sustained increases in alpha-band power (ABP) during the delay period of verbal and visual short-term memory (STM) tasks. There have been various proposals regarding the functional significance of such increases, including the inhibition of task-irrelevant cortical areas, and the active retention of information in STM. The present study examines the role of delay-period ABP in mediating the effects of distractor interference in STM. Specifically, we reasoned that, if load-dependent ABP increases represent the gating of sensory inputs, they should be associated with modulations of the visual evoked potential (VEP) elicited by a task-irrelevant probe presented during the delay interval. Previous results from our lab (Heinz & Johnson, VSS 2014) failed to find this predicted relationship. However, we suspect that the complicated nature of the design may have obscured possible effects. Using a simplified design for the present study, we recorded the electroencephalogram (EEG) while subjects performed a change detection task requiring the retention of two or four novel shapes. Importantly, on a portion of trials, a task-irrelevant bilateral checkerboard probe was presented during the delay interval. Our analysis focused on examining correlations between load-dependent increases in ABP and the magnitude of both the P1 and N1 ERP components. Results revealed that reductions in the amplitude of both the P1 and N1 were predicted by load-dependent increases in ABP prior to the probe. Additionally, for the P1, the load-dependent amplitude change predicted load-dependent differences in the disruptive effect of the probe on STM capacity. This same pattern was not observed for the N1. We conclude that load-dependent increases in ABP may play a role in gating task-irrelevant sensory inputs during STM maintenance. Ongoing analyses are examining the potential role of frontal feedback in mediating these effects.

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26.4049 **Encoding-related neural correlates of set-size limitations of working memory** Gennadiy Gurariy[1] (genaxl@yahoo.com), Dwight Peterson[2], Marian Berryhill[1], Gideon Caplovitz[1]; [1]University of Nevada, Reno, [2]University of Missouri, Columbia

It is well established that visual working memory is capacity limited with retrieval performance declining as set size increases. The vast majority of studies investigating working memory capacity have focused on the maintenance phase of working memory tasks. In a recent study we found that neural resources allocated to individual items during encoding are an important factor in the overall capacity limitations of VWM. Here we expand upon those findings by investigating the effects of set size on encoding related processing. We use High Density Electroencephalography (HD-EEG) to analyze steady state visual evoked potentials (SSVEP) elicited by individual items in a standard change detection working memory recognition task. For each trial, participants viewed four shapes each flickering for 1s at distinct frequencies: 3Hz, 5Hz, 12Hz, 20Hz. Subjects were informed that squares presented in the array would never be probed. In this way a set size of two could be manipulated by having two of the shape be squares. After a blank delay period, a single shape appeared and participants had to respond whether the item was "old" or "new". A Fast Fourier Transform (FFT) was performed on the data from which the fundamental frequency as well as the second harmonic of the probed stimulus were extracted. Behaviorally, we found participants were more accurate on set size 2 trials than set size 4 trials. Correspondingly, across a number of electrode locations, the amplitude of the second harmonic of the probed stimulus was found to be greater in the set size 2 condition compared to the set size 4 condition. This result suggests that working memory performance declines with increased set size in part as a consequence of encoding-related neural mechanisms.

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26.4050 **Non-linear neural interactions at the time of encoding underlie grouping benefits in working memory** Kyle Killebrew[1] (kylekillabees@gmail.com), Marian Berryhill[1], Gnnadiy Gurairy[1], Dwight Peterson[2], Gideon Caplovitz[1]; [1]Psychology Department, University of Nevada Reno, [2]Department of Psychological Sciences, University of Missouri

It is well established that Visual Working Memory is capacity limited. Recent behavioral research has demonstrated that perceptual grouping can facilitate the retrieval of items stored in working memory. At what stage and by what mechanism are these grouping effects manifesting? In order to answer this question we used high-density electroencephalography (hdEEG) to examine neural correlates of perceptual grouping during the encoding phase of a standard change detection working memory recognition task. Specifically, we used an EEG technique, known as frequency tagging. This technique takes advantage of the fact that flickering stimuli will elicit a steady-state oscillation at a corresponding frequency in the EEG data. Using this technique we designed an experiment in which participants were presented with sets of four novel shapes, each flickering at one of four chosen frequencies: 3Hz, 5Hz, 12Hz and 20Hz, between black and a randomly chosen color on a grey background. The experiment consisted of two conditions: grouped and non-grouped. In the grouped condition two of the four shapes were the same, had the same color and were always presented on the same side of the screen. In the non-grouped condition, all shapes and colors were different. Behaviorally, we found that participants were significantly more accurate in performing the task in the grouping condition. This grouping benefit was accompanied by a significant increase in two non-linear harmonics of the grouped items. Conclusion: our data demonstrate that the grouping benefit observed in visual working memory tasks arises in part at the time of encoding from a non-linear neural interaction between the items comprising the group.

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26.4051 **Storing and updating non-visual features in visual long-term memory** Ghootae Kim[1] (ghootaek@princeton.edu), Kenneth A. Norman[1,2], Nicholas B. Turk-Browne[1]; [1]Department of Psychology, Princeton University, [2]Princeton Neuroscience Institute, Princeton University

It is tempting to think that visual long-term memory (VLTM) is composed of the visual features of objects we encounter. However, there is a long tradition in the memory literature of thinking of memories as inherently contextual. VLTM for objects may thus not only be based on visual features but also on non-visual features of the encoding context, such as the current task. We ran an fMRI study to examine this possibility and address two questions: (1) Are tasks previously performed on an object retrieved during subsequent object recognition? (2) How are such associations updated when we have to perform a new task on the object? In a first phase, observers were exposed to a sequence of objects, which were randomly assigned to one of two tasks: How easy would it be to draw the object? (artist task); How useful is the object? (function task). Some of these objects were presented again in a second phase with a different task: How natural is the object? (organic task). To address the first question above, we applied multivariate pattern analysis and found that, despite being irrelevant, the artist or function task initially performed on each object was automatically reactivated in the brain. Now, however, two tasks had been performed on the object, raising the question of which task(s) persisted in memory. We hypothesized that the reactivation of the first task during the organic task would trigger competition between these representations and result in the first task being weakened. Indeed, greater classifier evidence for the first task during the second phase was linked to an increased likelihood of later forgetting that this task had been performed on the object. These findings emphasize the contextual nature of visual memory and the role of competition-dependent learning in updating its contents.

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26.4052 **Reconstructing perceived and retrieved face images from activity patterns in posterior parietal cortex** Hongmi Lee[1] (hongmi.lee@nyu.edu), Alan Cowen[2], Brice Kuhl[1,3]; [1]Department of Psychology, New York University, [2]Department of Psychology, University of California, Berkeley, [3]Center for Neural Science, New York University

Recent findings suggest that posterior parietal cortex (PPC) represents information retrieved from long-term and short-term memory. However, the nature and quality of parietal memory representations remain largely unknown. Here, we tested whether exemplar-level details of perceived and remembered stimuli are represented in PPC, using a recently developed method that allows for individual face images to be reconstructed from fMRI activity patterns (Cowen, Chun, & Kuhl, 2014). The experiment consisted of two phases: perception and working memory. During the perception phase, participants viewed hundreds of faces while performing a continuous recognition task, where they judged whether each image was repeated within a block or not. For the working memory phase, we employed a retro-cue paradigm (Harrison & Tong, 2009) in which two faces were presented in rapid succession followed by a cue to maintain one of the two faces. We first tested whether individual faces can be reconstructed from PPC activity patterns elicited during perception. We estimated a regression model that mapped face components to multi-voxel activity patterns using a set of training faces. Reconstructions were then generated for a distinct set of test faces by taking linear combinations of the predicted component weights. Reconstructions created from PPC were more similar to the actually viewed face than other test faces, indicating that PPC distinguishes individual face images. We further explored whether we could reconstruct faces retrieved from working memory. We trained the model on the perception phase data and applied it to the patterns obtained during the working memory delay period. Reconstructions generated from the delay period activity in PPC exhibited above-chance similarity to the original face, suggesting that the contents of memory can be reconstructed from PPC activity patterns. Together, these findings indicate that PPC activity patterns reflect exemplar-level details of visual stimuli during perception and retrieval from memory.

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26.4053 **The decision, not the decision task, causes perceptual biases away from the decision boundary** Long Luu[1] (longluu@sas.upenn.edu), Alan Stocker[1]; [1]Department of Psychology, University of Pennsylvania

After having made a decision in a fine motion discrimination task, subjects' perceived motion direction is systematically biased away from the decision boundary. These repulsive biases were considered the result of a neural readout mechanism that is optimized for the specific discrimination task, relying on the most informative neurons whose tuning preferences are slightly away from the decision boundary (Jazayeri and Movshon, 2007). Based on this explanation we would expect the biases to disappear if subjects were given the correct answer to the discrimination task instead of performing the task themselves. We conducted two psychophysical experiments to test this prediction. Experiment 1 was aimed at replicating the effects of the original study for an orientation discrimination task. We used stimuli that consisted of an array (N=24) of small line segments (length of 0.7 degs) shown within

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a circular aperture (diameter of 5 degs). The orientation of each line segment was drawn from a Gaussian centered on the true stimulus orientation. Stimulus orientations were uniformly sampled over a range +/- 21 degrees relative to a randomly chosen reference orientation. Subjects first had to indicate whether the stimulus orientation was clockwise (CW) or counter-clockwise (CCW) of the reference orientation. Subsequently they had to reproduce the stimulus orientation. Experiment 2 was identical to Experiment 1 except that subjects were given the correct stimulus' category (CW/CCW) at the beginning of each trial. We found nearly identical repulsive biases in both experiments. Hence, we conclude that the repulsive biases cannot be the result of a task-dependent neural read-out mechanism as previously suggested. Rather, we argue that they occur in both experiments because humans i) treat their own perceptual decisions as if they were true and ii) condition their subsequent estimates accordingly as predicted by a "self-consistent" Bayesian observer model (Stocker and Simoncelli, 2008).

26.4054 **Topographically specific effects of TMS over early visual cortex during visual working memory** Rosanne Rademaker[1] (rosanne.rademaker@maastrichtuniversity.nl), Vincent van de Ven[1], Frank Tong[2], Alexander Sack[1]; [1]Cognitive Neuroscience Department, Maastricht University, [2]Psychology Department, Vanderbilt University

Recent fMRI studies demonstrated that patterns of activity in early visual cortex (V1-V4) are predictive of stimulus properties actively maintained in visual working memory. However, exactly why sensory areas represent such information, and whether they are necessary for successful high-precision maintenance, remains largely unknown. In this study, observers remembered the orientations of 4 briefly presented gratings (200ms), one in each quadrant of the visual field. Triple-pulse TMS was applied either directly at stimulus offset, or midway through a 2-second retention interval, targeting early visual cortex corresponding retinotopically to a sample item in the lower hemifield. After retention, memory for one of the gratings was randomly probed, independent of the location targeted with TMS, and participants reported the remembered orientation. Memory performance, defined as the absolute error between memory target and response, was best when the visual field location targeted by TMS overlapped with that of the cued memory item. This result implies that information about memorized items was stored in a topographic fashion in early visual cortex, and that triple-pulse TMS had a memory-enhancing effect at the targeted location. Memory enhancement was most prevalent when TMS was applied midway through the retention, with memory performance being generally worse for early TMS pulses. Next, empirical fitting of the errors was performed (using a mixture model analysis) to characterize memory precision and forgetting rates. Memory was more precise for items coinciding with the pulse location, irrespective of pulse timing. The probability that items were forgotten was larger when pulses were delivered early, regardless of their proximity to the pulse location. Thus, whereas TMS administered at the offset of the stimulus array might disrupt early-phase consolidation, TMS during the retention phase acts to boost the precise representation of an item in working memory, perhaps by increasing attentional resources at its retinotopic location.

26.4055 **Task-modulated, feature-selective responses in early visual, parietal and frontal cortices during visual working memory maintenance** Qing Yu[1] (qing.yu.gr@dartmouth.edu), Won Mok Shim[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College

Recent fMRI studies have revealed that the parietal and frontal cortices, as well as the early visual areas, convey memory-related, feature-selective information during visual working memory maintenance (Ester & Serences; Yu & Shim, VSS 2014). However, it remains unclear if such feature-tuning responses are modulated by task demand. In the current study, using fMRI and a forward encoding model (Brouwer & Heeger, 2009; 2011), we examined the effect of task-relevance on the voxel-based, feature-selective tuning responses over memory delay. On each trial, two gratings with different colors and orientations were presented sequentially. Participants remembered color, orientation, or both color and orientation of the cued grating. The stimuli and procedure remained identical across conditions, and only the to-be-remembered feature dimension(s) differed. After a long delay period, participants were required to reproduce the remembered feature as accurately as possible on an orientation/color wheel. We successfully reconstructed color-selective as well as orientation-selective population tuning responses in early visual areas (V1-V4v), IPS and FEF during the retention period. These results indicate that non-spatial surface features, such as color, can be retained over delay even in parietal and frontal areas. Crucially, the two features showed distinct task-modulated effects during working memory: orientation tuning responses were significantly degraded when orientation was not remembered, whereas color tuning responses remained similar regardless of whether color was remembered or not. This result is consistent with behavioral memory precision measures, which showed that color memory is more immune to task demands than orientation memory. Therefore, our results suggest that the quality of the reconstructed feature-tuning responses in early visual, parietal, and frontal areas during memory delay can reflect the strength of each feature representation in multi-feature objects in working memory, even when that feature is task-irrelevant.

Attention: Capture

Saturday, May 16, 2:45 - 6:45 pm
Poster Session, Pavilion

26.4056 **The effects of saliency on manual reach trajectories and reach target selection** Dirk Kerzel[1] (dirk.kerzel@unige.ch), Wieske van Zoest[2]; [1]Faculté de Psychologie et des Sciences de l'Éducation, Université de Genève, Switzerland, [2]Center for Mind / Brain Sciences, University of Trento, Italy

Reaching trajectories curve toward salient distractors, reflecting the competing activation of reach plans toward target and distractor stimuli. We investigated whether the relative saliency of target and distractor influenced the curvature of the movement and the selection of the final endpoint of the reach. Participants were asked to reach a bar tilted to the right in a context of gray vertical bars. A bar tilted to the left served as distractor. Relative stimulus saliency was varied via color: Either the distractor was red and the target was gray, or vice versa. Throughout, we observed that reach trajectories deviated toward the distractor. Surprisingly, relative saliency had no effect on the curvature of reach trajectories. Moreover, when we increased time pressure in separate experiments and analyzed the curvature as a function of reaction time, no influence of relative stimulus saliency was found, not even for the fastest reaction times. If anything, curvature decreased with strong time pressure. In contrast, reach target selection under strong time pressure was influenced by relative saliency: Reaches with short reaction times were likely to go to the red distractor. The time course of reach target selection was comparable to saccadic target selection. Implications for the neural basis of trajectory deviations and target selection in manual and eye movements are discussed.

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26.4057 **The impact of long-term memory based attentional control settings on spatial and non-spatial components of attention** Maria Giammarco[1] (agiammar@uoguelph.ca), Kate Turner[1], Emma Guild[2], Naseem Al-Aidroos[1]; [1]Psychology Department, College of Social and Applied Human Sciences, University of Guelph, [2]Krembil Neuroscience Centre, University Health Network

In recent work we demonstrated that long-term memory can guide the capture of visual spatial attention. Specifically, when participants look for any of a number of task-relevant objects in their visual environment, they adopt attentional control settings (ACSs) based on representations of the target objects in episodic long-term memory. With these ACSs implemented, cues in an attention cueing task only capture visual spatial attention when they match targets in memory. In the present study we investigated how contingent cueing is affected by varying memory demands. In Experiment 1 participants studied 2, 4, 8, or 16 images of visual objects (set size was manipulated across blocks); these objects were then designated as targets in a subsequent cueing task. Specifically, participants monitored two spatial locations for the appearance of studied objects; shortly beforehand, one of the two locations was cued by either a studied or non-studied object. We observed differences between studied and non-studied cueing effects (ie., an effect of ACSs), and no differences in cueing effects across set size; however response times (RTs) appeared to be influenced by forward masking on cued trials. We examined masking in Experiment 2 by comparing trials with no cues, two studied cues, or two non-studied cues across set sizes. Because both target locations were cued (or not), differences between conditions are unlikely to reflect spatial attention, but should reveal masking effects. Consistent with masking, participants were significantly faster on no-cue trials versus non-studied-cue trials. Interestingly, RTs were even slower for studied-cue trials, and this effect increased with set size. These data provide evidence that episodic-contingent cueing is unaffected by set size, and that studied cues have an additional, non-spatial effect on RTs. That this later effect is mediated by set size, suggests it may be an effect of reflexive long-term memory retrieval on perception.

26.4058 **Bottom-up capture is a top-down phenomenon** Yehoshua Tsal[1] (Jehoshua@freud.tau.ac.il), Ricardo Max[1], Hanna Benoni[2]; [1]Tel Aviv University, [2]Department of Psychology, College of Management

pAttentional capture produced by a task-irrelevant color singleton is assumed to reflect stimulus-driven processing, completely governed by bottom-up factors. Results from two converging paradigms – search reaction time and free letter report – support the conclusion that singleton capture is fully determined by (top-down) expectation. The first series of experiments resulted in strong expectation-based capture when the color singleton is expected in a given location (or color) but is not actually presented. For example, when participants are presented with a sequence of trials with a red singleton (among green items) randomly switching among four positions, attention ends up being captured by red stimuli within a non-singleton (four color) display (red, green, blue and yellow) presented unexpectedly. In the second series of experiments we eliminated singleton expectation by embedding singleton displays with visually similar but non-singleton displays. For example, participants were presented with nine letter circular displays with all possible combinations of red and white letters, of which a fourth of the trials were singleton displays (one red letter among eight white letters, or one white letter among eight red letters). In this condition singleton capture was completely eliminated (i.e. did not exceed chance - calculated separately for each participant). We conclude that singlet on capture is a top-down phenomenon originated from pervasive mental programs that direct the attentional system to seek out unique items in the visual field irrespective of task demands. We speculate that the rationale for such programs may derive from the fact that whereas processing several identical non-singleton items is redundant, processing the singleton, which is statistically most likely to be missed (one vs. many), provides important unique information.

26.4059 **Attentional and oculomotor capture by stimuli that signal the availability of reward** Jan Theeuwes[1] (J.Theeuwes@psy.vu.nl), Michel F. Failing[1]; [1]Vrije Universiteit, Amsterdam, Netherlands

It is well known that attentional selection is influenced by our previous experience of rewards. Stimuli whose selection was previously rewarded continue to capture attention in a subsequent test session when these rewards are no longer available. In this study we provide evidence of both attentional and oculomotor capture by stimuli that merely signal the magnitude reward available on a particular trial. The selection of these stimuli was not necessary but rather detrimental for actual payout. Participants searched for a target (a diamond) among 5 uniquely colored circles. The color of one of these circles signaled the magnitude of reward available for that trial (e.g., a red circle would indicate a high reward, a green circle a low reward). Even though this colored circle signaling the reward availability was never part of the task set nor physically salient, it captured both attention and the eyes. Our results suggest that stimuli signaling reward get prioritized through reward-learning and that this learning only occurs when the reward signaling stimuli are attended. We conclude that task-irrelevant and non-salient stimuli that signal the availability of reward gain priority in attentional selection even if selecting them is not necessary but rather detrimental for reward payout. Furthermore we show that a stimulus signaling reward only gained priority if it was the only stimulus predicting reward outcome. These findings expand the growing evidence which suggests that attentional selection cannot fully be explained in terms of the traditional separation in top-down and bottom-up processes (Awh, Belopolsky & Theeuwes, 2012).

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26.4060 **Forget Me if You Can: Attentional capture by to-be-remembered and to-be-forgotten visual stimuli** Edyta Sasin[1] (e.sasin@rug.nl), Mark Nieuwenstein[1]; [1]Department of Experimental Psychology, University of Groningen

Previous research has shown that visual attention is biased towards items that match the content of working memory (WM). Here, we investigated whether attention is still guided towards matching items after an instruction to forget them. Participants memorized a colored shape, which was followed by a cue that indicated whether it should be remembered or forgotten. Subsequently, participants searched for a tilted line among vertical distractor lines, each embedded within a colored shape. The interval between the cue and the visual search task was 200, 600, 1000 or 1400 ms and on some trials, one of the distractors in the search task matched the earlier-memorized object. The results showed that the matching distractor captured attention regardless of whether it had to be remembered or forgotten, but the capture effect by to-be-forgotten distractors was smaller. In addition, the capture effects were independent on the interval separating the cue and the search array. Taken together, these results suggest that an instruction to forget an earlier-memorized object attenuates but does not fully abolish memory-driven capture.

26.4061 **Oculomotor capture by the unexpected: exploring the temporal profile of surprise in visual search.** James Retell[1] (j.retell@uq.edu.au), Dustin Venini[1], Stefanie Becker[1]; [1]The University of Queensland

New and unannounced color singletons have been shown to capture attention and induce surprise during visual search; a phenomenon referred to as ‘surprise capture’ (Horstmann, 2005). Interestingly, it has been reported that the temporal profile of capture by new and unannounced stimuli is distinct from that of capture by expected stimuli (Horstmann, 2002; 2005; 2006). Specifically, it has been argued that attention shifts to unexpected stimuli are delayed relative to expected stimuli. This claim is interesting because it points to separate underlying attentional control mechanisms for expected and unexpected stimuli. However, much of the work investigating capture by the unexpected has done so using behavioral measures such as response time and response accuracy; measures that can be affected by decision and response level processes that are often unrelated to search. Here we used eye-movements as the primary index of attentional selection to explore the temporal profile of surprise capture and to investigate the claim that shifts of attention to unexpected stimuli are delayed relative to expected stimuli. Across two experiments we found little evidence to support the claim that shifts of attention are delayed to unexpected stimuli during visual search. Rather, the temporal profile of surprise capture appears to reflect delays that manifest post attentional selection that are likely associated with decision and response level processes.

26.4062 **Set-specific contingent attentional capture costs are modulated by color similarity** Katherine Moore[1] (katherine.moore@elmhurst.edu), Greg Ramos[2], Kathleen Trencheny[1]; [1]Department of Psychology, Elmhurst College, [2]Department of Psychology, Notre Dame University

Contingent attentional capture costs can double or triple when participants search for multiple targets simultaneously (e.g. pink and green letters). Specifically, these costs occur when a distractor related to one goal (e.g. a pink digit) appears on the same trial as a target related to another goal (e.g. a green letter). We call this effect “set-specific capture,” because the pink distractor captures attention and causes a corresponding enhancement of the “search for pink letters” attentional set over the other “search for green letters” set (Moore & Weissman, 2010, 2011, 2014). In the present investigation, we examined whether color similarity has an impact on a) how attentional sets are maintained in a dual-target search, and b) set-specific capture costs incurred by attentional set enhancement. Participants searched for letters appearing in either of two colors in a continuous rapid serial visual presentation (RSVP) stream. Half of participants, in the “opponent” group, searched for color opponents (e.g. pink and green) on opposite ends of an isoluminant, equally saturated color wheel. The other half, in the “similar” group, searched for colors separated by approximately 120° on the same wheel (e.g. purple and orange). For both groups, distractor letters appeared in the RSVP stream that linearly separated the target colors in color space, ensuring participants maintain two distinct attentional sets. Overall target identification accuracy did not differ across groups, indicating that color similarity does not have an impact on the maintenance of attentional sets, as long as the colors are linearly separable. However, set-specific capture costs were significantly greater in the “opponent” group, suggesting that attentional set enhancement may capitalize on opponent-process circuitry: when two attentional sets are maintained simultaneously, enhancement of one may cause inhibition of its color opponent.

26.4063 **Context-driven suppression of attentional capture** Jeff Moher[1] (jeff_moher@brown.edu); [1]Williams College

Context plays a powerful role in guiding attention towards relevant objects. In the present study, we investigated whether context can similarly drive salient distractor suppression. Observers were asked to indicate the orientation of the line inside a singleton shape target (e.g., one diamond among five circles). On some trials, a salient color (red) singleton distractor was presented. Otherwise, all objects were presented in either all green or all blue (hereafter labeled display color); display color varied randomly from trial-to-trial. While salient distractors typically capture attention, capture is reduced when distractors appear frequently (e.g., Müller et al., 2009). Thus, we varied the probability that a salient distractor would be present as a function of the display color. One display color was associated with a high probability that a salient distractor would be present (80%), and the other color was associated with low singleton distractor prob-

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ability (20%). Color contingencies were counterbalanced across participants, and debriefing questionnaires revealed that participants were not aware of color contingencies. On distractor present trials, response times were shorter when the display color indicated high distractor probability (1113 ms) relative to low distractor probability (1139 ms). Thus, observers were able to learn context-specific distractor probabilities and selectively implement distractor suppression mechanisms when a distractor was highly likely. Furthermore, compatibility effects – response times depending on whether the line inside the distractor matched the line inside the target - were also greater in the low probability condition (80 ms) than in the high probability condition (12 ms). This result indicates processing of the distractor line on high probability trials was minimal, again consistent with increased distractor suppression in contexts where salient distractors are likely. Together, these results indicate that distractor suppression is selectively applied in contexts where distractors are expected. Thus, contextual learning can drive salient distractor suppression.

26.4064 **Feature-driven attentional capture is modulated by the distribution of spatial attention** Carly Leonard[1] (cjleonard@ucdavis.edu), Steve Luck[1]; [1]Center for Mind and Brain, University of California, Davis

Feature-based attention is often described as being global, although it is unclear if this only occurs in situations that support a broad window of spatial attention or whether this is a more obligatory phenomenon. Leonard et al. (in press, JEP:HPP) have shown that capture by a peripheral distractor that shares a target feature (i.e., contingent capture) is reduced as the distance of the distractor from the locus of spatial attention increases. These results suggest a strong interaction with spatial attention. If feature-based effects are interactive with spatial attention, changes in the distribution of spatial attention should modulate the magnitude of feature-driven capture. The current experiments include manipulations that should theoretically alter the spatial distribution of attention during task performance. The task required the identification of a single target-colored letter in a rapid serial visual presentation stream of other task-irrelevant letters. A manipulation of the frequency of nearby distractors might be expected to alter the distribution of spatial attention, and accordingly we found that capture effects were reduced when there was a higher frequency of proximal distractors. Other experiments further examine this interaction using different manipulations of task difficulty and similar-distractor frequency. Overall, the general pattern of results supports the hypothesis that spatial attention is critical in mitigating contingent attentional capture, supporting an interactive rather than purely global model of feature-based attention.

Acknowledgement: R01MH076226 and R01MH065034.

26.4065 **Inter-Trial Contingencies in Contingent-Capture Experiments** Florian Goller[1] (florian.goller@univie.ac.at), Ulrich Ansorge[1]; [1]Department of Basic Psychological Research and Research Methods, University of Vienna

Several studies showed that attention can be captured in a top-down contingent way. Here, attention capture by cues depended on a match of cues' features to the features of the searched-for targets. However, the influence of the cue-target position relations in a preceding trial n-1 has not been considered in most studies, although these relations can have an influence: Cueing effects in a trial n can be larger if the preceding trial n-1 was valid rather than invalid (Gratton Effect). Such inter-trial contingencies could contribute to contingent-capture effects, but this was never tested. The aim of our study was to fill this gap. We used the classic contingent-capture protocol and analysed cueing effects in trial n as a function of cue validity (valid versus invalid) and cue type (matching versus non-matching) in trial n-1. In Experiment 1, participants searched for a white onset target. A valid cue in trial n-1 boosted the cuing effect in a subsequent trial n, which indicates a Gratton effect. Surprisingly, these inter-trial contingencies did not hold for matching onset cues but only for non-matching red color cues. Similar effects of the non-matching cues were also found if cues and targets both changed their positions from trial to trial, rendering position priming as an unlikely explanation (Experiment 2). However, no inter-trial contingencies were found during search for red color targets (Experiment 3). In an additional experiment, we explored whether task difficulty may be an important moderator for inter-trial contingencies in the contingent-capture paradigm. Our results provide a new perspective on contingent capture and add to the growing literature on the importance of inter-trial contingencies.

26.4066 **Behavioral Evidence of Top-Down Suppression of Attention Capture with the Letter-Probe Technique** Nicholas Gaspelin[1] (ngaspelin@ucdavis.edu), Steven Luck[1]; [1]Center for Mind and Brain, University of California, Davis

There is considerable debate about how visual attention is involuntarily drawn to salient stimuli (called attention capture). Stimulus-driven theories posit that certain super salient stimulus features automatically capture attention, whereas goal-driven theories posit that only stimuli matching our attentional set (i.e., what we are looking for) capture attention. In the current study, we test a hybrid account (called the signal suppression theory), which posits that salient stimuli produce an automatic "attend-to-me" signal but that this signal may be suppressed if the observer exerts strong top-down control. To test this hypothesis, we used a modified additional singleton paradigm in which participants searched for a target shape and attempted to ignore an irrelevant color singleton. We manipulated search mode (singleton-detection mode vs. feature search mode) to encourage or discourage attention capture. On a small subset of trials, participants were instead asked to perform a probe task. On these trials, letters appeared briefly at each search location and participants reported all letters they saw. When singleton detection mode was encouraged, attention capture was observed on the no-probe trials. On probe trials, participants were more likely to report the singleton probe letter than distractor or target probes. When feature search mode was encouraged, capture was not observed on the no-probe trials. On probe trials, participants were less likely to report the singleton probe letter than the target or distractor probes. This behavioral evidence corroborates previous ERP-based evidence of top-down suppression of singleton distractors when participants are in feature search mode. In addition, the finding that singleton detection mode led to improved probe processing at the singleton location provides strong evidence against the hypothesis that attention capture effects in the additional singleton paradigm reflect "filtering costs" (a generalized slowing of responses) rather than true capture of attention to the singleton's location.

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26.4067 **The Influence of Salience on Attentional Capture by Set-Consistent and Set-Inconsistent Stimuli** Charles Folk[1] (charles.folk@villanova.edu), Charles Folk[1]; [1]Department of Psychology, Villanova University

There is now substantial evidence that the capture of attention by salient, irrelevant stimuli is modulated by top-down attentional control settings. For example, when searching for a target defined by a particular color, irrelevant , noninformative spatial precues that match the color of the target produce cuing effects consistent with capture, whereas those that do not match the target color produce no evidence of capture. This suggests that attentional capture is not simply a function of bottom-up salience. In the present experiments, we explore the potential interaction between bottom-up salience and top-down set. Participants searched for targets of a particular color preceded by irrelevant, non-informative precues that either matched or did not match the target color. Critically, the salience of the precues was also systematically varied by adding apparent motion to the cues on half the trials. The results revealed that non-matching cues produced no evidence of attentional capture, regardless of whether their salience was enhanced with apparent motion. However, when the cues matched the target color, significant cuing effects were obtained, and the magnitude of those effects was significantly increased when the cues were rendered more salient by apparent motion. Thus, cross-dimensional bottom-up salience plays a role in attentional capture, but only for stimuli matching the current top-down set.

26.4068 **Recapturing captured attention** Fook Chua[1] (fkchua@nus.edu.sg); [1]Department of Psychology, National University of Singapore

This work examined the limits of re-capturing attention that had just been captured. Specifically, the question was whether attentional capture by some types of stimuli leads to a more robust engagement, thereby hampering attempts at re-capturing attention. The experiments used the contingent capture paradigm. Each trial consisted of three frames: a (1) fixation frame containing nine objects, of which six were "filled", each enclosing a placeholder and surrounded by four grey spots. The (2) capture frame appeared thereafter, with the spots surrounding all the filled objects changing to the same color (e.g., yellow), except for a single set which changed to a different color (e.g., blue), making the latter a color singleton. The (3) search frame then appeared: the spots disappeared and the placeholders turned into letters. All the objects changed to one color (e.g., green), except for one object which changed to a unique color (e.g. red). The task was to locate this color singleton and identify the letter that it enclosed. If attention had been captured by the singleton spots, the search latencies would be shorter if

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the target appeared in the same location as the spots (a valid trial) than if it appeared elsewhere (an invalid trial). To examine whether attention could be re-captured, the single-capture condition, described above, was contrasted with the double-capture condition, in which a second capture stimulus was presented 150 ms after the first, e.g., one set of the yellow non-singleton spots turned blue. Attention re-capture was diagnosed by comparing latencies when the target appeared in the second capture location, or in a different location. The results showed that attention re-capture occurred if the second capture stimulus possessed the target's diagnostic feature. But, if attention had initially oriented to an object possessing this diagnostic feature, re-capturing attention to a different location was unlikely.

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26.4069 **ERP correlates of contingent attentional capture and suppression** Caroline Barras[1] (caroline.barras@unige.ch), Dirk Kerzel[1]; [1]University of Geneva

We investigated the processing of stimuli associated with behavioral inhibition. Different target colors told participants to either execute the response (go trial) or to withhold the response (nogo trial). Four letters appeared in each of four placeholders but only the target was colored. On go trials, participants had to indicate the identity of the target letter by pressing one of two keys. The cue disks appeared 150 ms before target onset and were displayed around the four placeholder boxes in which the letters were displayed. One set of cue disks was colored. Cue and target color were equal on 50% of trials. The cue position did not predict the target position, but behavioral results showed faster responses with valid cues on go-trials. The EEG results showed that the cues in the color of the nogo-target triggered a Pd, whereas the cues in the color of the go-target triggered an N2pc. The N2pc component was considered a measure of attentional capture whereas the distractor positivity (Pd) is assumed to reflect attentional suppression. Our findings suggest that processing of the colored cue was modulated by the response requirements associated with the two colors. The intention to inhibit a response led to attentional suppression of the associated color, whereas the intention to respond led to attentional enhancement, even when the cue required no response. Thus, the attentional enhancement or suppression serves to prepare behavioral decisions.

Acknowledgement: FNS 100014_152684 / 1

26.4070 **Electrophysiological indices of learned distractor suppression** Joshua Cosman[1] (joshua.d.cosman@vanderbilt.edu), Geoffrey Woodman[1]; [1]Vanderbilt University Department of Psychology

The extent to which a salient distractor captures attention during visual search depends on a number of bottom-up and top-down factors. We have recently demonstrated that in order to effectively overcome attentional capture individuals must learn to ignore distractor-defining features, with behavioral capture effects decreasing as exposure to these features increases. In the current work, we examined the electrophysiological signature of this distractor-related learning process, examining ERP components related to both attentional selection (N2pc) and distractor suppression (Pd). Participants performed a simple visual search task in which they searched heterogeneous displays for a shape-defined target while ignoring a salient color singleton distractor that appeared on half of trials. Critically, we manipulated participants' ability to learn distractor-defining features from block to block. In fixed distractor blocks distractor color was held constant throughout block, allowing participants the opportunity to learn and suppress the distractor-defining feature. Conversely, in random distractor blocks distractor color varied unpredictably from trial to trial, eliminating the ability of participants to learn a specific distractor-defining feature. In random distractor blocks we observed behavioral capture effects and an N2pc to the distractor item, suggesting that the distractor captured attention. In contrast, in fixed color blocks we observed a decrease in behavioral capture effects and a Pd to the distractor item, suggesting that participants were able to learn distractor-defining features and use this information to attenuate the influence of the distractor on performance. In addition, in fixed blocks the Pd emerged after ~15 trials of exposure to the distractor, suggesting a rapid learning process enabling distractor suppression. This is consistent with behavioral results showing that the effectiveness of top-down control over attentional capture relies on having sufficient exposure to distractor defining features, and underscores the importance of feature-based learning processes in attentional control.

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26.4071 **Loosening the Snare: Top-down goals overcome singleton driven attentional capture** Corbin Cunningham[1] (cunningham@jhu.edu), Howard Egeth[1]; [1]Johns Hopkins University

Previous work suggests that salient distractors capture attention during visual search (Theeuwes, 2010). However, additional studies have demonstrated that this is not always the case. For example, when observers search for a specific shape feature (e.g. a square), they are able to overcome attentional capture by a color singleton (Egeth, Leonard, & Leber, 2010). Alternatively, when observers are not given specific information about what the target will look like (i.e., search for any singleton shape), they are captured by the presence of an irrelevant color singleton. Can observers learn to use top-down attentional goals during singleton search to suppress capture by a salient distractor? Our study utilized a between-subjects design where both groups received two trial types: trials with a salient distractor singleton (either a red among green objects or a green among red objects, counterbalanced across participants) and trials without a salient distractor (either all green or all red). Observers searched for an oddball letter in a circular array (a B among Fs or a F among Bs) and responded whether the letter was capitalized or lowercase. The target letter and the set of distractor letters were each randomly assigned a case (capitalized or lowercase) on each trial. Critically, for one group we provided cues prior to trials with a salient distractor (e.g. "Ignore Green") and cues for trials without salient singleton distractors ("Neutral"). Results revealed that observers who received cues learned to overcome singleton-driven attentional capture. However, the group that did not receive cues demonstrated typical attentional capture for the duration of the experiment. Additionally, we found that the group that received cues was faster than the group that did not receive cues, suggesting that the additional top-down goal processes did not result in less efficient search. These results indicate that distractor expectancy can override attentional capture.

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Perceptual Organization: Contours and surfaces

Saturday, May 16, 2:45 - 6:45 pm
Poster Session, Pavilion

26.4072 **Modal and amodal shape completion** Vicky Froyen[1] (vickyf@rutgers.edu), Naoki Kogo[2], Manish Singh[1], Jacob Feldman[1]; [1]Center for Cognitive Science, Department of Psychology, Rutgers University, New Brunswick, USA, [2]Laboratory of Experimental Psychology, Katholieke Universiteit Leuven, Leuven, Belgium

Shape completion is essential for representing the visual world under conditions of partial occlusion. A number of accounts of shape completion have been proposed, some of which entail differences between modal (completing in front) and amodal (completing behind) cases. Our aim in this study was to better understand shape completion in general, to clarify what differences, if any, exist between modal and amodal completion, and specifically to understand how probabilistic estimation of the visual interpolated contour might differ in the two cases. Stimuli consisted of a red circle to which Gaussian noise was added at three levels of standard deviation. Overlaid on the circle was a dark triangle, and the circle was set up so that across all conditions the inducers' location and orientation was fixed. The circle was shown in either positive disparity (modal condition), or negative disparity (amodal condition) relative to the triangle. The visually completed shape perceived by the subject was measured by flashing a dot on top of the inducer, after which the subject had to indicate whether the dot appeared inside or outside the circular shape. A staircase procedure was used to find the distribution over possible perceived completions for each condition. The stimulus setup allowed us to readily compare different completion models. We found that the distribution over completions differed across different levels of standard deviation, even though the geometry of the local inducer was held constant, meaning that shape completion was influenced by statistical aspects of the global shape. For most subjects, we replicated the strong tendency for the perceived completing contour to be pulled "inward" towards the center of the circle. Overall, the results cannot be explained by conventional completion models, and suggest that modal and amodal completion processes embody somewhat different probabilistic assumptions about shapes.

26.4073 **Spatially-global integration of closed, fragmented contours** Tae Kwon[1] (kwont@purdue.edu), Kunal Agrawal[2], Yunfeng Li[1], Zygmunt Pizlo[1]; [1]Department of Psychological Sciences, Purdue University, [2]Department of Computer Science, Purdue University

Finding the occluding contours of the objects in real 2D retinal images of natural 3D scenes is done by determining, which contour fragments are relevant, and the order in which they should be connected. This task, until recently, has been considered to be insoluble. Spatially-local operations, which are used by almost everyone, never guarantee producing globally-optimal solutions. Spatially-global operations are also impractical because of combinatorial explosion. We developed a spatially-global model that finds the closed contour represented in the image by solving a shortest path problem (SPP) that uses a log-polar representation of the image; the kind of representation known to exist in area V1 of the primate cortex. This works because the shortest path in a log-polar representation favors smooth, convex and closed contours in the retinal image, with the minimum number of gaps. Furthermore, this approach is practical because finding a globally-optimal solution to SPP is computationally easy. Our model was tested in a psychophysical experiment in which the subject was presented with a fragmented convex or concave polygon target among a large number of unrelated pieces of contour (distracters). The density of the pieces of contour was made uniform all over the screen to minimize spatially-local cues. The orientation of each target contour fragment was randomly perturbed by varying levels of jitter. Subjects were required to draw a closed contour on a screen representing the target. The subjects' performance was nearly perfect when the jitter-level was low. Their performance deteriorated as jitter-levels were increased. The performance of our SPP model was as good as our subjects' with the convex polygons. It was not as good with the concave polygons until we revised it by adding a local interpolation at its front-end. Our revised model can detect both convex and concave polygons as well as our subjects do.

Acknowledgement: National Eye Institute

26.4074 **It is more difficult to judge global properties of shapes described by vertices than shapes described by curvature extrema.**

Letizia Palumbo[1] (l.palumbo@liverpool.ac.uk), Nicole Ruta[2], Marco Bertamini[1]; [1]Department of Psychological Sciences, University of Liverpool, UK., [2]Department of Psychology, Sapienza University of Rome, Italy.

Contours are important to perceive solid shape. Along contours extrema of curvatures (convexities and concavities) specify surface curvature. Vertices of polygons are a special case of extrema assuming that when a vertex is perceived as convex (or concave) its processing is similar to the processing of a positive maximum (or negative minimum). The famous Attneave's cat was described by a set of vertices. There is also a corner enhancement phenomenon: faster responses to probes located near vertices (as opposed to straight contours). We used polygons and their smoothed versions to compare vertices and extrema in two tasks involving global properties of shape. In the smoothed versions a cubic spline removed the vertices. In Experiment 1 observers discriminated stimuli with bilateral symmetry from random stimuli. To test the importance of objectness the contours were either closed to form a single object, or faced each other to form two separate objects. In Experiment 2 observers decided whether a pair of stimuli were identical (translation) or different. In both experiments the presence of vertices or curvature extrema was task irrelevant. Counterintuitively, vertices can make the task harder because the visual system is tuned to processing smooth curvature. Therefore we expected lower performance on reaction time, accuracy and sensitivity (d prime) for polygons. In both Experiments when stimuli were regular (bilateral symmetry in Experiment 1, translation in Experiment 2) smooth contours led to better performance. In our experiments perception of global shape from contours was harder when the convexities and concavities were vertices as opposed to curvature extrema. Note that the involvement of global shape properties in our tasks is critical, as responses to vertices are very fast in a simple detection task. These findings are discussed in relation to theories of shape representation.

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26.4075 **Visual acuity differences within the normal range strongly alter visual perception: A cautionary tale for studies of special populations**

Matthew Roche[1] (rochemw@rutgers.edu), Brian Keane[1,2,3], Sabine Kastner[4,5], Thomas Papathomas[3], Steven Silverstein[1,2]; [1]University Behavioral Health Care, Rutgers, The State University of New Jersey, [2]Department of Psychiatry, Rutgers, Robert Wood Johnson Medical School, [3]Center for Cognitive Science, Rutgers, The State University of New Jersey, [4]Princeton Neuroscience Institute, Princeton University, [5]Department of Psychology, Princeton University

The majority of studies that examine visual processing in special populations ensure that subjects have normal or corrected-to-normal vision, without also reporting whether subject groups are matched on visual acuity (VA) within the normal range. This is problematic because many factors compromise VA (e.g., aging, schizophrenia) and optimal VA among healthy younger adults is better than 20/20. Therefore we ask: Do VA differences within the normal range alter visual performance? To consider the question, we measured binocular VA with a logarithmic eye chart, and compared healthy adults with 20/20 vision (N=13) to those with better-than-20/20 vision (SharpPerceivers, N=23) on three behavioral tasks. In the contour integration (CI) task, subjects located an integrated shape embedded in varying quantities of randomly-oriented noise elements; in the collinear facilitation task, subjects detected a low-contrast element flanked by collinear or orthogonal high-contrast elements; in the discrimination task, subjects discerned the orientation of four briefly-presented, high-contrast pac-man elements. The SharpPerceivers integrated contours under noisier conditions ($p < .001$), benefited more from collinear flankers ($p < .05$), had higher contrast sensitivity ($p=.002$) and discriminated orientation more accurately than the 20/20 group ($p=.02$). To verify that refractive error generated these results, 5 additional observers ran the above tasks, once with 20/20 uncorrected vision (logMAR=-.04) and once with optical correction (better than 20/20; logMAR=-.14). Even with this small sample, we found worse CI and lower contrast sensitivity when subjects were not wearing their corrective lenses ($ps < .05$). Therefore, previous studies reporting contour integration, collinear facilitation, contrast sensitivity, or orientation discrimination in aging, development, or mental disorders may need to be re-evaluated if they did not match for VA within the normal range. Our results also offer a surprisingly powerful explanation of individual differences and show that residual refractive error strongly alters visual performance for observers with 20/20 vision or better.

Acknowledgement: F32MH094102

26.4076 **The integration of edge and region cues: the effect of a compressive nonlinearty in search tasks**

Alexander Coningham[1] (alex.coningham@gmail.com), Geoff Stuart[2], Ken McAnally[2], Mark Edwards[1]; [1]Research School of Psychology, Australian National University, Australia, [2]Aerospace Division, Defence Science and Technology Organisation

Contrasting hypotheses for the interaction of edge and region information in object conspicuity advocate additive or nonlinear strategies. Results from studies that assess the interactive contributions of edge and region information to target conspicuity via search time often report nonlinear feature combination, whereas the results from paradigms employing subjective evaluations of conspicuity such as pair-wise comparisons often report linear summation. We suggest that this discrepancy is due to the compressive influence of a floor effect in search paradigms, where subjectively discriminable conspicuities in search tasks manifest subadditive feature summation due to a generalised floor effect. In an investigation of the relative contributions of edge and texture information to object conspicuity, we employed both a search task and a subjective conspicuity ranking task to explore this hypothesis. We developed filtered noise textures that enabled the independent manipulation of a target's edge and region information. Edges were manipulated via logistic blurring (95% of the blur function occurred over 0.105, 0.315, 0.630 or 2.520 deg), resulting in edge strengths from sharp to unnoticeable. Region texture content was manipulated both in scale (0%, 15% and 30%), and orientation (0, 8, or 16 degrees), relative to background texture. Results from both paradigms suggest a critical role for edge information, a strong contribution of scale contrast, and a relatively weaker contribution of orientation contrast. Results from the subjective ranking paradigm suggest that features are combined via linear summation. Results from the search paradigm also suggest summation once the compressive nonlinearity induced by the performance ceiling has been accounted for.

26.4077 **Attentional Effects in Contour Integration in Dynamic Scenes**

Axel Grzymisch[1,2] (axel@neuro.uni-bremen.de), Cathleen Grimsen[1], Udo Ernst[1,2]; [1]University of Bremen, [2]Institute for Theoretical Physics

Contour integration (CI) is an integral part of visual information processing requiring the combination of aligned edge configurations into coherent percepts. Subjects are efficient at detecting contours, reaching peak performances for stimulus presentation times of 100-200ms. CI research usually employs flashed static stimuli, making this an artificial situation compared to the continuous observation of everyday scenes. We addressed this discrepancy between commonly employed stimuli in CI and natural vision by employing novel dynamic stimuli comprising slowly rotating Gabor elements. Contours formed at predefined times and locations when 10 Gabor aligned. We expect these stimuli to better approximate natural vision as they require sustained observation and accounting of dynamic changes to generate a coherent picture of a visual scene in order to detect

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the appearance of a contour. Since CI is believed to be a pop-up effect we expected similar performances for brief and extended presentations. However, results show a statistically significant ($t(8)=8.83$, $p< 0.001$) drop in performance of 19.5% for extended presentations of varying lengths, between 1840ms and 3680ms, when compared to a peak performance of 87% for a presentation time of 230ms. This dramatic decrease in performance led us to hypothesize that contour perception in extended presentations is a more demanding task, hence, that it might draw higher benefits from attention than brief presentations. By employing distinct single cues, and their combinations, we evaluated the capabilities of the visual system to use and combine independent information about a target. Cues targeting feature-based attention and location-based attention lead to a 6.7% and a 5.5% improvement in performance, respectively, when compared to a no-cueing condition in extended presentations. Their combination lead to an apparent additive effect, significantly ($t(8)=3.3$, $p< 0.05$) improving performance by 12.2%, thus restoring most of the decrease in performance seen between the peak condition and the extended condition.

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26.4078 The spatial range of peripheral collinear facilitation

Marcello Maniglia[1,2] (marcello.maniglia@gmail.com), Andrea Pavan[3], Yves Trotter[1,2]; [1]Université de Toulouse, Centre de Recherche Cerveau et Cognition, Toulouse, France, [2]Centre Natoinal de la Recherche Scientifique, Toulouse Cedex, France, [3]University of Lincoln, School of Psychology, Brayford Pool, Lincoln LN6 7TS, United Kingdom

In visual perception contextual influences on the detection of a target stimulus have been widely investigated. A striking number of studies have shown that detection thresholds for a central Gabor patch (target) can be modulated by the presence of co-oriented and collinear high contrast Gabor stimuli (flankers) with the same phase and spatial frequency. This phenomenon is thought to be mediated by lateral interactions between neurons' receptive fields, and depending on the distance between the central target and flankers modulation can be facilitatory or suppressive. More specifically, collinear facilitation can be observed for target-to-flankers distances beyond two times the wavelength (λ) of the Gabor's carrier, while for shorter distances (< 2λ) there is a suppressive effect. Collinear facilitation vanishes for target-to-flankers distances larger than 12λ. Recently, a series of studies showed the existence of such effects with stimuli presented at 4° of eccentricity, but only for larger target-to-flankers distances than in the fovea (>7λ). The aim of this study is to assess whether peripheral collinear facilitation extends beyond the limits of foveal presentation, shifting the peak of collinear facilitation towards higher target-to-flankers distances. We measured contrast detection thresholds for different spatial frequencies (1-6 cpd) and target-to-flankers distances (6-16λ), with configuration presented at 4° of eccentricity. Results showed that the range of collinear facilitation extends beyond 14λ for the higher spatial frequencies tested (4 and 6 cpd), while for the lowest spatial frequency (1cpd) it returns to baseline already at 10λ. One of the reasons for this reduced range of facilitation might be that for low spatial frequencies time integration window is a constrain for facilitation when flankers are too far away. Moreover, we found that the peak of collinear facilitation shifts towards larger target-to-flankers distances as the spatial frequency increases, a phenomenon never reported for peripheral or for foveal presentation.

Acknowledgement: Fouassier Foundation (France) and the CerCo, Toulouse (France).

26.4079 Figure Ground and Perception: Gelb and Granit Revisited

Rolf Nelson[1] (rnelson@wheatonma.edu), NIcholas Hebda[1]; [1]Psychology Department, Wheaton College (MA)

The relation between figure ground organization and attention is a complicated one. Some findings (Nelson & Palmer, 2008; Wong & Weisstein, 1982) have indicated an advantage for the figural region. However, in a much earlier work, Gelb & Granit (1923) presented evidence that targets in the ground region were more perceptually distinguishable than targets in the figure region, a claim that would seem to be contrary. In the present research, we re-examine Gelb & Granit's work, and claim that these effects are due to a lower-level effect, that of masking due to proximity to surrounding contours. In a series of experiments using stimuli constructed from the original studies, using a 2AFC detection procedure, we find that targets are more detectible in the ground region only when the figure is surrounded by fully articulated contours.

26.4080 The Lemon-Illusion: Seeing curvature where there is none

Lars Strother[1] (lars@unr.edu), Kyle Killebrew[1], Gideon Caplovitz[1]; [1]Department of Psychology, University of Nevada Reno

Curvature is a highly informative visual cue for object recognition. We present a novel illusion—the Lemon Illusion—in which subtle illusory concavities are perceived in the absence of actual curvature. We offer several perceptual demonstrations that show when the illusion does or does not occur. Based on some of our observations, and the large body of research on the role of curvature in the visual perception of object shape, we conclude that the Lemon Illusion likely arises due to the reconciliation of contour curvature interpolation and explicit zero-curvature contour. The observations are consistent with two non-mutually exclusive neural mechanisms within visual cortex that could account for the Lemon Illusion. The first involves curvature-continuation mechanisms such as those thought to subserve contour integration as early as V1 and V2. The second involves global shape processing within V4.

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26.4081 Is the Ebbinghaus illusion a size contrast illusion

Dejan Todorovic[1] (dtodorov@f.bg.ac.rs), Ljubica Jovanovic[1]; [1]Laboratory of Experimental Psychology, Department of Psychology, University of Belgrade, Serbia

In recent decades the Ebbinghaus illusion was used mainly to study issues such as the relation of action and perception or the neural basis of size perception. However, there is still no consensus on the basic question why it occurs at all. An intuitively appealing approach, based on the description of the effect (identical targets look smaller/larger when surrounded by larger/smaller figures) is that the essential cause of the illusion is size contrast. However, several studies, mostly in the nineteen seventies and eighties, have indicated a variety of other factors, such as number and distance of surrounding figures and the vicinity of their contours to targets. In three experiments we tested whether the presence, per se, of groups of similar surrounding figures contrasting in size with the targets was a relevant factor in this illusion. Experiment 1 was a control/baseline study in which the standard effect was replicated. For better control of contour positions and extents, instead of conventional circular shapes square-shaped targets and surrounding figures were used, in an arrangement similar as in the conventional display. Experiment 2 used a modified, geometrically related display in which the surrounds of the two target squares were constituted by single homogeneous frame-like figures, which encompassed the surround squares in Experiment 1 and shared half of their contours. Despite the absence of conventional size contrast there was an illusion of very similar strength and structure as in Experiment 1. Experiment 3 used a display in which the target squares were surrounded by many larger/smaller squares, but in a somewhat different arrangement than in the conventional display, including overlap of targets and a minority of surrounding figures. Despite the presence of size contrast the illusion was absent or reversed. These results suggest that size contrast is neither sufficient nor necessary for the Ebbinghaus illusion.

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26.4082 Global pair-wise statistics of edge luminance polarities reflect object boundaries in natural images

Bart Machilsen[1] (bart.machilsen@ppw.kuleuven.be), Maarten Demeyer[1], Naoki Kogo[1]; [1]Laboratory of Experimental Psychology, University of Leuven, Belgium

The perceptual organization of natural scenes requires a global evaluation of spatially separated retinal image features. In the encoding of border-ownership, for instance, information from remote image locations co-determines the belongingness of a boundary to one of the two abutting surfaces. In natural viewing conditions a stable perceptual organization is established in a split-second, despite the low quality and the inherent ambiguity of the retinal input. This quick inference seems only possible through the use of prior knowledge on the structure of both the world and the visual input resulting from that world. Over the past few decades, natural systems analysis has successfully identified local-scale structure in natural images, and has related this structure to locally defined principles of perceptual organization (e.g., good continuation, co-linearity). In the current study, we extract more global scene statistics related to contours, shapes and objects, and examine their role in global-scale organizational processes. First, we record the contrast-polarity of luminance-defined oriented edges in natural images. We then analyze the consistency of contrast-polarity within a pair of spatially separated edges. We find that this consistency statistically depends on the geometrical relationship between the edges. Specifically, the resulting pattern reveals a co-circular organization of edges in natural

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images. To investigate the source of the observed co-circularity, we apply the same analysis on a subset of edges that do or do not coincide with human-traced object boundaries. We show that co-circularity is mainly preserved when the analysis is constrained on edges that fall on object boundaries, while it is largely reduced for edges that do not coincide with object boundaries. We conclude that large-scale statistical regularities in the input can be exploited by the visual system in global processes of perceptual organization in general, and in the computation of border-ownership in particular.

Perceptual Organization: Segmentation

Saturday, May 16, 2:45 - 6:45 pm

Poster Session, Pavilion

26.4083 **Gains and Losses: Is Figure Ground Perception Influenced by Motivation or Learned Value?** Michelle Burrola[1] (michelleb@email.arizona.edu), Danielle Mathieson[2], Jane Raymond[4], Mary Peterson[1,3]; [1]Psychology Department, College of Science, The University of Arizona, [2]Neuroscience and Cognitive Science Program, College of Science, The University of Arizona, [3]Cognitive Science Program, College of Science, The University of Arizona, [4]School of Psychology, University of Birmingham, UK

Can learned value influence figure-ground perception? Participants learned to associate probabilistic gains and losses with novel shapes. Shapes were presented in fixed pairs: two win pairs, two loss pairs, and two control pairs. Within win and loss pairs, one shape had a p(80%) value (win: +10¢; loss: -10¢) the other had a p(20%) value. The complement of the p(80%)-shape in one win(loss) pair was the p(20%)-shape in the other win(loss) pair. Subjects learned to maximize their earnings by choosing the p(80%)-win shape and the p(20%)-loss shape. Next, participants reported on perceived figure-ground organization of bipartite displays in which an 80% win(loss) shape competed for figural status with a 20% shape in the same win(loss) condition. If learned value influences figure assignment, the relatively high-value shape should be seen as the figure (80% win shape, 20% loss shape). Instead, participants were more likely to perceive the low-value shape as figure, evident across eight repetitions of figure-ground displays in the win condition (57%, p< .04), but only four repetitions in the loss condition (58%, p< .02). Thus, the expected effect of value was not observed: When a low-value shape competed for figural status with a high-value shape, the low-value shape won. This is the shape participants were motivated to avoid [p(-10¢)=80% in loss pairs and p(+10¢)=20% in win pairs]. The high-value shape that participants were motivated to choose during learning (because it maximized earnings) lost the competition for figure assignment. Our results are the first to show that motivation, particularly motivation to avoid, influences figure assignment. Why does motivation to avoid rather than motivation to choose influence figure assignment? The decision-making literature shows that losses loom greater than gains; our results are consistent with that human tendency provided that we consider a low p(gain) a loss relative to a high p(gain).

Acknowledgement: Neuroscience and Cognitive Science Summer Research Program

26.4084 **Detecting structure in visual sequences** Matthias Hofer[1,2] (matthiashofer@live.de), Laurence Maloney[3,4], Jozsef Fiser[1]; [1]Department of Cognitive Science, Central European University, [2]Faculty of Philosophy and Education, University of Vienna, [3]Department of Psychology, New York University, [4]Center for Neural Science, New York University

We investigated how well people discriminate between different statistical structures in letter sequences. Specifically, we asked to what extent do people rely on feature-based aspects vs. lower-level statistics of the input when it was generated by simple or by more hierarchical processes. Using two symbols, we generated twelve-element sequences according to one of three different generative processes: a biased coin toss, a two-state Markov process, and a hierarchical Markov process, in which the states of the higher order model determine the parameters of the lower order model. Subjects performed sequence discrimination in a 2-AFC task. In each test trial they had to decide whether two sequences originated from the same process or from different ones. We analyzed stimulus properties of the three sets of strings and trained a machine learning algorithm to discriminate between the stimulus classes based either on the identity of the elements in the strings or by a feature vector derived for each string, which used 13 of the most common features split evenly between summary statistics (mean, variance, etc.) and feature-based descriptors (repetitions, alternations). The learning algorithm and subjects were trained and tested on the same sequences to identify the most significant features used by the machine and humans, and to compare the two rankings. There was a significant agreement between the ranks of features for machine and humans. Both used a mixture of feature-based and statistical descriptors. The two most important features for humans were ratio between relative frequencies of symbols and existence of repeating triples. Repetitions of length three or higher were consistently ranked higher than alternations of the same length. We found that, without further help, humans did not take into account the complexity of the generative processes. Acknowledgements: Marie-Curie CIG 618918, NIH EY019889

Acknowledgement: Marie-Curie CIG 618918, NIH EY019889

26.4085 **Background subtraction as a mechanism for efficient motion segregation** Woon Ju Park[1,2] (wjpark@bcs.rochester.edu), Duje Tadin[1,2,3]; [1]Center for Visual Science, University of Rochester, [2]Department of Brain and Cognitive Sciences, University of Rochester, [3]Department of Opthalmology, University of Rochester

Segregation of objects from backgrounds is essential to everyday visual tasks. Computational and neurophysiological evidence suggests that segregation can be achieved by suppressing background motion signals. Behavioral evidence for this hypothesis, however, is lacking. Here, we hypothesized that spatial suppression (i.e., perceptual insensitivity to large, background motion; Tadin et al., 2003) enables rapid segregation of moving objects by suppressing motion signals belonging to the background, thereby effectively implementing background subtraction. Thus, efficient motion segregation should only occur for stimulus conditions linked with strong spatial suppression (e.g., high contrast stimuli and fast motion speeds). METHODS: We measured participants' ability to segregate a small moving object (0.75° radius) presented on a large background (12° radius) that was either moving or stationary. Participants reported the target object location in a 4-AFC task. Duration thresholds were measured for both low and high contrast stimuli (3% and 99%) across different speed levels (1-16°/sec). RESULTS: At high contrast, participants were substantially better at object segregation when the background was moving than when it was stationary. For fast speeds (≥8°/sec), this advantage persisted even after we corrected for differences in relative motion between the two conditions. For slower speeds (≤4°/sec), the results were equivalent for moving and stationary backgrounds when corrected for relative motion differences. These results indicate that the presence of a moving background can strongly facilitate motion segregation—especially for fast, high-contrast stimuli. At low contrast, on the contrary, the benefits of the moving background largely disappeared. When the data were corrected for relative motion differences, stationary backgrounds elicited significantly better performance. CONCLUSIONS: These findings reveal highly efficient background subtraction under stimulus conditions that support strong spatial suppression. Evidently, perceptual insensitivity to large, background-like moving stimuli effectively implements background subtraction, which, in turn, enhances the relative visibility of moving objects.

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26.4086 **Bridging the gap between standard Accretion/Deletion and Rotating Columns** Ö. Tanrıkulu[1], Vicky Froyen[1], Jacob Feldman[1], Manish Singh[1]; [1]Department of Psychology, Rutgers University

Standard accounts of accretion/deletion treat it as a reliable, self-sufficient cue to depth ordering: the accreting/deleting surface is interpreted as behind the adjoining surface. However accretion/deletion can also result from self-occlusion of a rotating 3D object. When accretion/deletion occurs on both sides of each contour in a multi-region display, one set of regions (odd or even) tends to be perceived as 3D rotating columns, despite the constant-speed motion (Froyen et al., 2013, JOV). Moreover, making one set of regions more "convex" makes them more likely to be perceived as rotating in front (Tanrikulu et al., 2014, VSS). Our rotating columns displays differ from standard accretion/deletion displays along a number of variables. Here, we systematically manipulated these variables to identify the factors that are most relevant to interpreting an accreting/deleting surface as a nearer surface that owns the common border. We manipulated the shape of the border (straight, curved with unbiased f/g geometry, or biased via "convexity"), the number of regions (two, four or eight), and whether accretion/deletion was present only in one set of regions, or in all regions (with opposite motion in alternating regions). In Exp. 1, the width of each region was kept fixed, and in Exp. 2, the width of the overall display was kept fixed. Observers indicated which set of regions they perceived to be in front. In both experiments, accreting/deleting regions were most likely to be seen in front when geometric figural cues were present, and when textural motion was introduced in all regions. The number of regions had a relatively small effect (although this effect was larger in Exp. 2). The findings indicate that the geometry of the occluding contour is a critical factor in the

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interpretation of accretion/deletion. Computational models of accretion/deletion must therefore include contour geometry as a key component.

26.4087 The Leuven Embedded Figures Test (L-EFT): Re-embedding the EFT into vision sciences Ruth Van der Hallen[1,2] (ruth.vanderhallen@ppw.kuleuven.be), Rebecca Chamberlain[1], Lee de-Wit[1], Johan Wagemans[1,2]; [1]Laboratory of Experimental Psychology, KU Leuven, Belgium , [2]Leuven Autism Research (LAuRes), KU Leuven, Belgium

Based on Gestalt psychological work on perceptual organization (Gottschaldt, 1926, 1929), Witkin (1950) developed the Embedded Figures Test (EFT) where he asked participants to find a target stimulus (e.g., a triangle) within a complex figure which was designed to camouflage the target. Since then, several different EFT versions have been developed. As a result of these modifications, the perceptual demands of the EFT have been subsumed by aspects of intelligence, executive function and personality. In its pure form the EFT is a valuable measures of perceptual bias, as more "local" processors are less distracted by the global pattern or complex figure. Therefore, we have set out to re-investigate the perceptual factors that predict effective embedding and develop a new EFT which systematically manipulates those perceptual factors. In a first experiment (N=250) we evaluated the impact of several perceptual factors, such as line continuity, complexity, closure, 3D depth cues and different part-whole relationships, on the degree of perceptual embedding. Although most perceptual factors were relevant, line continuity and complexity of the embedding context proved most important. Based on the outcome of this experiment, a large set of EFT stimuli was assembled, in which perceptual embedding was carefully manipulated. In addition to this classic EFT version, versions were designed with 3D depth cues and meaningful versus meaningless embedding contexts, which are especially interesting with regard to (clinical) subgroups known to present atypical EFT performance (e.g., autism spectrum disorder, artists, etc.). In a second experiment (N=150) test-retest reliability and sensitivity to individual differences were evaluated. With this novel Leuven-EFT (L-EFT), which offers a more sensitive and controlled measure of perceptual bias, we have re-embedded Witkin's paradigm in modern vision science and designed an EFT that is better able to differentiate between genuine perceptual, as opposed to executive, contributions to EFT performance.

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26.4088 Human Perception of Statistical Significance and Effect Size Bhavin Sheth[1,2] (brsheth@uh.edu), Jasmine Patel[3,2]; [1]Department of Electrical & Computer Engg, University of Houston, [2]Center for NeuroEngineering and Cognitive Science, University of Houston, [3]Department of Biomedical Engg, University of Houston

Statistics are ubiquitous in the information age. While they are fundamental to scientific discovery, understanding the layperson's intuitive grasp of statistics is necessary if scientific advances and policies are to garner popular support. We asked two questions: First, how tightly matched are our perceptions of statistical significance and statistics? Second, are perceptual judgments of discriminability driven by statistical significance or by effect size? To address the first question, we displayed scatter plots of differently colored points chosen from two gaussian distributions had different mean/variance; observers judged if the two patterns of dots were similar or different. Perceptual judgments were compared to the results of statistical tests. Observers perceived the two arrangements of dots as "different" when there was no true difference at all (Type I: false positives), but were more conservative than statistics when the level of true discriminability increased (Type II: misses). When distributions overlap in space, we seem to be, by and large, immune to statistical significance. To address the second question, we displayed two plots in which we varied the level of statistical significance and effect size in opposite directions. Each plot contained red and blue points chosen from two Gaussian distributions of different mean and variance and observers had to judge, in a binary choice task, which of the two plots had red and blue points that appeared more different. The plots were designed so that one had the larger effect size (effect size is defined as the difference in means over the pooled standard deviation: Cohen's d), and the other the higher level of statistical significance. Over a range of effect sizes and p-values, observes chose the plot with the larger effect size as being more different. Our results suggest that effect size, rather than statistical significance, drives perceptual judgments.

26.4089 Is prior experience necessary for 5.5 month-old infants to use the statistical regularity of an unchanging object on an changing background for segmentation? Elizabeth Salvagio[1,2] (bsalvag@email.arizona.edu), Rebecca Gomez[1,2], Mary Peterson[1,2]; [1]Psychology Department, College of Science, University of Arizona, [2]Cognitive Science Program, College of Science, University of Arizona

How do infants segregate objects from patterned backgrounds? We showed that 5.5-month-old infants can segregate a novel object from a patterned background when the background changes during habituation but not when it remains constant (Salvagio, et al. VSS 2014). There, we measured infants' relative looking time (LT) at two novel objects on an unpatterned background during a single pre-test trial. Then, infants habituated to one of the novel objects, accompanied by a verbal phrase, on either a changing or constant background. At post-test, infants viewed the pre-test display while hearing the habituation phrase. If infants segmented the object during habituation, their post-test LTs at the habituation object should be longer than at the other object. Infants in the changing background group showed evidence of segmentation (LT at habituation object pre- and post-test = 0.44 & 0.55), $p < 0.05$; infants in the constant background group did not (LT pre- and post-test = 0.55 & 0.50), $p > 0.46$. This year we asked whether a changing background was sufficient for segmentation or whether experience with the pre-test display established a memory for a segmented object that operated when infants viewed the habituation displays. Perhaps, in the changing background group stronger weights were assigned to this interpretation with each presentation, whereas, weights for individual unified representations remained lower. In the constant background group a single unified representation garnered stronger weights over time. Here, we tested the changing background condition without pretest. No evidence of segmentation was observed (post-test LT = 0.51), $p > 0.46$. These results may support the memory interpretation. Alternatively, the novelty of the test displays may have caused exploration behavior that overpowered preference for the habituation object at post-test. This second interpretation raises an important methodological concern for many infant studies. An experiment to distinguish these possibilities is underway.

26.4090 The effects of motion cues on figure-ground perception across the lifespan Jordan Lass[1] (jwlass@gmail.com), Patrick Bennett[1], Mary Peterson[2], Allison Sekuler[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University, [2]Department of Psychology and Cognitive Science Program, University of Arizona

Figure-ground (FG) perception involves segmenting adjacent regions sharing a border into figure and background. Border convexity is one static cue that influences FG perception in a context-dependent manner: The probability of perceiving the figure on the convex side of a border increases with the number of alternating convex and homogeneously filled concave regions (Peterson & Salvagio, J Vision, 2008). This Convexity Context Effect (CCE) is reduced in older adults compared to younger adults (Lass, et. al., VSS, 2013). The reduced CCE in older observers may result from decreased competition resolution in FG patterns, making it more likely that the stimuli are interpreted as flat patterns. If so, then adding cues that indicate depth in the stimulus may enhance the CCE in seniors. We examined this hypothesis by testing younger (M=22.1 years) and older (M=65.9 years) observers in a FG task using 100 ms static displays consisting of 2 or 8 alternating lighter and darker regions of random dot textures, and dynamic displays in which the textures in adjacent regions moved in opposite directions. Froyen, Feldman, and Singh (J Vision, 2013) found that such motion evokes a strong percept of depth in younger observers. The FG task was to indicate the colour of the region that appeared to be in the foreground. Contrary to the hypothesis, the CCE exhibited by older observers was not larger for moving stimuli compared to static stimuli. This result is consistent with the idea that healthy aging alters the way that configural cues influence FG organization, even when additional cues signal depth in the displays. Currently, we are examining the possibility that seniors require longer presentation times to accurately perceive the motion (Bennett, Sekuler & Sekuler, Vis Res, 1997). We are also investigating the relationship between individual differences in perceived depth and CCEs.

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26.4091 Contour integration in chronic schizophrenia and first-episode psychosis Brian Keane[1,2,3] (brian.keane@gmail.com), Sabine Kastner[4,5], Danielle Paterno[1], Steven Silverstein[1,2]; [1]University Behavioral Health Care, Rutgers, The State University of New Jersey, [2]Department of Psychiatry, Rutgers, Robert Wood Johnson Medical School, [3]Center for

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Cognitive Science, Rutgers, The State University of New Jersey, [4]Department of Psychology, Princeton University, [5]Princeton Neuroscience Institute, Princeton University

Background. Contour integration (CI) is a visual process that combines spatially aligned edge elements into unified boundaries or shapes. We have shown that CI is compromised in chronic schizophrenia, especially for higher spatial frequency displays, but it remains unclear when this dysfunction arises in the illness. Methods. To consider the issue, we behaviorally compared chronic schizophrenia patients (SZs; N=25), healthy controls (N=24), and first episode psychosis patients (FEs; N=19) on a CI task. Groups were well-matched on a number of variables including visual acuity and gender. On each trial, subjects identified the screen quadrant thought to contain an integrated target shape, and task difficulty depended on the number of randomly oriented noise elements that were co-presented with the target. Spatial frequency was modulated by scaling the entire screen display (4 or 12 cycles/deg). To consider possible group differences in attention or motivation, certain "catch" trials were presented in which the target was shown by itself without any noise. Results. For catch trials, the FE group did not differ from the controls or schizophrenia group, and all subject groups performed above 95% accuracy. Replicating our earlier study, controls integrated contours under noisier conditions than SZs and this effect was strongest at 12 cycles/deg (ps< .002). The FE group integrated marginally better than the chronic SZ group (p=.06), and significantly worse than the control group (p=.02). The FE group differences did not depend on spatial frequency, although there was a trend for SZs to become worse relative to FEs at 12 cycles/deg (p=.07). Conclusions. Contour integration dysfunction arises by the first episode of psychosis and may worsen as schizophrenia unfolds over time, especially for high spatial frequency displays. Schizophrenia gradually alters the mechanisms underlying fine-grained perceptual organization, perhaps via changes in V1/V2 connectivity.

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Scene Perception: Categorization and memory

Saturday, May 16, 2:45 - 6:45 pm

Poster Session, Pavilion

26.4092 Independent processing of statistical regularities in different hierarchical levels

Jihyang Jun[1] (jihy.jun@gmail.com), Sang Chul Chong[1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

Visual statistical learning (VSL) refers to an ability to extract statistical regularities that exist in our environment. When we perceive a natural scene, a number of statistical regularities appear simultaneously in different hierarchical levels. The current study investigated how such regularities could be acquired. Specifically, we examined the learning of temporal regularities that simultaneously occurred in the local and global levels. Participants passively viewed a stream of hierarchical scenes, in which two different shapes were structured into the local and global levels as in Navon letters. In this stream, the temporal regularities existed among three shapes (i.e., triplet) that always appeared in the same order in each of the levels. Following familiarization, participants performed 2AFC of familiarity judgments between old triplets in the same orders and new triplets in changed orders. In Experiment 1, triplets were presented in one level so that participants could only rely on the temporal regularities in the single level. We found that temporal VSL occurred similarly in each of the two levels. In Experiment 2, participants could rely on the temporal regularities either in the single levels (local or global), or in both levels, since we maintained the hierarchical structure in the test unlike in Experiment 1. The extent of learning was higher in the latter condition than in the former condition, suggesting that participants additively used temporal regularities in each level. Importantly, the summed probability of correct judgments in the local level and that in the global level was higher than the correct percentage in both of the levels. This analysis suggests that temporal VSL in each of the two levels occurred independently. Taken together, our results suggest that human observers can extract the statistical regularities that simultaneously appear in different hierarchical levels, and that the regularities in the two levels are processed independently.

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26.4093 Tell me how you look and I will tell you what you are looking at

Antoine Coutrot[1] (a.coutrot@ucl.ac.uk), Nathalie Guyader[2]; [1]CoMPLEX, University College London, UK, [2]Gipsa-lab, CNRS & Grenoble-Alpes University, France

The great ability of the human visual system to classify natural scenes has long been known. For instance, some objects (faces, animals) can be spotted in less time than the duration of a single fixation. Many studies also show that exploration strategies depend on many different high and low level features. However, the link between natural scene classification and eye movement parameters has rarely been explored. In this study, we built a base of 45 videos split into three visual categories: Landscapes (forest, meadow, seashore, etc.), Moving Objects (cars, plane, chain reactions, etc.), and Faces (one to four persons having a conversation). These categories were chosen because of the wide variety of regions of interest they contain. We tracked the eyes of 72 participants watching these videos using an Eyelink 1000 (SR Research). Firstly, univariate analyses show that visual categories substantially influence visual exploration, modify eye movement parameters (fixation duration, saccade amplitude, saccade direction), and impact on fixation locations (mean distance to centre, mean dispersion between the eye positions). Secondly, multivariate analyses were performed via Linear Discriminant Analysis (LDA) on the latter variables. The resulting vectors were used as a linear classifier. On the eye movements recorded with our stimuli, the accuracy of such a classifier reaches 86.7%. The contributions of this study are twofold. First, we quantified the deep influence that visual category of a natural scene has on eye movement parameters. As a consequence of these influences, some eye-tracking results obtained using stimuli belonging to a given visual category may not be generalised to other categories. Second, we showed that simple eye movement parameters are good predictors of the explored visual category. This has numerous applications in computer vision, including saliency-based compression algorithms adapted to the content of the scene.

26.4094 Gaze patterns are predictive of scene category across line drawings and photographs

Claudia Damiano[1] (claudia.damiano@mail.utoronto.ca), Jay Schmidt[2], Dirk Walther[1]; [1]Department of Psychology, University of Toronto, [2]Department of Psychology, The Ohio State University

Recent research from our lab has shown that gaze patterns of subjects viewing color photographs are predictive of scene category. Here we ask if this result extends to grayscale photographs and line drawings. 77 participants viewed grayscale photographs and line drawings of real-world scenes. In a leave-one-subject-out cross validation analysis, viewed scene category was predicted from gaze patterns by computing the best match between the gaze path of the left-out subject in a given trial and a set of fixation density maps (FDMs) that were derived from all other subjects. Gaze patterns are predictive of scene category for photographs (accuracy=33.6%, significantly above chance level of 16.7% with p=3.1 ·10-52) and line drawings (accuracy=30.9%, p=4.5 ·10-43). Predicting category of line drawings from FDMs of photographs was accurate for 28.5% (p=6.6 ·10-39) of the trials, and predicting photographs from FDMs of line drawings for 29.9% (p=5.0 ·10-50). However, prediction accuracy across image types was significantly lower than accuracy within image type (p=4.5 ·10-11). This pattern of results suggests that gaze patterns between line drawings and photographs are compatible to a limited extent. We investigated the temporal aspect of gaze patterns by restricting the analysis to time bins with a width of 300 ms. In all four cases, prediction accuracy increased for the first few hundred milliseconds, peaked at 600ms after stimulus onset, and then slowly decreased. What are the image properties that drive gaze behavior that is so distinctive of scene category? We have recently shown that localized features, such as contour junctions, are important for scene categorization. Using the line drawings, we are currently investigating whether subjects look at those important features and use them to guide their gaze patterns.

26.4095 Can the gist of a natural scene be extracted in crowding?

Mingliang Gong[1] (gongmliang@gmail.com), Lynn Olzak[1]; [1]Department of Psychology, Miami University

Visual crowding is a deterioration of object recognition in periphery vision due to the presence of neighbored objects. Instead of being fully suppressed, recent studies have shown that crowded high-level information such as words meaning, number and facial expression gets through to conscious level in crowding (Fischer, Whitney, 2011; Huckauf, Knops, Nuerk, Willmes, 2008; Kouider, Berthet, Faivre, 2011; Peng, Zhang, Chen, Zhang, 2013; Yeh, He, Cavanagh, 2012). While it is well documented that the gist of a natural scene can be extracted rapidly (e.g., Greene & Oliva, 2009) and even without focal attention (Li, VanRullen, Koch, Perona, 2002),

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no study so far, to our knowledge, has investigated whether gist can be extracted in crowding. To test this, a scene categorization task was conducted. The target scene, either surrounded by four other scenes (0, 2 or 4 shared category with the target) or presented alone, appeared at three eccentricities (9°, 11°, 13°) to the left or right of the fixation for 100ms. Participants categorized whether or not the target scene belonged to a basic-level category (building, highway, forest, mountain) specified at the beginning of each block. Preliminary data showed that both hit rate and false alarm became higher as the number of category-share flankers increased, indicating a confusion of target and flankers. More importantly, crowding significantly impaired scene categorization, but even so, accuracies at all three eccentricities were higher than .71, which was significantly higher than chance level (.50). Furthermore, reaction times were not affected by the presence of nearby scenes. Taken together, the study indicates that scene gist can largely get through crowding even though its extraction is significantly impaired. Further study will examine the effects at superordinate-level (e.g., naturalness, indoor/outdoor) and with scrambled flankers.

26.4096 **Is Boundary Extension effected by the position and orientation of people in scenes?** Carmela Gottesman[1] (cvgottesman@sc.edu), William Dodson[1]; [1]University of South Carolina, Salkehatchie

Memory for scenes shows systematic consistent distortions, Boundary Extension, attributed to the creation and use of spatial layout representations in perceptual processing of scenes. Prior studies used scenes with mainly inanimate objects. However, many scenes we interact with in everyday life include people and social undercurrents. This study examined boundary memory for scenes focused on people, and the effects of their location, orientation and gaze direction. Experiment 1 demonstrated Boundary Extension for portrait pictures, head and torso pictures against natural backgrounds. Experiment 2 tested the effects of the location and orientation of the person in the picture and their gaze (looking toward the viewer or to the side). Participants viewed 24 pictures of people, in 16 pictures people were located close to a picture boundary, in eight of those they were oriented slightly away from that boundary, and in the other eight they oriented towards that close boundary. In the remaining pictures people were located in the middle. In each of these conditions half the people where looking at the camera and half were looking in the direction their body was oriented. A three-choice test followed. One choice had uniform extended boundaries. In another choice, extension was bigger in the direction the person was oriented towards; in the last choice extension was bigger in the opposite direction. Participants' choices indicate that boundaries closer to the person in the pictures were expanded more than boundaries farther from the person. Unexpectedly, gaze didn't affect the degree of directional extension. However, extension was stronger in the direction that the person's body was oriented towards. This effect was strong both when the person was located closer to that boundary and also when the person was in the middle of the picture, indicating preferential treatment to the area the person is directed towards.

26.4097 **Selective increase in recurrent processing during object detection in complex natural scenes** Iris Groen[1,3] (iris.groen@nih.gov), Sara Jahfari[2], Victor Lamme[1], H Steven Scholte[1]; [1]Amsterdam Center for Brain and Cognition, University of Amsterdam, The Netherlands, [2]Cognitive Psychology Department, Vrije Universiteit, Amsterdam, The Netherlands, [3]Laboratory for Brain and Cognition, National Institutes of Health, Bethesda, USA

Object recognition in natural scenes occurs extremely rapidly, suggesting that it requires only feed-forward processing (Serre et al., 2007). However, recurrent processing is involved in many operations that are relevant for object recognition, such as perceptual grouping and figure-ground segmentation (Lamme, 1995; Roelfsema et al., 2000), and disruption of feedback impairs object recognition performance (Koivisto et al., 2011). Interestingly, the effects of feedback disruption are strongest when the object is 'less easily segregated' from the background (as assessed by post-hoc ratings; Koivisto et al., 2013). This suggests that the degree of feedback may depend on overall scene complexity. Here, we tested this hypothesis by manipulating scene complexity based on two global image statistics: contrast energy (CE) and spatial coherence (SC). These statistics respectively summarize local edge intensity and higher-order correlations between edges. Together, they are predictive of the degree of inherent figure-ground segregation in a scene. In particular, low CE/SC scenes are sparse, containing single objects against simple backgrounds, whereas high CE/SC scenes are cluttered or textured. Subjects performed an animal vs. non-animal categorization task in the fMRI scanner for scenes with low, medium or high CE/SC values. Slowed reaction times and increased error rates indicated that categorization was especially difficult for high CE/SC scenes (high clutter). Accordingly, in early visual cortex (V1), only high clutter animal scenes gave rise to increased fMRI activity relative to non-animal scenes. Separate ERP recordings showed that the increased V1 activity was not driven by feed-forward differences, but instead reflected feedback activity from ~200 ms onwards. These results suggest that during object recognition in natural scenes, recurrent activity depends on scene complexity determined from an initial, global representation described by CE and SC. For sparse scenes with clear figure-ground segregation, this feed-forward representation may be sufficient, whereas for cluttered scenes, object recognition involves feedback.

26.4098 **Distinguishing the roles of color and other surface properties in rapid natural scene categorization: Evidence from ERPs** Qiufang Fu[1] (fuqf@psych.ac.cn), Xiaoyan Zhou[1], Zoltan Dienes[2], Yongjin Liu[3], Xiaolan Fu[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences, China, [2]Sackler Centre for Consciousness Science and School of Psychology, University of Sussex, United Kingdom, [3]Tsinghua National Laboratory for Information Science and Technology, Department of Computer Science and Technology, Tsinghua University, China

The present study aims to determine the roles of color and other surface properties (e.g., texture, brightness) in rapid natural scene categorization. Six natural scene categories were adopted as stimuli. Each stimulus was in three versions: color photographs, grayscales, and line-drawings, with a resolution of 320 * 240 pixels. The line-drawings were produced by trained artists through tracing contours in the color photographs (see Walther et al., 2011). Each image was flashed for 13 ms, and then followed by 80 ms of masks and 500 ms of a blank. The stimulus onset asynchrony (SOA) between the image and the mask was 13, 27, 40 or 200 ms at random. On each trial, participants were asked to make a choice among the six categories by pressing a corresponding key, during which EEGs were recorded. Each block included 84 trials. There were 12 blocks, for a total of 1008 trials. The behavioral results showed that accuracy was lower for grayscales than for line-drawings or color photographs in each SOA, meanwhile accuracies were higher for line-drawings than for color photographs in short SOAs of 13, 26, 40 ms. For correct trials, the ERP results revealed that there were no significant differences for amplitudes of posterior P1, N1, and P2 between grayscales and color photographs, but amplitudes of anterior P2, N2, and P3b were larger for color photographs than for grayscales. That is, color does not increase the difficulty of feature analysis, but contributes to decision making later. In addition, although amplitudes of posterior P1, N1, and anterior P2 were greater for grayscales than for line-drawings, conversely, amplitudes of posterior P2 and anterior N2 and P3b were larger for line-drawings than for grayscales. That is, although other surface properties increase the difficulty of feature analysis, they impair decision making for correct classification.

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26.4099 **Evidence for iconic memory of natural scenes before change blindness** Jason Clarke[1] (clarj081@newschool.edu), Arien Mack[1]; [1]New School for Social Research

This study examined whether iconic memories for natural scenes, similar to those used in Rensink et al.'s (1997) change blindness experiments, exist. A change detection procedure was used which included 120 scenes. Changes consisted of a deletion to the scene. Scenes were shown to each subject in one of four ways: change with cue (30 trials), change without cue (30 trials), no change with cue (30 trials), and no change without cue (30). There were two main conditions, each with twelve observers who were shown every scene (500 msec), followed by an inter-stimulus interval (1500 msec), and the same scene with or without a change (500 msec). In condition 1, on half of the trials, a red arrow (cue) appeared 0 msec after offset of the first scene, pointing to the location of a possible change. In condition 2, the cue appeared 300 msec after offset of the first scene. Observers reported change and the identity of the pre-change item. In both conditions, change detection and identification benefitted from the cue. In the first, the mean frequency of change detection with a cue (35%) was more than twice that without the cue (14%), and the mean frequency of change identification with a cue (29%) was almost three times that without a cue (10%). In the second, the mean change detection with a cue was 34% and 17% without it. Change identification with a cue (24%) was double that without it (11%). These results indicate that more information is available from a brief presentation of a natural scene than change blindness suggests, and that this information is available at least 300 msec after scene

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offset. Clearly the information in the iconic memory of scenes is sufficiently processed to afford some identification of the pre-change objects.

26.4100 Is a scene's 'gist' processed automatically in the absence of attention? The role of color, local-global factors and task relevance in unattended scene categorization. Nurit Gronau[1] (nuritgro@openu.ac.il), Rotem Amar[1,2], Anna Izoutcheev[1,2], Tsafnat Nave [1,3], Inbal Ravravi[1]; [1]Department of Psychology, The Open University of Israel, [2]Department of Psychology, Tel-Aviv University, [3]Department of Cognition Studies, Ben-Gurion University of the Negev

During a brief glance people mainly grasp the main category, or the "gist" of a scene. Is categorical scene information registered in the absence of attention? Previous studies investigating this question have typically involved explicit scene detection, or an explicit report of a scene's gist. A possible limitation of such explicit methods is that scenes are prioritized by task demands (e.g., in dual tasks), and/or the assessment of scene processing is prone to working memory capacity limitations (e.g., in the inattentional blindness paradigm). To avoid these potential limitations, we examined scene categorization under conditions in which unattended processing was assessed implicitly (i.e., indirectly). Participants searched for a superordinate scene category (e.g., "nature") among briefly presented pairs of colored scenes positioned below and above fixation. Within pairs containing scenes from non-searched categories (e.g., "urban", "indoor"), items either belonged to same or to different categories. When both scenes were attended, RT for same-category pairs was significantly shorter than for different-category pairs, indicating that scene category was registered. Critically, when participants were cued to respond to one of two scenes in a pair, while its counterpart scene served as an irrelevant distractor positioned outside the main focus of attention, the categorical effect was eliminated. These findings suggest that the unattended scene category was not automatically categorized. An irrelevant (unattended) scene affected behavior only if it served as a to-be-detected target, or if it appeared as a background for a central scene. Similar findings were obtained with achromatic scene images. Collectively, our findings suggest that when focusing on a task-relevant scene flanked by an irrelevant (distractor) scene, the latter's gist is not necessarily registered. However, if one focuses on a central stimulus embedded within a background scene, categorical information concerning the surrounding environment may be extracted rapidly and automatically, even with little attention capacity.

Acknowledgement: This research was funded by the Israel Science Foundation (ISF)

26.4101 Does segmentation influence rapid scene categorization? Jonas Kubilius[1,2] (jonas.kubilius@ppw.kuleuven.be), Lee de-Wit[2], Hans Op de Beeck[1], Johan Wagemans[2], Caitlin Mullin[2]; [1]Laboratory of Biological Psychology, KU Leuven, [2]Laboratory of Experimental Psychology, KU Leuven

Converging evidence from behavioral, neural, and computational investigations has led to the theory that rapid scene categorization can be performed based on the extraction of simple features (e.g. oriented edges, colors, etc.) and does not necessarily require an organization of these features into coherent parts, objects, or surfaces. This is consistent with findings that many perceptual grouping tasks and image segmentation in general are computationally expensive processes requiring multiple iterations of feedback. Therefore, these grouping and segmentation processes must take place after scene category information has already been computed (a process assumed to be rapid and feedforward). In a series of three experiments, we questioned whether segmentation processes indeed did not play a role in the rapid scene categorization. In particular, if categorization were only based on feature extraction, with relations between features or objects playing only a minor role, segmentation cues should not influence categorization accuracy. If, however, categorization was also based on the relations between these features, misleading segmentation cues should impede categorization performance. In each trial, we presented participants with two scenes divided into four parts, using segmentation cues displayed for 300 ms prior to image onset. These cues established either a congruent (supporting the correct image segmentation into two scenes) or incongruent (pushing observers to incorrectly group scene segments) figure-ground segmentation on the display. We found that participants were less accurate in scene categorization when incongruent segmentation cues were presented, indicating that segmentation plays a role in rapid categorization decisions. Moreover, the effect remained robust even when the cues were presented concurrently with the images, suggesting that whilst scene categorization might be rapid, it also interacts with equally fast mechanisms of scene segmentation.

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26.4102 A rapid whole-brain neural portrait of scene category inference Pavan Ramkumar[1] (pavan.ramkumar@northwestern.edu), Bruce Hansen[2], Sebastian Pannasch[3], Lester Loschky[4]; [1]Sensorimotor Performance Program, Rehabilitation Institute of Chicago and Departments of Physical Medicine & Rehabilitation and Neurobiology, Northwestern University, Chicago IL, USA, [2]Department of Psychology and Neuroscience Program, Colgate University, Hamilton NY, USA, [3]Department of Psychology, Technische Universität Dresden, Dresden, Germany, [4]Department of Psychological Sciences, Kansas State University, Manhattan, KS, USA

Perceiving the world around us is a process of active inference from incoming visual information. One opportunity to study brain processes underlying perceptual inference is when perception deviates from reality. Here, we focus on errors in rapid scene categorization. How do humans accurately categorize natural scenes after extremely brief presentations (< 20 ms)? To elucidate the role of brain areas involved in visual encoding and perceptual inference, we measured cortical activity using whole-scalp magnetoencephalography (MEG). Scenes were flashed for 33 ms and subjects responded with one of six scene categories. We localized single-trial sensor-level data to the cortical surface reconstructed from individual MRIs. Next, we computed categorization confusion matrices (CMs) using support vector machines based on (1) cortical activity, (2) spatial envelope image features, and (3) behavioral responses. We then used these CMs to examine the functions of different cortical areas. Behavioral categorization confusions can result from either visual representation errors or perceptual inference errors. Thus, if confusions in neural decoders (neural CMs) are driven by errors in image feature-based decoders (image-feature CMs), then any associated cortical activity is attributable to the visual representations. Conversely, if confusions in the perceived category (behavioral CMs) can explain errors in neural CMs, then any associated cortical activation could be attributed to errors in perceptual inference. Using multiple linear regression at each cortical vertex and each millisecond time bin to explain neural CMs as a function of image-feature CMs and behavioral CMs, we found that neural CMs within early visual cortices were explained primarily by image-feature CMs from 90–110 ms, whereas neural CMs within regions such as PRC, PHC, RSC, and OFC were explained primarily by behavioral CMs during 120–200 ms. Our results suggest that medial temporal areas and OFC actively infer visual percepts rather than passively representing categorical information.

26.4103 Using object color diagnosticity to influence access to semantic information in a boundary extension paradigm Ralph Hale[1] (rusty7@uga.edu), Benjamin McDunn[1], James Brown[1]; [1]Psychology, Franklin College, University of Georgia

Individuals consistently remember seeing a more wide-angle version of a previously viewed scene than actually existed. The multi-source model of boundary extension (BE) (Intraub, 2010) suggests many sources of information contribute to this visual memory error (e.g., amodal perception at the view boundaries, semantic information about the scene). The color diagnosticity of an object's color is known to affect object recognition with poorer recognition for atypically vs. typically colored objects. If atypically colored objects lead to poorer recognition (i.e., reduced availability of semantic information) then, according to the multi-source model, a less precise initial encoding should lead to greater BE. Scenes classified as having high or low color diagnostic objects were used as stimuli. Low color diagnostic stimuli (i.e., color non-diagnostic) and two versions of high color diagnostic scenes were tested. Typical and atypical versions of the high color diagnostic scenes were made by changing the central object's color only. Scenes were presented for either 46 or 250 ms followed by a mask, and then immediately presented again for test. Observers first identified the central object, then gave a BE rating. As expected, recognition was significantly poorer for atypically colored vs. typically colored and color non-diagnostic scenes at the 46 ms duration, while there were no differences at 250 ms. BE occurred for all conditions. Most importantly, the BE was greatest at 46 ms for scenes with atypically colored objects. This finding suggests the reduced availability of semantic information for this condition lead to a less precise memory representation leading to increased boundary extension. At 250 ms where recognition was similar, semantic information would have been equally available leading to consistent BE ratings across the three types of colored scenes. These findings provide further insight into the role of object recognition and semantic information on boundary extension.

26.4104 **The tree in the bathroom: The role of inconsistent information in understanding the gist of a scene**

Preeti Sareen[1,2] (psareen@partners.org), Jeremy Wolfe[1,2]; [1]Harvard Medical School, [2]Brigham & Women's Hospital

Real-world scenes can be quickly categorized (bedroom, forest, etc.). This "gist" is based on global information, integrated across the entire scene. However, scenes can have components consistent with two or more gists; for example, a bedroom with a forest view outside a large window. We call such scenes "chimeric." What would be the gist of such a chimeric scene: "bedroom", "forest", both, or neither? In Experiment 1, 15 observers indicated whether or not a pre-cued scene category appeared in a rapid serial visual presentation (RSVP) stream. 50 Hz RSVP streams contained 5 Simoncelli masks with the scene in the second position. Six scene categories, three indoor (bedroom, bathroom, office) and three outdoors (forest, beach, desert), were shown in three types of trials (regular, standard-chimeric, non-standard-chimeric). Regular images contained information consistent with a single category. Chimeric images contained information from two categories. Standard-chimeras were scenes that might normally occur (e.g., kitchen with a beach view). Non-standard-chimeras were unusual but still real scenes (e.g., a bed placed in a forest). Typicality of chimeras was based on ratings from 50 observers on Mechanical Turk. Cued category and trial type varied randomly, intermingled with filler trials. d' for chimeras was barely above chance (0.19), significantly worse than for regular scenes (d'=0.93). Standard and non-standard chimeras did not differ. In Experiment 2, 15 observers made 4AFCs following RSVP presentation of chimeric scenes (e.g., pick Bedroom, Forest, Both, or Neither). Correct responses (29%) were barely, but significantly above the 25% chance level for pooled data. Chi-square tests were significant for only three of 16 individuals, taken separately. While humans have an impressive ability to extract the gist of a scene in a fraction of a second, that ability may be fragile, failing dramatically in chimeric scenes.

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26.4105 **The Role of Gist Processing in Boundary Extension**

Aisha Siddiqui[1] (aps23@uga.edu), James Brown[2]; [1]Department of Psychology Midwestern State University, [2]Department of Psychology University of Georgia

Boundary extension is a ubiquitous phenomenon in which participants remember seeing more of an image than was previously shown. According to the Multisource Model of Scene Perception, viewers create a representation of their environment within a single fixation that integrates presented scene information with their expectations of what should exist there. The purpose of the following experiments was to determine the extent to which boundary extension relies on gist processing, and particularly, whether access to certain scene gist properties could be used to explain previous findings in the boundary extension literature. The gist of the scene is readily available at short timespans and was hypothesized to facilitate the existence of boundary extension by contributing schematic information about the scene into the representation. By shortening the encoding duration, access to the gist was gradually reduced to threshold levels. Experiment 1 was used to determine whether boundary extension could be elicited with natural complex scenes. The results from Experiment 1 showed that boundary extension could be elicited from complex natural, landscape scenes; however, it heavily depended on the participants' perceived depth rating and their perceived navigability of the scene. Experiment 2 manipulated access to the mean depth gist property and showed that boundary extension decreased as access to the gist was reduced, whereas Experiment 3 manipulated access to the navigability gist property and found that boundary extension increased as access to the gist was reduced. Experiment 2 provides evidence that the gist property depth is essential to the existence of boundary extension, making available schematic information to our scene representation which leads to increases in the source monitoring error. Experiment 3 shows evidence that navigability also provides schematic information to our scene representation however due to the adaptive function of the property it serves to provide veridical memory for the scene.

26.4106 **Do high-level perceptual schemata influence the encoding of novel everyday scenes?**

Thomas Sanocki[1] (Sanocki@usf.edu), Steve Schultz[1]; [1]U. of South Florida

How do observers encode information from a rich, novel scene? A classical idea is that high-level schemata aid in the encoding and retention of schema-consistent information. In the present experiment, we primed a high-level schema, and measured the richness of perception with a full report technique. Observers saw 5 prime pictures of everyday scenes that emphasized either structure (interesting buildings) or people doing activities (sports and games). Observers typed in either brief descriptions or complete perceived details. Then, on critical trials 6 and 7, we presented pictures that contained both structures (but not buildings) and active people (but not sports or games), for 150 ms. The complete-detailed full reports were scored by raters blind to the priming conditions. The results indicate that full reports were rich and accurate (M = 39.9 informative structure or people words per report). Most important, the prime experiences resulted in a change in the reports; there were 15.0% more structure words for structure-primed observers than for people-primed observers. Since the prime-pictures had different objects or events than the critical pictures, the effects can be attributed to high-level schemata, rather than specific object or event priming. The building pictures primed the perception of artistic non-building structures, whereas the sports and games pictures primed the perception of walking and playing people. The results serve to illustrate both the efficiency and the intelligence of rapid scene perception.

26.4107 **Temporal Yoking in Target Detection**

Mary Potter[1] (mpotter@mit.edu), Carl Hagmann[2], Quan Wan[1]; [1]Brain and Cognitive Sciences, MIT, [2]Psychology Department, Syracuse University

Temporal yoking has been shown to enhance performance in dual auditory-visual tasks (Jiang & Swallow, 2014). Here we investigate the relative timing of a picture target in an RSVP sequence and the spoken name of the target. Prior studies (Potter, Wyble, Hagmann, & McCourt, 2014) showed that presenting a written target name 900 ms before the visual sequence led to more accurate detection than when the name appeared 200 ms after the sequence. By using a spoken target name in the present study, we avoided visual interference between the name and the visual sequence, enabling us to investigate temporal yoking in greater detail. The target, which appeared on 50% of the trials, was one of a stream of 6 pictures presented for 53 ms per picture; all pictures were new to the participants. The spoken name of the target began at four possible times, relative to the onset of the 320 ms picture sequence: 1000 or 500 ms before the sequence, at the beginning, or 500 ms after the beginning of the sequence (180 ms after the sequence ended). Strikingly, performance remained well above chance in each temporal condition, although it dropped significantly the later the onset of the spoken target. While advance conceptual information can enhance picture selection, matching can still occur when the target information is simultaneous with or immediately follows the sequence.

26.4108 **The effect of scene category distinctiveness on memory performance**

Jiri Lukavsky[1] (lukavsky@praha.psu.cas.cz), Filip Dechterenko[1,2]; [1]Institute of Psychology, Academy of Sciences of the Czech Republic, [2]Faculty of Mathematics and Physics, Charles University in Prague

Previous studies showed a remarkable capacity to memorize large number of scenes (Konkle et al., 2010). Same study showed exemplar effect (higher number of exemplars per category led to decreased performance). Can images of similar gist from different categories also impair the performance? Alternatively, people are trained to deal with these similarities: when they encounter a scene coming from the class of scenes of similar gist and mixed categories, they are more sensitive when encoding it. We used a set of 2048 grayscale scenes (64 categories). We evaluated the pairwise scene similarity using gist metric (Oliva & Torralba, 2001). For each image we inspected the most proximate 32 images and calculated its category distinctiveness as the proportion of the images of the same category. The distinctiveness was later averaged over categories. To each participant (N=29) we presented 320 unique scenes (5 per category) and additional 2x40 scenes for repeat detection. In the second part, the participants were making old/new judgments with 256 images (128 new, 128 old, 2+2 per category). We pooled the categories into four groups based on the distinctiveness and evaluated its effect on memory performance. We found no effect of category distinctiveness on d'. In two subsequent experiments, we found no effect in a more difficult version (12 scenes per category) or in a color version. Our experiments suggest there is no benefit in memorizing visually distinct categories (with lower gist similarity to other scene categories). The images with similar global characteristics (gist) from different categories did not serve as additional exemplars and their presence did not decrease the memory performance.

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26.4109 **Vision for action: saccadic and manual responses to clear threat and ambiguous negative scenes**

Kestas Kveraga[1,2] (kestas@nmr.mgh.harvard.edu), Jasmine Boshyan[3], Noreen Ward[1], Nouchine Hadjikhani[1,2], Reginald Adams Jr.[4]; [1]Martinos Center for Biomedical Imaging,

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Radiology, Massachusetts General Hospital, [2]Radiology, Harvard Medical School, [3]Psychology, Brandeis University, [4]Psychology,The Pennsylvania State University

Eye movements are critical for identifying and acting in response to visual threat stimuli. Saccades are produced by a highly streamlined system that is immune to response uncertainty, with simple stimulus-response associations, while manual responses are strongly affected by response uncertainty (Kveraga, Boucher and Hughes, 2002; Kveraga & Hughes, 2005). The aim of this study was to examine how saccadic and manual responses would be affected by more complex stimulus-response uncertainty, in which subjects had to select between negative (clear or ambiguous threat) and neutral scene images. We presented images of scenes depicting clear threat or ambiguous negative situations along with neutral scene images. The two images were presented bilaterally on the left and right side of the screen while we recorded subjects' (N=57) saccades and manual responses. The task was to detect the scene image which depicted harm and respond to that side with the corresponding hand as quickly and accurately as possible. The paired scene stimuli were matched in general context, but differed in affective tone. Subjects were faster to make a saccade to clear threat images than to ambiguous threat images, but only when the clear threat scenes appeared in the left visual field (LVF): responses to clear threat were not significantly faster than responses to ambiguous negative stimuli overall. Conversely, the manual responses were faster to all negative stimuli presented in LVF, consistent with previous reports, and were faster bilaterally for clear threat vs. ambiguous negative scenes. Lastly, saccadic responses were much faster (by ~600 ms) than manual responses, but the saccadic response times (RT) did not predict the RT of the matching manual responses. We conclude that saccadic and manual responses to clear and ambiguous threat scenes follow different response patterns, with no overall LVF or clear threat RT advantage for saccades.

Acknowledgement: NIMH R01MH01194, NIMH K01MH084011

Saturday PM

Sunday Morning Talks

Multisensory Perception

Sunday, May 17, 8:15 - 9:45 am
Talk Session, Talk Room 1
Moderator: Marc Ernst

31.11, *8:15 am* **Tactile-Evoked V1 responses in Argus II Retinal Prosthesis Patients assessed with fMRI: A Case Study** Samantha Cunningham[1] (samicunn@gmail.com), Bosco Tjan[2,3], Pinglei Bao[2], Paulo Falabella[4], James Weiland[1]; [1]Department of Biomedical Engineering, University of Southern California, [2]Neuroscience Graduate Program, University of Southern California, [3]Department of Psychology, University of Southern California, [4]USC Eye Institute, University of Southern California

Neuroimaging studies demonstrate that vision loss in late-blind patients causes the primary visual cortex (V1) to respond to other sensory modalities. In a case-study, we characterized the effect of partial vision restoration with an electronic retinal prosthesis on cross-modal responses in V1. Following successful implantation with the Argus II epiretinal prosthetic system, two late-blind retinitis pigmentosa (RP) patients completed a series of MRI scans to determine: 1) the feasibility of acquiring images in the presence of the implant and 2) subjects' BOLD response to three tactile tasks. Argus II subjects' V1 tactile-evoked responses were acquired following counter-balanced periods of device use and no device use, and were further compared to the responses of 9 late-blind RP subjects and 9 sighted control subjects who previously completed the same tasks. Artifacts from the Argus II were limited to the orbit in which the device was implanted. No image distortion was evident in visual cortices for either structural or functional scans. For each subject and tactile task, the extent of the V1 tactile-evoked response increased following a period of not using their device. When compared to the 18 late-blind RP and sighted subjects, one Argus II subject who had been implanted for the shortest period of time (6 weeks) exhibited V1 tactile-evoked BOLD responses similar to RP subjects with only minimal light perception. The Argus II subject who had been implanted the longest (15 weeks) had a response extent similar to sighted control subjects and response strength similar to RP subjects with partial vision loss. Results from these two Argus II subjects indicate that long-term use of a retinal prosthesis may result in a reduction of tactile-evoked responses in V1. Our study also demonstrates that successful acquisition of structural and functional MR images is feasible in the presence of the electronic implant.

Acknowledgement: NSF CBET-1353018 (JDW), NIH R01 EY017707 (BST)

31.12, *8:30 am* **Representational changes in retinotopic cortex during the development of depth cue combination in childhood.** Tessa Dekker[1] (tes.m.dekker@gmail.com), Hirhoshi Ban[2], Martin Sereno[3], Andrew Welchman[4], Bauke Van der Velde[1], Marko Nardini[1,5]; [1]Department of Visual Neuroscience, Institute of Ophthalmology, University College London, [2]Center for Information and Neural Networks (CiNet), NICT, Japan, [3]School of Psychology, University College London, [4]Department of Psychology, University of Cambridge, [5]Department of Psychology, Durham University

Human adults can improve their perceptual precision by averaging multiple sensory estimates (e.g., vision and touch, or depth via multiple visual cues). Strikingly, it is not until ~age 10 years that children combine multiple cues to reduce sensory uncertainty. Why perceptual benefits from sensory fusion emerge so late in childhood is currently unclear. It is possible that the neural computations by which single cues are fused develop slowly in childhood. For example due an extended process of learning how cues relate to each other (Gori et al., 2008, Curr Biol). An alternative possibility is that the required neural computations are in place, but that children are still learning how to use the resulting output adaptively to improve perception. To understand the development of sensory fusion at the level of neural representation, we combined psychophysics, retinotopic mapping, and pattern classification fMRI in a developmental study with children, using methods that were first validated with adults (Ban et al., 2012, Nat. Neurosci). In a sample of 100 children aged 6-13 years we measured perceptual depth discrimination thresholds and established that adult-like fusion of motion-parallax and disparity cues develops between the 10th and 11th year. In a subset of 27 children aged 8-13 years, we then investigated the changes in neural representations that occurred while adult-like cue integration emerged perceptually. There was clear evidence of depth cue integration in visual area V3B in older children (>10.5 years), a region that also combines visual depth cues in the mature brain. In contrast, we found no evidence for sensory fusion in the visual cortex of younger children, who also did not display perceptual cue combination in the behavioral psychophysics task (< 10.5 years). This suggests that the neural processes giving rise to fused depth representations in V3B are still developing at these younger ages.

Acknowledgement: This work was funded by the ESRC, grant code RES-061-25-0523

31.13, *8:45 am* **Neuroanatomical correlates of cross-modal transfer performance in object categorization: from vision to touch** Haemy Lee[1] (hello-stranger@nate.com), Christian Wallraven[1]; [1]Cognitive Systems Lab, Brain and Cognitive Engineering, Korea University

Previous behavioral and neuroimaging studies have shown that object shape knowledge acquired in vision or touch can be transferred to the other modality. Studies on cross-modal processing so far, however, have exclusively focused on averaged population data. Here, we investigate individual variability in cross-modal transfer, as well as neuroanatomical correlates of transfer performance based on voxel-based morphometry (VBM). 38 participants underwent a cross-modal categorization task and an anatomical scan. The categorization task started with a training phase, in which participants had to categorize eight novel, parametrically-defined 3D objects into two categories. Participants were trained with feedback until they were correct twice for all objects (randomly presented in blocks). Visual training was followed by a haptic testing phase for ten blocks. From this testing data, we calculated haptic accuracy and – since objects were parametrically-defined – haptic sensitivity from fitted psychometric functions. The results show that participants on average transferred visual knowledge to haptics. Importantly, however, we observed a considerable amount of individual variance in performance measures. Next, we looked for anatomical correlates of this individual variability using VBM. We therefore conducted multiple regressions between haptic performance and regional concentrations of grey-matter using age, gender, and total brain size as nuisance covariates. Regressions were done at the whole-brain level and for selected ROIs known to be involved in multisensory object shape processing. Results showed positive correlations between grey-matter volume and haptic sensitivity for left early somatosensory cortex (BA3) and right inferior-temporal gyrus (a well-known area for visuo-haptic shape processing). In addition, left middle-temporal gyrus (known for multisensory integration and higher-level memory processing) positively correlated with haptic accuracy. Our results underscore the importance of investigating individual differences in multisensory shape processing, suggesting for the first time anatomical correlates of such performance differences that may also be useful for future clinical applications.

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31.14, *9:00 am* **Vision during tool use is both necessary and sufficient for recalibration of tactile perception of body size** Luke Miller[1] (lumiller@ucsd.edu), Matthew Longo[3], Ayse Saygin[1,2]; [1]Department of Cognitive Science, University of California, San Diego, [2]Neuroscience Program, University of California, San Diego, [3]Department of Psychology, Birkbeck, University of London

The brain combines information across sensory modalities to construct finely calibrated multisensory models of the body. The parameters of these models are largely dependent upon online sensory feedback, particularly visual. For example, visually magnifying a body part recalibrates somatosensory perception on it. Tool use has also been shown to recalibrate tactile perception on the tool-using limb. Here, we show that vision during tool use is both necessary and sufficient for recalibrating tactile perception. In a series of experiments, we assessed tactile distance judgments on the hand and arm before and after tool use. Responses were fit with psychometric functions using a maximum likelihood estimation technique; a difference between the pre- and post-PSE indexed tool-induced perceptual recalibration. Following the use of a hand-shaped tool, we found significant recalibration in tactile processing on the hand (Experiment 1). No recalibration

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was found when subjects were blindfolded during tool use, demonstrating a necessary role for visual feedback (Experiment 2). We next investigated whether vision is sufficient for recalibration. We used a mirror visual illusion to decouple visual and somatosensory feedback during tool use. Participants viewed a reflection of their right arm while keeping their left arm stationary behind a mirror. After participants used the tool with their right arm, we found significant perceptual recalibration on the left forearm, even though this limb remained completely stationary (Experiment 3). This effect was abolished when subjects performed the reaching task with their right arm only (Experiment 4), held the tool stationary (Experiment 5), or used the tool without the mirror box (Experiment 6). Taken together, these studies demonstrate that vision during tool use is both necessary and sufficient for recalibrating multisensory models of body size. The importance of overt tool movement in the illusion further suggests an important role for visual biological motion mechanisms in embodiment.

Acknowledgement: NSF (CAREER BCS1151805), KIBM Innovative Research Grant

31.15, *9:15 am* **Multisensory Integration is based on Information, not Efficacy** Benjamin Rowland[1] (browland@wakehealth.edu), Thomas Perrault[1], John Vaughan[1], Barry Stein[1]; [1]Wake Forest School of Medicine

Multisensory neurons integrate concordant visual-auditory cues in order to enhance the detection and reaction to such cross-modal events. As shown in studies of superior colliculus (SC) neurons, the magnitude of multisensory enhancement obeys a principle of inverse effectiveness: proportionately larger products are achieved when the effectiveness of the component cues is reduced; whether that reduction is caused by changes in their physical properties or the complexity of the scene in which they appear. The question posed here was whether these products were truly sensitive to the effectiveness of the cues or, as we hypothesize, to the underlying reliability of the sensory estimates. These two features generally co-vary in laboratory circumstances. In the present study they were dissociated in the alert cat by repeated presentations of visual, auditory, or visual-auditory cues. Temporal redundancy, like spatial complexity, reduces stimulus efficacy (often described as "habituation") but, unlike spatial complexity, does not decrease the reliability of the sensory estimates. The results revealed that the unisensory and multisensory responses of SC neurons are reduced in equal proportion so that, contrary to the stated principle of inverse effectiveness, the products of multisensory integration are maintained despite changes in response efficacy. Thus, while the principle of inverse effectiveness remains a good "rule of thumb" because efficacy generally scales with informational content, it is the latter rather than the former that is crucial for the adaptive scaling of multisensory integration. In this way familiar and non-salient cross-modal events can be appropriately discounted in favor of novel and salient events of any modality or modality combination. Supported by NIH grant (EY016716) and the Tab Williams Family Foundation.

Acknowledgement: NIH grant (EY016716), Tab Williams Family Foundation

31.16, *9:30 am* **Correlation detection as a general mechanism for multisensory integration** Cesare Parise[1] (cesare.parise@uni-bielefeld.de), Marc Ernst[1]; [1]University of Bielefeld

To better interact with their surrounding, all animals are equipped with multiple sensory systems to redundantly perceive their body and the world around them. Over the last decade, a number of studies have demonstrated that, by selectively combining related information across the continuous stream of sensory inputs, the nervous system is able to integrate multisensory cues in a statistically optimal fashion. However, the fundamental question of how the brain selects which signals to combine, that is, how it solves the correspondence problem, is still waiting for a proper explanation. Here we propose and validate a biologically plausible, multi-purpose model for multisensory correlation detection. Such a model can solve the correspondence problem, perform optimal cue integration, and detect both correlations and lags across multiple sensory signals. The model could tightly replicate human performance in a variety of both novel and previously published psychophysical tasks. The present results provide for the first time a unique general explanation for a number of key aspects of multisensory perception, such as optimal cue integration, breakdown of integration, and the detection of correlation, lag, and synchrony across the senses.

Acknowledgement: C.V.P. and M.O.E. were supported by the 7th Framework Programme European Project

Eye Movements: Cognition

Sunday, May 17, 8:15 - 9:45 am
Talk Session, Talk Room 2
Moderator: Alexander Schütz

31.21, *8:15 am* **A model of saccade programming during scene viewing based on population averaging in the superior colliculus** Hossein Adeli[1] (hossein.adelijelodar@stonybrook.edu), Françoise Vitu[2], Gregory Zelinsky[1,3]; [1]Department of Psychology, Stony Brook University, [2]Laboratoire de Psychologie Cognitive, CNRS, Aix-Marseille Université, [3]Department of Computer Science, Stony Brook University

Models of eye movements during scene viewing attempt to explain distributions of fixations and do not typically address the neural basis of saccade programming. Models of saccade programming are tied more closely to neural mechanisms, but have not been applied to scenes due to limitations on the inputs that they can accept—typically just dots. This work bridges the gap between these literatures by adding an image-based "front end" to a model of saccade programming in the superior colliculus (SC). An image of a scene is first blurred to reflect acuity limitations existing at the current fixation, and a saliency map is computed from this fixation-blurred image. This saliency map (in pixel coordinates) is projected onto the collicular surface (in mm coordinates), where the activity of each SC neuron is modeled as a Gaussian-weighted sum of its inputs. A local population average is then computed from this activity relative to each SC neuron, with the most active of these local populations determining the next saccade landing position following inverse projection back to visual space. Scanpaths are generated by injecting inhibition on the saliency map at each new fixation location and allowing the above process to repeat. We tested the model on a 30-image subset of the MIT saliency dataset (1000 scenes, 15 participants performing a free-viewing task), selected to maximize inter-subject agreement in first saccade landing positions. Our model predicted the first, second and third saccade landing positions significantly better than either the adaptive-whitening model or the Itti-Koch model, which both predict fixations on peaks in a saliency map. Subsequent saccades could not be evaluated due to lack of agreement in the behavioral data; all model predictions dropped to chance. These results suggest that neurophysiological constraints from saccade programming should be incorporated into image-based models of fixation selection during scene viewing.

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31.22, *8:30 am* **Embodied salience for gaze analysis in ecologically valid environments** William Abbott[1] (wwa06@ic.ac.uk), Andreas Thomik[1], Aldo Faisal[1,2,3]; [1]Dept. Bioengineering, Imperial College London, [2]Dept. Computing, Imperial College London, [3] MRC Clinical Sciences Centre, Imperial College London

The brain is a dynamical system, mapping sensory inputs to motor actions. This relationship has been widely characterised by reductionist controlled lab experiments. However, with the emergence of mobile eye-tracking, increasing emphasis has been placed on the ecological validity of gaze studies, taking them out of the lab and into the "wild" (Hayhoe & Ballard, 2005; Kingstone et al., 2003; Land & Tatler, 2009). Here we build on this by capturing, rather than constraining, sensory inputs and motor outputs in natural behaviour. We record 90% of sensory inputs using head mounted eye-tracking, scene camera and microphone. Simultaneously, recording 95% of skeletal motor outputs by motion tracking 51 degrees of freedom in the body and a total of 40 degrees of freedom in the hands. All tracking equipment is markerless and thus allows unconstrained behavioural monitoring "in the wild". The eye-tracker data is processed post-hoc to give 3D gaze position relative to the subjects' head and limb endpoints using our GT3D decoding method (Abbott & Faisal, 2011; Abbott & Faisal, 2012) and the motion capture data. This enables us to evaluate classical relationships in ecologically valid environments including 3 daily scenarios: breakfast in the kitchen, evening activities in the home and in-door ambulation. We find that the classical categorisation of gaze data to saccades and fixations is insufficient to capture eye-movement repertoire in natural behaviour. We spend the majority of daily life making smooth eye-movements directly coupled to body movements (eg VOR). Classically, allocation of gaze has been attributed to both bottom up scene salience and top down ongoing task demands. We propose a new method for analysing and interpreting eye-movements in the wild, by relating them directly to body posture. Thus, the interpretation of gaze and attention is integrated, not disembodied, from the kinematics of motor behaviour.

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31.23, *8:45 am* **Using Experts' Eye Movements to Influence Scanning Behaviour in Novice Drivers** Andrew Mackenzie[1] (akm9@st-andrews.ac.uk), Julie Harris[1]; [1]School of Psychology & Neuroscience, University of St Andrews

In many areas, experts often exhibit specialised eye movement behaviour which allows for more efficient task execution than novices. In some areas (e.g. Radiology), showing this pattern of eye movement behaviour to novices can help cue overt visual attention to more relevant areas; which allows for more efficient task completion. We present a study which investigated the effects of eye movement cueing in a dynamic task – that of driving. The aim was to investigate whether a more efficient visual search pattern (e.g. increased scanning of the road, increased use of mirrors) could be induced in novice drivers if they are shown eye movements of expert drivers, when driving in a simulated environment. One group of participants (eye movement condition) were asked to drive a set of courses in a driving simulator programme whilst their eye movements were tracked. After one week, this group was shown two five minute videos of an expert's drive with the corresponding eye movements overlaid. Participants were then asked to drive the three courses again whilst their eye movements were tracked. Another group of participants (control) were asked to complete similar drives (one week a part also) but were not shown eye movements. After the second driving session, those in the eye movement condition exhibited increased horizontal scanning of the road, larger saccade sizes and showed an increased use of their mirrors as measured by total dwell time and total fixation counts. The control group showed no such improvement in visual strategies. These beneficial eye movement patterns were retained after a six month follow-up. The results show that eye movement cueing can be used to train more efficient search strategies in a dynamic task such as driving. The current results highlight a possible training intervention which could be introduced to educate early-stage drivers.

Acknowledgement: Engineering and Physical Sciences Research Council (EPSRC)

31.24, *9:00 am* **Evidence for the Common Coding of Location in Auditory and Visual Space** Hannah Krüger[1], Therese Collins[1], Daniel Pressnitzer[2], HiJee Kang[2], Sundeep Teki[2], Cavanagh Patrick[1]; [1]LPP, Université Paris Descartes, Paris, France, [2]LSP, Ecole Normale Superieure, Paris, France

Perception of space is a multimodal construct and orienting our eyes towards a light, sound or touch occurs effortlessly, despite coordinate transformations that have to occur from head-based (sounds) or body-centred (touch) coordinates to eye-centred coordinates. One possible explanation for this effortless orientation behaviour is that space is coded on a common, supramodal map utilised in maintaining locations. Here we present two experiments in support of the view that space is coded on such a common map. The first experiment shows that both, auditory and visual space show similar illusory distortions induced by saccades. Sixteen subjects were asked to judge the direction of an apparent motion straddling a saccade, revealing shifts in judging the direction of auditory as well as visual stimuli in direction of the saccade. Furthermore, the effects were correlated across modalities: Individuals with a large effect in one modality also revealed a large effect in the other modality. This finding suggests that eye movements affect perception of position regardless of the modality in which it is presented. Further evidence comes from the flash-grab effect, the illusory position shift of a brief transient presented on a moving object. We asked observers to judge the location of a transient presented on a moving target in the auditory or visual modality. In both cases, observers reported the location to be further in direction of the motion, suggesting that this position extrapolation is modality invariant. Together the results of these experiments suggest a common mechanism underlying the perception of space across modalities.

31.25, *9:15 am* **A computational account on the development of a preferred retinal locus** Helga Mazyar[1] (mazyar@usc.edu), Bosco Tjan[1,2]; [1]Neuroscience Graduate Program, University of Southern California, [2]Department of Psychology, University of Southern California

A saccade brings a retinal locus to a target in the visual field. For normally sighted individuals, this retinal locus is the fovea. Central field loss (CFL) caused by macular degeneration often leads to the adoption of a preferred retinal locus (PRL) in the peripheral retina for saccades and fixation. Factors underlying the development of a PRL are not known. Here we show that a conceptually simple computational model can account for the formation of a PRL and its idiosyncrasies. We assume that the visual system always intends to aim the retinal locus with the highest expected post-saccade acuity at the saccade target. The expected post-saccade acuity of a retinal locus is a function of the physiological acuity at and around the locus and the expected saccade error. The expected saccade error is a combination of motor error that is proportional to the saccade amplitude (vector error) and the spatial uncertainties associated with the retinal locus and the saccade target (endpoint errors). We assume that the motor error does not improve, but the spatial uncertainties associated with the neural representation of the endpoints are optimally re-estimated after each saccade from the observed saccade error. A generic forgetting function is assumed to prevent spatial uncertainty from vanishing. Simulations showed that immediately after CFL, the utilized retinal loci are close to the edge of the scotoma on the side nearest to saccade targets. After each saccade, spatial uncertainties associated with the pre-saccade target and utilized retinal locus decrease. Decrease in spatial uncertainty increases the expected post-saccade acuity of the retinal locus. The net effect is that a previously selected retinal locus is more likely to be selected for a future saccade, further reducing its spatial uncertainty, and forming the PRL. Idiosyncrasies at the early stages of CFL strongly influence PRL formation.

Acknowledgement: NIH R01 EY017707

31.26, *9:30 am* **Does time stop when we blink?** Marianne Duyck[1] (marianne.duyck@parisdescartes.fr), Thérèse Collins[1], Mark Wexler[1]; [1]LPP, Université Paris Descartes, CNRS UMR 8242

Visual perception appears nearly continuous despite frequent disruptions of the input caused by saccades and blinks. While research has focused on perception around saccades, blinks also constitute a drastic perturbation of vision, leading to a complete interruption of the visual input that lasts about 100ms but that we barely notice. Does the visual system actively fill in the missing information or does it simply ignore it? We addressed this question in two experiments in which observers judged the durations of brief visual stimuli in different temporal relations to blinks, using the method of single stimuli. In the first experiment stimuli either straddled the entire blink (onset before the start and offset after the end of the blink), or onset 200ms after the end of the blink. An analysis of the relative biases in the two conditions revealed that stimuli that straddled the blink appeared as 90ms briefer than those that followed the blink—a difference equal to about 77% of the mean blink duration. In a second experiment, the stimulus straddled the end of the blink (onset during the blink, offset after the end), or onset either just after or 200ms following the end of the blink. The optically visible durations of the stimuli that straddled the end of the blink were overestimated by about 20ms in comparison to stimuli that appeared long after. Significantly, we found that in both experiments the duration errors were correlated with trial-by-trial variations in blink durations. Thus, our results suggest that the default mode of the visual system is to ignore the absence of information during blinks. However, in the case of unexpected events, vision partially fills in the blink.

Object Recognition: Mechanisms and models

Sunday, May 17, 10:45 am - 12:30 pm
Talk Session, Talk Room 1
Moderator: Kendrick Kay

32.11, *10:45 am* **Convolutional Neural Networks in the Brain: an fMRI study** Kandan Ramakrishnan[1] (K.Ramakrishnan@uva.nl), Steven Scholte[2], Victor Lamme[2], Arnold Smeulders[1], Sennay Ghebreab[1,2]; [1]Intelligent Systems Lab Amsterdam, Institute of Informatics, University of Amsterdam, Amsterdam, Netherlands, [2]Department of Psychology, Cognitive Neuroscience Group, University of Amsterdam, Amsterdam, Netherlands

Biologically inspired computational models replicate the hierarchical visual processing in the human ventral stream. One such recent model, Convolutional Neural Network (CNN) has achieved state of the art performance on automatic visual recognition tasks. The CNN architecture contains successive layers of convolution and pooling, and resembles the simple and complex cell hierarchy as proposed by Hubel and Wiesel. This makes it a candidate model to test against the human brain. In this study we look at 1) where in the brain different layers of the CNN account for brain responses, and 2) how the CNN network compares against existing and widely used hierarchical vision models such as Bag-of-Words (BoW) and HMAX. fMRI brain activity of 20 subjects obtained while viewing a short video clip was analyzed voxel-wise using a distance-based variation partitioning method. Variation partitioning was done on successive CNN layers to determine the unique contribution of each layers in explaining fMRI brain activity. We observe that each of the 7 different layers of CNN accounts for brain activity

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consistently across subjects in areas known to be involved in visual processing. In addition, we find a relation between the visual processing hierarchy in the brain and the 7 CNN layers: visual areas such as V1, V2 and V3 are sensitive to lower layers of the CNN while areas such as LO, TO and PPA are sensitive to higher layers. The comparison of CNN with HMAX and BoW furthermore shows that while all three models explain brain activity in early visual areas, the CNN additionally explains brain activity deeper in the brain. Overall, our results suggest that Convolutional Neural Networks provide a suitable computational basis for visual processing in the brain, allowing to decode feed-forward representations in the visual brain.

Acknowledgement: COMMIT

32.12, *11:00 am* **Psychophysically disrupting the delayed feedback signal to foveal retinotopic cortex selectively impairs extra-foveal object perception** Xiaoxu Fan[1] (smartcandies@163.com), Lan Wang[1], Hanyu Shao[1], Daniel Kersten[2], Sheng He[1,2]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, China , [2]Psychology Department, University of Minnesota

Previous neuroimaging and TMS studies (Williams et al, 2008; Chambers et al, 2013) suggest that object information from peripherally presented images was available in foveal retinotopic cortex and is functionally relevant, presumably due to feedback signals from high-level object sensitive cortex. In this study, we further investigated the behavioral significance and timing of this potential feedback signal. Two objects with fine details similar to the ones used in Williams and colleagues' study were presented for 100 ms in diagonal quadrants on two sides of the fixation point and subjects were asked to make a same/different decision. A dynamic noise patch was presented for 80 ms in the fovea region at five different SOAs, at 50, 150, 250, 350, and 450 ms after the onset of the object images. The results showed that subjects' ability to discriminate object images was severely impaired at the SOAs of 50 ms and 250 ms, mildly at 150 ms, but not at other SOAs. At 50 ms SOA, the fovea noise overlapped with the peripheral objects in time, and presumably attracted attention away from the object images. The severe dip in performance at SOA of 250 ms is more interesting and is unlikely due to a simple masking effect in the feedforward sweep, given that performance was only mildly affected at the SOA of 150 ms. However, the foveal noise-induced temporally selective impairment at 250ms was not found in a control condition in which subjects performed a motion speed comparison task at the same peripheral locations. Presumably processing of motion speed in the periphery does not benefit from feedback signals to foveal cortex. Our results support a task-dependent and temporally specific feedback signal from high-level cortex to foveal retinotopic cortex that plays an important role in processing spatially detailed object information.

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32.13, *11:15 am* **Neural tuning changes underlying visual shape learning** Sach Sokol[1] (ssokol3@jhu.edu), Charles Connor[1]; [1]Zanvyl Krieger Mind/Brain Institute, Johns Hopkins University

Learning to discriminate new shapes ultimately depends on processing changes at the level of individual neurons and neural populations. We sought to quantify and model the precise neural tuning changes that underlie shape learning. We trained a macaque monkey to discriminate 8 categories of letter-like stimuli. These stimuli were configurations of medial axis components (line segments, curves, junctions) drawn from a common set of 8 components. This enforced learning of global shape, since stimuli sharing components were confusable on a local level. In addition, the 8 stimuli constituted only a subset of the potential component configurations, making it possible to test for processing of specific configurations. After training we characterized neural tuning functions in anterior inferotemporal cortex (AIT), the final stage in the object pathway of monkey visual cortex. We used a genetic algorithm to guide large-scale sampling (500–1500 initially random, progressively evolving stimuli) in the medial axis shape domain. Our previous study showed that this method can constrain quantitative, predictive models of AIT tuning for medial axis structure (Hung et al., Neuron, 2012). Here, we hypothesized that a substantial number of AIT neurons would show structural tuning for medial axis components and component configurations unique to the learned stimuli. This hypothesis was confirmed in our current sample of AIT neurons. Many neurons were tuned for components common to multiple stimuli. Many neurons were tuned for configurations diagnostic for specific stimuli. We did not observe tuning for potential component configurations outside the learned stimulus set. This is the first direct observation of structural tuning changes that could explain visual shape learning.

32.14, *11:30 am* **Object Representations In Human Parietal And Occipito-Temporal Cortices: Similarities And Differences** Maryam Vaziri-Pashkam[1] (mvaziri.p@gmail.com), Yaoda Xu[1]; [1]Vision Sciences Laboratory, Department Of Psychology, Harvard University

Although visual objects are largely represented in the primate occipital and temporal cortices, many studies have also documented the existence of object representations in the primate parietal cortex. What are the characteristics of the parietal object representations? And how do they differ from those in occipital and temporal cortices? Here, using fMRI multi-voxel pattern analysis, we examined object representations in human observers in topographically defined parietal regions (IPS0-IPS4) and two functionally defined parietal regions previously implicated in object processing, namely, superior and inferior IPS. To compare and contrast, we also examined topographic regions in occipital cortex (V1-V4) and object shape selective regions in lateral occipital and ventral temporal cortices. Observers viewed objects from eight categories and performed a one-back repetition detection task. In the first set of studies, we varied the position, size and spatial frequency of the object images, and whether or not image luminance and spatial frequency were matched across the categories. We obtained significant object category decoding in all the regions examined. Importantly, parietal regions showed similar tolerance to changes in low-level features as occipital and temporal regions (excluding early visual areas). However, when we compared object category similarity measures across brain regions, we found that parietal object representations were not a mere copy of those in occipital and temporal regions. In a second set of studies, we varied the task and found that, when attention was diverted away from the objects, although category decoding was still significant in occipital and temporal regions, it was no longer significant in multiple parietal regions. Overall these results show that, just like regions in occipital and temporal cortices, high-level object representations exist in human parietal cortex; however, they are distinct from those in occipital and temporal regions.

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32.15, *11:45 am* **Convergence and divergence in the neural organization of object responses to pictures and words** Talia Konkle[1] (tkonkle@fas.harvard.edu), Xiaoying Wang[2], Marius Peelen[3], Alfonso Caramazza[1,3], Yanchao Bi[2]; [1]Department of Psychology, Harvard University, [2]State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, China, [3]Center for Mind/Brain Sciences, University of Trento, Italy

Visual information is transformed from early sensory formats into increasingly abstract representations of its content. We probed this abstraction by exploring the convergence in the neural responses to pictures of objects and their spoken names, taking a broad look at several major semantic divisions between object categories. Our aim was to explore which neural regions show reliable responses that are specific to visual pictures, specific to auditory words, or common between these two modalities, using a data-driven clustering approach. Using fMRI, we measured neural response patterns to objects from 18 broad semantic categories, presented as both pictures and auditory words, in 16 participants. We used a clustering technique to group together voxels by their response profile similarity over these 18 categories, in a way that is agnostic to where the voxels are located and whether they reflect responses from the visual or auditory modality. They key advantage of this procedure is that it simultaneously discovers common and unique structure across both modalities without presupposing any regional boundaries in advance. This analysis identified several regions with similar neural profiles to pictures and words (parahippocampal, transverse occipital sulcus, retrosplenial cortex), which primarily had a response preference for inanimate categories of objects. In contrast, other neural regions were only reliably modulated by pictorial stimuli (lateral occipital, fusiform), and these regions primarily had a response preference to pictures of animate entities. Taken together, these results demonstrate a surprising and currently unexplained link between the neural organization of broad object domains and activations by different modalities.

32.16, *12:00 pm* **Mapping human visual representations in space and time by neural networks** Radoslaw Cichy[1] (rmcichy@gmail.com), Aditya Khosla[1], Dimitrios Pantazis[2], Antonio Torralba[1], Aude Oliva[1]; [1]Computer Science and Artificial Intelligence Laboratory, MIT, [2]Department of Brain and Cognitive Sciences, MIT

The neural machinery underlying visual object recognition comprises a hierarchy of cortical regions in the ventral visual stream. The spatiotemporal dynamics of information flow in this hierarchy of regions is largely unknown. Here we tested the hypothesis that there is a correspondence between the spatiotemporal neural processes in the human brain and the layer hierarchy of a deep convolutional neural network (CNN). We presented 118 images of real-world objects to human participants (N=15) while we measured their brain activity with functional magnetic resonance imaging (fMRI) and magnetoencephalography (MEG). We trained an 8 layer (5 convolutional layers, 3 fully connected layers) CNN to predict 683 object categories with 900K training images from the ImageNet dataset. We obtained layer-specific CNN responses to the same 118 images. To compare brain-imaging data with the CNN in a common framework, we used representational similarity analysis. The key idea is that if two conditions evoke similar patterns in brain imaging data, they should also evoke similar patterns in the computer model. We thus determined 'where' (fMRI) and 'when' (MEG) the CNNs predicted brain activity. We found a correspondence in hierarchy between cortical regions, processing time, and CNN layers. Low CNN layers predicted MEG activity early and high layers relatively later; low CNN layers predicted fMRI activity in early visual regions, and high layers in late visual regions. Surprisingly, the correspondence between CNN layer hierarchy and cortical regions held for the ventral and dorsal visual stream. Results were dependent on amount of training and type of training material. Our results show that CNNs are a promising formal model of human visual object recognition. Combined with fMRI and MEG, they provide an integrated spatiotemporal and algorithmically explicit view of the first few hundred milliseconds of object recognition.

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32.17, *12:15 pm* **How bottom-up and top-down factors shape representation in word- and face-selective cortex** Kendrick Kay[1] (kendrick@post.harvard.edu), Jason Yeatman[2]; [1]Department of Psychology, Washington University in St. Louis, [2]Institute for Learning and Brain Sciences, University of Washington

Specific regions of ventral occipitotemporal cortex (VOT) appear to be specialized for the representation of certain visual categories: for example, the visual word form area (VWFA) for words and the fusiform face area (FFA) for faces. However, a computational understanding of how these regions process visual inputs is lacking. Modeling these regions is particularly challenging because responses depend on both bottom-up stimulus properties and top-down cognitive processes. To develop a model of VOT, we measured BOLD responses in VWFA and FFA to a wide range of carefully controlled grayscale images while subjects performed different behavioral tasks. During a demanding fixation task (judge the color of a small central dot), responses in VWFA and FFA were not strictly categorical but were sensitive to low-level properties such as image contrast and phase coherence. This suggests that category-selective regions inherit response properties present in early visual cortex. Combined with previous work demonstrating systematic receptive fields in VOT (Kay et al., VSS 2014), we suggest that a cascade model of visual processing may be able to explain a substantial component of VOT responses. During a categorization task (judge the category of the stimulus), responses in VWFA and FFA were substantially stronger than responses observed under the fixation task. Importantly, the categorization responses were not a simple linear rescaling of the fixation responses. Rather, the enhancement was disproportionately large for low-contrast stimuli, and the amount of enhancement observed for a stimulus was highly correlated with the reaction time measured for that stimulus. These results indicate that when stimuli are behaviorally relevant, top-down influences can selectively enhance VOT responses to weak stimuli, effectively increasing the amount of information conveyed by VOT. In sum, our results lay the groundwork for the development of models that quantitatively predict VOT responses.

Binocular Vision

Sunday, May 17, 10:45 am - 12:30 pm
Talk Session, Talk Room 2
Moderator: Laurie Wilcox

32.21, *10:45 am* **Short-term ocular dominance changes in human V1.** Eva Chadnova[1,2] (eva.chadnova@mail.mcgill.ca), Alexandre Reynaud[1], Simon Clavagnier[1], Sylvain Baillet[2], Robert Hess[1]; [1]McGill Vision Research Unit, McGill University, [2]McConnell Brain Imaging Center, Montreal Neurological Institute, McGill University

Ocular dominance describes the contribution of each eye to binocular vision. This balance is disrupted in some clinical conditions such as amblyopia. It has been shown psychophysically that short-term monocular deprivation shifts the equilibrium towards the occluded eye (1). In this study, we wanted to investigate the cortical mechanism underlying this phenomenon using magnetoencephalography (MEG). Subjects were presented with monocular and dichoptic stimuli using a frequency tagging paradigm to identify the input coming from each eye. Three 10-minute blocks of MEG recordings were followed by 2.5 hours of monocular deprivation. Immediately after removal of the patch, another three consecutive blocks were recorded followed by a final recording 45 min post deprivation. Immediately following the removal of the patch, we observed an increase in power of the response from the occluded eye as early as in V1, and reflected in the response of subsequent brain areas as well. At the same time, the power of the response from the undeprived eye was reduced. The pre-deprivation ocular power distribution was achieved again at the 45 min post-deprivation recording. The power redistribution was observed both monocularly and dichoptically, but was more pronounced on dichoptic recording. We also observed an increase in variability of the response from the occluded eye post-deprivation. In conclusion, short-term monocular deprivation perturbes the binocular equilibrium as measured psychophysically. We were able to observe a physiological correlate of this perturbation in area V1 of the visual cortex with MEG. The change in V1 neuronal population activity observed here might be a direct consequence of the underlying plasticity occurring in the brain.

Acknowledgement: CIHR MOP-53346, NSERC 46528-2011

32.22, *11:00 am* **Short-term monocular deprivation reduces inter ocular surround suppression** Ignacio Serrano-Pedraza[1,2] (iserrano@psi.ucm.es), Sandra Arranz-Paraíso[1], Verónica Romero-Ferreiro[1], Jenny Read[1], Holly Bridge[3]; [1]Departamento de Psicología Básica I. Complutense University of Madrid, Madrid, 28223, Spain, [2]Institute of Neuroscience, Newcastle University, Newcastle upon Tyne, NE2 4HH, UK, [3]Functional MRI of the Brain Centre, John Radcliffe Hospital, Oxford, OX3 9DU, UK

The detection of a grating located in the periphery is impaired by the presence of a surrounding grating of same spatial frequency and orientation. This suppression is the psychophysical counterpart of the surround suppression found in the striate cortex that is orientation tuned and can be mediated dichoptically (De Angelis, et al 1994). The proposed sources of this suppression involve long-range lateral connections and feedback connections to V1 from extrastriate cortex, thus the neurotransmitter GABA may regulate this intracortical inhibition. A recent study (Lunghi, et al, 2014) has shown that a short-term monocular deprivation reduced GABA concentration by 11%, thus, our hypothesis is that monocular deprivation will reduce surround suppression. Four subjects performed two contrast-detection experiments where the target was a 1c/deg grating located at 5 deg eccentricity. We tested three conditions: a) target with no surround (NS), b) target embedded within a surrounding grating of 20 deg diameter, 25% contrast, same spatial frequency, and orthogonal orientation (OS), and c) target embedded within a surrounding grating with parallel orientation (PS). We tested both eyes independently using a 3D display. In the first experiment stimuli were monocular. In the second, stimuli were dichoptic, i.e. target in one eye and surround in the other. Both experiments had three sessions; (1) baseline, (2) after 150 min of patching the right eye and (3) 24 hours later. Monocular deprivation did not change the relative contrast sensitivity of the two eyes (Exp 1, NS). Neither did it cause significant differences in suppression indices monocularly (Exp 1, $\log_{10}$(PS/NS)). However, after deprivation, we found a strong, temporary reduction (-41%) of the suppression in the PS condition only when the target was presented in the deprived eye. Thus, brief (2.5hrs) monocular deprivation reduces inter ocular surround suppression but not monocular surround suppression.

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32.23, *11:15 am* **Stereoacuity for physically moving targets is unaffected by retinal motion** Matthew Cutone[1] (cutonem@yorku.ca), Robert Allison[2], Laurie Wilcox[1]; [1]Dept. of Psychology, York University, [2]Dept. of Electrical Engineering and Computer Science, York University

Westheimer and McKee (1978, Journal of the Optical Society of America, 68(4), 450-455) reported that stereoacuity is unaffected by the speed of moving vertical line targets by up to 2 deg/s. Subsequent studies found that thresholds rise exponentially at higher velocities (Ramamurthy, Patel & Bedell, 2005, Vision Research, 45(6), 789-799). This decrease in sensitivity has been attributed to retinal motion smearing; however, these experiments have not taken into account the additional effects of display persistence. Here we reassess the effects of lateral velocity on stereoacuity in the absence of display persistence, using physically moving stimuli. Luminous vertical line targets were mounted on computer-controlled motion stages.

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This purpose-built system permitted precise control of target position and movement, in three dimensions. In a 1IFC paradigm with 120ms viewing duration, observers fixated a stationary point and discriminated the relative depth of the two moving lines. The velocity of the line pair ranged from 0 (stationary) to 16 deg/s; each speed was tested in a separate block of trials. Our results confirm the resilience of stereoacuity to lateral retinal motion at velocities less than 2 deg/s. At higher speeds, for all observers thresholds increased marginally with speed. The rate of increase was 0.6 arc seconds per deg/s which was approximately 10 times smaller than reported by Ramamurthy et al. (2005). It is clear that stereoacuity is more robust to lateral motion than previously believed; we argue that the threshold elevation reported previously is largely due to display persistence.

32.24, *11:30 am* **Attention modulation and divisive normalization in interocular suppression** Hsin-Hung Li[1] (hsin.hung.li@nyu.edu), Marisa Carrasco[1,2], David Heeger[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Purpose. In interocular suppression, a suprathreshold target presented monocularly (to target-eye) can be rendered invisible by a salient competitor presented to the other eye (competitor-eye). Here we develop and test a computational model of interocular suppression and distinguish the role of feature-based and eye-based attention. Psychophysics. Observers performed an orientation-discrimination task on a small (1.5° diameter) monocular target, either presented alone or simultaneously with one of several competitors. The size and eye-of-origin of the competitors were manipulated. Three competitors–small (1.5°), medium (2.5°) and large (8°)–were presented to the competitor-eye. To disentangle feature-based and eye-based attention, large split competitor (8°) was segmented into two regions: the center (same as the small competitor) was presented to the competitor-eye whereas the surround was presented to the target-eye. Target contrast varied from trial-to-trial randomly, and competitor contrast was fixed at 23%. We measured psychometric functions: d' vs. target contrast. Computational model. Two processes contributed to the strength of interocular suppression. According to the model, the salient competitor induced an exogenous attentional modulation selective for the location and orientation of the competitor, thereby increasing the gain of the responses to the competitor and reducing the gain of the responses to the target. Additional suppression was induced by divisive normalization, similar to other forms of visual masking. Results. Small and medium competitors induced a response-gain change for responses to the target (consistent with Ling & Blake, 2012). But large competitors induced a contrast-gain change, even when the competitor was split between the two eyes. The model correctly predicted these results and outperformed an alternative model in which the attentional modulation was eye specific. Conclusion. Both exogenous attention (selective for feature and location) and divisive normalization contribute to interocular suppression.

Acknowledgement: NIH RO1 EY019693 to DJH and MC

32.25, *11:45 am* **Attending away makes semantic information available during rivalry** Kang Yong Eo[1] (gazz11@empal.com), Oakyoon Cha[1], Min-Suk Kang[2,3], Sang Chul Chong[1,4]; [1]Graduate Program in Cognitive Science, Yonsei University, Seoul, Republic of Korea, [2]Center for Basic Neuroscience and Biophysics, Institute for Basic Science (IBS), Suwon, Republic of Korea , [3]Department of Psychology, Sungkyunkwan University, Seoul, Republic of Korea, [4]Department of Psychology, Yonsei University, Seoul, Republic of Korea

Several studies have shown that the meaning of stimuli under continuous flash suppression (CFS) is processed unconsciously (e.g., Costello et al., 2009). However, Kang et al. (2011) found the opposite result. To reconcile conflicting evidence, we hypothesized that inattention to the suppressed stimulus under CFS makes its semantic information available. Although counter-intuitive, this hypothesis is reasonable because of the following two reasons. Attention is not necessary for semantic processing (Luck et al., 1996), while rivalry suppression is attenuated without attention (Brascamp & Blake, 2012). Taken together, attention withdrawn from rival figures makes interocular suppression weak so that semantic information under CFS becomes available. We tested this hypothesis by obtaining the N400 component, a sensitive ERP measure for semantic processing, while participants were performing a semantic judgment task under CFS. To manipulate deployment of spatial attention, we adopted a cueing paradigm and resulted in three conditions. In the valid condition, the target was presented in a cued location of the suppressed eye. In the invalid condition, the target was presented in the opposite-to-the-cued location of the suppressed eye. Finally, in the visible condition, the target was presented to both eyes to ensure the cue validity, because participants had to make semantic judgments of the invisible targets in most of the trials. Consistent with the hypothesis, N400 modulation was absent in the valid condition but present in the invalid condition with the chance level semantic judgment performance. More importantly, the N400 amplitude obtained from the invalid condition was negatively correlated with independently obtained participants' detection performance, indicating how much feature information was consciously available. This result suggests that attention drawn to the target location disrupted unconscious semantic processing even in the invalid condition. To summarize, the current study demonstrated that inattention to the target location makes semantic analysis possible during CFS.

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32.26, *12:00 pm* **Identity-specific adaptation to invisible faces depends on the depth of interocular suppression** Runnan Cao[1] (runna90@126.com), Sheng He[1,2], Peng Zhang[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, China, [2]Psychology Department, University of Minnesota

The question of whether facial identity could be processed and represented in the brain in the absence of awareness remains unresolved and controversial. We took the view that visual information suppressed from awareness could be processed to different degrees dependent on the level of suppression. In this study, we investigated whether identity processing of invisible faces depends on how deep it was suppressed from awareness. In different experiments, gratings and faces, rendered invisible with interocular Continuous Flash Suppression (CFS), were used as adaptors to induce orientation and face-identity aftereffect. The strength of interocular suppression was manipulated by adjusting the contrast of the CFS noise. Results from the grating experiment showed that the orientation-specific adaptation effect from invisible gratings was stronger at lower CFS contrast. In the face adaptation experiment, we found no identity-specific aftereffect under high CFS contrasts, consistent with reports from previous studies using the interocular suppression paradigm. However, at lower CFS contrast, while the faces remained invisible (supported with both subjective and objective measures of visibility), significant identity-specific face aftereffect was observed. These findings suggest that although awareness state can be described in binary terms (i.e., with or without awareness), different degrees of information processing could occur in the absence of awareness; that the human visual brain can process face identity information in the absence of awareness.

32.27, *12:15 pm* **Fear conditioned visual information is prioritized for visual awareness** Surya Gayet[1] (s.gayet@uu.nl), Chris Paffen[1], Artem Belopolsky[2], Jan Theeuwes[2], Stefan Van der Stigchel[1]; [1]Experimental Psychology, Utrecht University, Helmholtz Institute, [2]Cognitive Psychology, Free University of Amsterdam

The present study addresses the question whether visual information that signals threat is prioritized for access to awareness. We combined a fear conditioning procedure with a breaking continuous flash suppression (b-CFS) task. In this task, participants were presented with high contrast dynamic masks to one eye, and a target grating presented to the other eye (suppression condition) or to the same eye (monocular condition). Participants were asked to report the orientation of the target as soon as it became visible. Throughout the entire experiment, target gratings were surrounded by a blue or red annulus. During the acquisition phase (phase 1), participants passively viewed both monocular and suppression trials, in which one annulus color was repeatedly paired with an electrical shock (from now on the CS+) while the other color was not (CS-). Subsequently, participants completed four blocks of b-CFS trials (phase 2), in which monocular and suppression conditions were intermixed, with CS+ and CS- annuli surrounding the targets. The results revealed that target orientation was reported faster on trials with CS+ annuli than with CS- annuli in the suppression condition. This difference in reaction times reflected shorter suppression durations for CS+ annuli rather than a response bias, as no difference in reaction times emerged between targets surrounded by CS+ or CS- annuli in the monocular condition. This pattern of findings is particularly striking, as (1) participants knew that no shocks would be administered during the b-CFS task, (2) the CS+ and CS- annuli were irrelevant for participants' behavioral task and (3) participants reported to be unaware of phenomenal differences between monocular and suppression conditions. Taken together, these results demonstrate that visual information that was previously paired with aversive stimulation, and thus signaled threat, is prioritized by the perceptual system such that it more readily breaches the threshold of awareness.

Acknowledgement: Grant 401-10-306 from the Netherlands Organization of Scientific Research to S. Van der Stigchel and C. L. E. Paffen

Sunday Morning Posters

Perceptual Learning: History effects

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

33.3001 Information integration in sequential visual decision-making József Arató[1,2] (arato_jozsef@ceu-budapest.edu), József Fiser[1]; [1]Department of Cognitive Science, Central European University, [2]Department of Medicine/Physiology, University of Fribourg

Although it is widely accepted that both summary statistics and salient patterns affect human decision making based on temporally varying visual input, the relative contributions and the exact nature of how these aspects determine human judgment are unclear and controversial, often discussed under the labels of priming, adaptation, or serial effects. To tease apart the role of the various factors influencing such decision making tasks, we conducted a series of 7 adult behavioral experiments. We asked subjects to perform a 2-AFC task of judging which of two possible visual shapes appeared on the screen in a randomly ordered sequence while we varied the long- and short-term probability of appearance, the level of Gaussian pixel noise added to the stimulus, and the ratio of repetitions vs. alternations. We found that the quality of the stimulus reliably and systematically influenced the strength of influence by each factor. However, instead of a simple interpolation between long-term probabilities and veridical choice, different pairings of short- and long-term appearance probabilities produced various characteristic under- and over-shootings in choice performances ruling out earlier models proposed for explaining human behavior. Independent control of base probabilities and repetition/alternation revealed that despite the two characteristics being correlated in general, repetition/alternation is a factor independently influencing human judgment. In addition, we found that human performance measured by correct answers and by reaction times (RT) yield opposing results under some conditions indicating that RT measures tap into motor rather than cognitive components of sequence coding. Our results can be captured by a model of human visual decision making that not only balances long- and short-term summary statistics of sequences, but in parallel also encodes salient features, such as repetitions, and in addition, relies on a generic assumption of non-discriminative flat prior of events in the environment.

33.3002 Does reward influence visual statistical learning? Kyle Friedman[1] (kylefriedman33@gmail.com), Timothy Vickery[1]; [1]Department of Psychological and Brain Sciences, University of Delaware

Two means by which humans learn about the environment are by detecting statistical regularity and by learning about which stimuli predict rewards. In three experiments, we sought evidence that the occurrence of reward impairs or enhances visual statistical learning. In all experiments, we grouped shapes into triplets and presented triplets one shape at a time in an undifferentiated stream. Triplets were additionally assigned no, low, or high-reward status. Participants were naïve to all underlying structure. In experiments 1 and 2, participants were asked to view shape streams while low and high rewards were "randomly" given, represented by low- and high-pitched tones played through headphones, respectively. Unknown to the subjects, however, rewards were always given on the third shape of a triplet (Experiment 1) or the first shape of a triplet (Experiment 2), and high- and low-reward sounds were always consistently paired with the same triplets. Experiment 3 was similar to Experiment 1, except that participants were asked to press the spacebar whenever they noticed a shape "jiggle," and we told participants that reward value was related to their actions, with jiggle always associated with a third item in a triplet. In the test phases for these experiments, participants viewed sequences of repeated triplets and foil triplets that were never previously presented in that order, and were asked to select the more familiar sequence. Across experiments, all three value categories showed significant visual statistical learning effects, but the strength of learning did not differ among no-, low-, or high-reward conditions for any of the three experiments. Thus, all three experiments failed to find any influence of rewards on statistical learning, implying that visual statistical learning may be unaffected by the occurrence of reward.

33.3003 Classifying EEG patterns of visual statistical learning Brett Bays[1] (bbays001@ucr.edu), Aaron Seitz[1]; [1]Department of Psychology, University of California, Riverside

Statistical learning (SL) refers to the extraction of probabilistic relationships between stimuli and is increasingly used as a method to understand learning processes. However, little is known regarding how SL accumulates over time, nor of the neural processes that underlie SL. To address these issues, in this study we employ pattern classification techniques to examine electroencephalography (EEG) data collected as participants acquire SL. While recording EEG, we exposed participants to a stream of visual shapes which, unbeknownst to them, were grouped into pairs, and then subsequently tested for statistical learning using a reaction time based search task. We then use a k-Nearest Neighbors pattern classification algorithm to classify corresponding EEG signals under two test conditions: classifying periods of activity after stimuli appear based on the presentation statistics of those stimuli; and classifying periods of activity after stimuli appear based on whether those stimuli correspond to "learned" or "non-learned" behavioral patterns. With these tests we show that by using behavioral measures to label certain items as "learned" and other items as "non-learned", we can design a classifier that is able to successfully discriminate those patterns of EEG activity within participants. In future work, we hope that these classifiers can be adapted to the online analysis of SL so as to detect SL as it is acquired. This has important implications for the field of SL and is a step toward understanding how SL accumulates over time and the neural processes that underlie SL.

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33.3004 Perceptual adaptation: Getting ready for the future Xue-Xin Wei[1] (weixxpku@gmail.com), Pedro Ortega[2], Alan Stocker[1]; [1]Department of Psychology, University of Pennsylvania, [2]Department of Electrical and Systems Engineering, University of Pennsylvania

Perceptual systems continually adapt to changes in their sensory environment. Adaptation has been mainly thought of as a mechanism to exploit the spatiotemporal regularities of the sensory input in order to efficiently represent sensory information. Thus, most computational explanations for adaptation can be conceptualized as a form of Efficient coding. We propose a novel and more holistic explanation. We argue that perceptual adaptation is a process with which the perceptual system adjusts its operational regime to be best possible prepared for the future, i.e. the next sensory input. Crucially, we assume that these adjustments affect both the way the system represents sensory information (encoding) and how it interprets that information (decoding). We apply this idea in the context of a Bayesian observer model. More specifically, we propose that the perceptual system tries to predict the probability distribution from which the next sensory input is drawn. It does so by exploiting the fact that the recent stimulus history is generally a good predictor of the future and that the overall long-term stimulus distribution is stationary. We assume that this predicted probability distribution reflects the updated prior belief of the Bayesian observer. In addition, we assume that the system is adjusting its sensory representation according to the predicted future stimulus distribution via Efficient coding. Because this sensory representation directly constrains the likelihood function, we can define an optimal Bayesian observer model for any predicted distribution over the next sensory input. We demonstrate that this model framework provides a natural account of the reported adaptation after-effects for visual orientation and spatial frequency, both in terms of discrimination thresholds and biases. It also allows us to predict how these after-effects depend on the specific form of the short- and long-term input histories.

33.3005 Neural sources of prediction in visual cortex Nicholas C. Hindy[1] (nhindy@princeton.edu), Felicia Y. Ng[2], Nicholas B. Turk-Browne[1,2]; [1]Princeton Neuroscience Institute, Princeton University, [2]Department of Psychology, Princeton University

Predictive coding refers to the theory that top-down expectations from higher-level brain areas interact with sensory evidence in lower-level areas. Neural responses in lateral occipital (LO) cortex reflect the consequences of this interaction, with reduced activity when expectations are fulfilled. But where do these predictions come from? We used a multi-session training paradigm and background connectivity to explore the neural mechanisms of prediction based on associations learned either immediately before ("Recent") or three days before ("Remote") an fMRI scan. Training sessions were separated in time because different memory systems are thought to support new and old memories. Within each training session, cue stimuli appeared individually and subjects pressed a button to transform

See page 3 for Abstract Numbering System

the cue into an outcome stimulus. For predictable cues, a particular outcome appeared when the left button was pressed and a different outcome appeared when the right button was pressed. For unpredictable cues, both outcomes appeared with equal probability irrespective of which button was pressed. After training, subjects completed an fMRI session in which Recent and Remote associations were presented in alternating runs. Each run was structured as a block design, with blocks containing either predictable or unpredictable cues. To examine background connectivity during these blocks, we first regressed out variance attributable to stimulus-evoked responses and nuisance variables, and then measured correlations among brain areas in the residual time-series. Correlations were computed in an exploratory manner using the residual time-series in stimulus-selective LO as a predictor of the time-series of all voxels. By comparing predictable to unpredictable blocks, initial results reveal a tradeoff in LO background connectivity for Recent vs. Remote associations between medial temporal lobe structures that support rapid encoding and broader areas of temporal cortex that represent consolidated long-term memories. These findings suggest a neural model of how actions influence predictive coding in the visual system.

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33.3006 Statistical regularities compress numerical representations

Jiaying Zhao[1,2] (jiayingz@psych.ubc.ca), Ru Yu[1]; [1]Department of Psychology, University of British Columbia, [2]Institute for Resources, Environment and Sustainability, University of British Columbia

Numerical information can be perceived at multiple levels of abstraction (e.g., one bird, or a flock of birds). The unit of input for numerosity perception can therefore involve a discrete object, or a set of objects grouped by shared features (e.g., color). Here we examine how the mere co-occurrence of objects shapes numerosity perception. Across three between-subjects experiments, observers viewed arrays of colored circles and estimated the number of circles in the array. In Experiment 1, unbeknownst to the observers, each array was constructed from either color pairs (i.e., regularities) in the structured condition, or the same circles in a random arrangement in the random condition. Aside from the regularities, the two conditions were identical in terms of numerosity, color, and density. We found that the number estimates were reliably lower in the structured condition than in the random condition, although observers were not explicitly aware of the regularities. This underestimation could be driven by either the presence of color pairs, or attention implicitly drawn to individual circles. To tease these two ideas apart, in Experiment 2 we examined the effect of grouping on numerosity perception, by introducing color duplicates (e.g., two red circles) in the structured condition. Number estimates were again reliably lower in the structured condition, suggesting that the underestimation could be explained by grouping. Finally, in Experiment 3 we examined the effect of local attention on numerosity perception, by presenting either two distinct colors in the array in the pop-out condition, or circles of the same color in the uniform condition. We found no difference in the number estimates between the two conditions, thus ruling out the role of local attention in numerosity perception. These results demonstrate that object co-occurrences cause numerical underestimation, suggesting that regularities serve as an implicit grouping cue that compresses numerical representations.

Acknowledgement: NSERC Discovery Grant to JZ

33.3007 Stimulus-specific regularities as a basis for perceptual induction

Yu Luo[1] (yuluo2008@hotmail.com), Jiaying Zhao[1,2]; [1]Department of Psychology, University of British Columbia, [2]Institute for Resources, Environment and Sustainability, University of British Columbia

A hallmark of visual intelligence is the ability to extract relationships among objects. One form of extraction produces stimulus-specific knowledge (statistical learning). Another form produces stimulus-general principles (inductive learning). These two learning processes seem incompatible on the surface, but may be related on a deeper level. Here we examine how statistical learning and inductive learning interact. In Experiment 1, observers were randomly assigned to one of three conditions where they viewed a sequence of circles of varying sizes. In the rule+regularities condition, the sequence contained repeated triplets (regularities) that followed a rule: the three circles increased in size in each triplet. In the rule-only condition, the sequence contained sets of three circles that followed the same rule, but all sets were unique (no regularities). In the regularities-only condition, the sequence contained repeated triplets that did not follow the rule. We found that learning of the rule and learning of the regularities were both stronger in the rule+regularities condition than in the rule-only, or the regularities-only condition. This suggests that statistical learning and inductive learning are mutually beneficial. To tease apart whether one learning process is necessary for the other, we increased the complexity of the rule in Experiment 2. Everything was identical to Experiment 1, except now the rule was that within each triplet or set, the first circle was smaller than the second circle, and the second was larger than the third. Learning of the rule was only successful in the rule+regularities condition, but not in the rule-only condition. Moreover, there was no learning of regularities. This suggests that the presence of regularities facilitated rule learning, but the presence of the rule did not help the learning of regularities. These findings demonstrate that statistical learning and inductive learning are related, and that stimulus-specific regularities are necessary for inductive learning.

Acknowledgement: NSERC Discovery Grant to JZ

33.3008 History effects in perception after manipulating the statistics of the environment

Kyle McDermott[1,2,3] (kyle.c.mcdermott@gmail.com), Adrien Chopin[1,2,4], Anna Ptuha[1,2], Pascal Mamassian[1,2]; [1]Laboratoire des Systèmes Perceptifs, CNRS UMR 8248, Paris, France, [2]Département d'Études Cognitives, École Normale Supérieure, Paris, France, [3]Vision Science and Advanced Retinal Imaging Laboratory, University of California, Davis, [4]University of California, Berkeley

The perception of stimuli depends, in part, on the properties of stimuli seen in the past. We examined the characteristics of observers' responses based on the stimuli they were shown and the responses they gave going back several minutes, Critically, we manipulated the statistics of the stimuli to be in a position to model the dynamics of these history effects on perception. Observers were presented with gratings in one of five orientations: two easy to discriminate (supra-threshold) 'far-left' and 'far-right', two intermediate (near-threshold) 'middle-left' and 'middle-right', and one ambiguous 'middle'. Far-left and far-right orientations were seen most frequently, and observers were not asked to respond to these 'standard' stimuli. When presented with one of the three orientations between the left and right standards observers had to indicate whether the orientation was closer to, or farther from, the randomly selected standard orientation which preceded it. In three contiguous conditions of 960 trials, left and right standard stimuli were presented in equal proportions, then biased to one side, then balanced. Not surprisingly, the data show a negative correlation between the orientation bias of the stimuli in the second condition and observers' mean responses, a negative aftereffect. While this negative correlation dominates in the near past, the data also suggest a weaker, positive correlation with stimuli seen in the more remote past (1000 trials). Critically, the aftereffect observed in the second condition disappears before the end of that condition, which is a prediction of the predictive adaptation model (Chopin and Mamassian, Current Biology, 2012). These results confirm earlier findings highlighting the contribution of remote past history on perception Adaptation appears to be predictive in that the statistics of the remote past are used to estimate a 'norm' against which present stimuli are compared.

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33.3009 Rapid effect of high-frequency tRNS over the parietal lobe during a temporal perceptual learning task

Sarah Tyler[1] (sarah.tyler@iit.it), Federica Contò[1], Lorella Battelli[1,2]; [1]Center for Neuroscience and Cognitive Systems, Instituto Italiano di Tecnologia, [2]Berenson-Allen Center for Noninvasive Brain Stimulation and Department of Neurology, Beth Israel Deaconess Medical Center, Harvard Medical School

Introduction. Transcranial random noise stimulation (tRNS) is a noninvasive neurostimulation technique in which random current levels applied to scalp electrodes elicit temporary changes in cortical excitability (Terney et al., 2008). This experiment explores modulatory effects of high-frequency tRNS on neural plasticity during a temporal perceptual learning task. We measured sensitivity to onset asynchronies (SOAs) during a temporal order judgment task as a function of both practice and active stimulation. Methods. Twenty-four subjects were randomly assigned to one of four conditions: hf-tRNS (up to 1000 Hz) over hMT+; hf-tRNS over parietal cortex; sham stimulation; and behavior only. Subjects undergoing active hf-tRNS were stimulated for 20 consecutive minutes concurrent with the task. Subjects viewed two discs flickering black and white for 1000 ms at 7.5 Hz. These discs were presented with onset asynchronies ranging from -66 ms (left disc first) to +66 ms (right disc first). During the flicker cycle, each disc was temporarily displayed as a Gabor for 133 ms (sp. frequency: 1.25 cycle/deg). Subjects judged whether the right or left disc appeared as a Gabor first. Feedback was provided for five out of six blocks. Results. SOA values across blocks were compared to determine sensitivity to the timing of Gabor onsets. As the experiment progressed, subjects exposed to parietal hf-tRNS were significantly better at correctly judging temporal order of the embedded Gabor discs at small onset asynchronies ($F(3,20)=14.37$; $p = 0$) as compared to all other conditions. Conclusions. Our results show the quick effect that parietal tRNS has in improving perceptual sensitivity during tasks that require attention to temporal patterns. These results shows promising insight into the relationship between cortical stimulation and neural plasticity, leading the way to neurostimulation as a possible therapy for patients suffering from neurological attention disorders.

33.3010 **Human brain circuits for learning hierarchical temporal structures**

Rui Wang[1] (rw517@cam.ac.uk), Yuan Shen[2], Peter Tino[2], Zoe Kourtzi[1]; [1]Department of Psychology, University of Cambridge, [2]School of Computer Science, University of Birmingham

Experience is known to facilitate our ability to extract regularities from simple repetitive patterns to more complex probabilistic combinations (e.g. as in language, music, navigation). However, little is known about the neural mechanisms that mediate our ability to learn hierarchical structures. Here we combine behavioral and functional MRI measurements to investigate the human brain circuits involved in learning of hierarchical structures. In particular, we employed variable memory length Markov models to design hierarchically structured temporal sequences of increasing complexity. We first trained observers with sequences of four symbols that were determined by their probability of occurrence (0.2, 0.8, 0, 0) and then sequences determined by their temporal context. We measured performance and fMRI responses before and after training on these two sequence types. In each trial, we presented observers with a sequence of symbols followed by a test stimulus. Observers were asked to indicate whether the test stimulus was expected or not. Our results demonstrate that dissociable brain circuits are involved in learning regularities determined by frequency of occurrence vs. temporal context. In particular, learning occurrence probabilities engaged frontal (inferior and middle frontal gyrus), parietal (inferior parietal lobule) and superior temporal regions, while learning temporal context engaged frontal (superior and medial frontal gyrus, cingulate) and subcortical circuits (putamen). Fronto-parietal regions showed increased fMRI responses to structured compared to random sequences early in training while decreased responses after training. In contrast, in subcortical regions, higher responses were observed for structured compared to random sequences only after training. Our results are consistent with the role of fronto-parietal circuits in identifying novel patterns, and the involvement of subcortical regions in contextual learning. Thus, our findings suggest that learning hierarchical structures is implemented by fast learning of frequency statistics in fronto-parietal regions, while conditional probability learning in subcortical regions later in training.

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Color and light: Adaptation and constancy

Sunday, May 17, 8:30 am - 12:30 pm

Poster Session, Banyan Breezeway

33.3011 **Monocular and binocular mechanisms mediating flicker adaptation**

Xiaohua Zhuang[1] (zxhelsa@gmail.com), Steven Shevell[1,2,3]; [1]Institute for Mind and Biology, University of at Chicago, Chicago, USA, [2]Department of Psychology, University of Chicago, Chicago, USA, [3]Department of Ophthalmology & Visual Sciences, University of Chicago, Chicago, USA

Purpose: Is the loss of contrast sensitivity following exposure to flicker (flicker adaptation) mediated by a mechanism at a monocular level, binocular level or both? New experiments address this by exploiting the observation that flicker adaptation is stronger at higher than lower temporal frequencies. Methods and Results: Experiment I used 3Hz square-wave 50%-contrast flicker with an incremental pulse at 1/4 duty cycle (83-msec pulse in each 333-msec cycle). Binocular contrast sensitivity was measured following adaptation to in-phase flicker in both eyes or 180-degree out-of-phase flicker. At the binocular level, the flicker rate is 6Hz in the out-of-phase condition if the two eyes' pulse trains sum up. This would cause stronger adaptation than binocular 3Hz flicker in the in-phase condition. However, similar sensitivity reduction was found in both phase conditions, as expected for independent monocular adapting mechanisms. Experiment II tested for interocular transfer of adaptation between eyes. Monocular left-eye contrast sensitivity was measured following adaption to (i) 10%-contrast flicker in only the left eye or (ii) 50%-contrast flicker in only the right eye. In addition, (iii) adaptation in both eyes simultaneously was tested with 10%-contrast flicker in the left eye and 50% in the right. Various phase differences between eyes were tested. Left-eye flicker (10%) alone caused the largest left-eye contrast-sensitivity reduction, though right-eye flicker (50%) alone caused some left-eye sensitivity loss. When presented in-phase, left-eye (10%) and right-eye (50%) flicker together resulted in similar left-eye sensitivity reduction as for right-eye flicker (50%) alone. Conclusion: Flicker adaptation was strongest when adapting and testing in only the same eye. Adaptation can be partially transferred interocularly with adaptation in only the opposite eye. Moreover, monocular adaptation was weakened when both eyes were adapted simultaneously at different contrasts. Thus flicker adaptation results from mechanisms at both the monocular and binocular levels.

33.3012 **Color constancy revisited: A better approach**

David Weiß[1] (david.weiss@psychol.uni-giessen.de), Marina Bloj[2], Karl Gegenfurtner[1]; [1]Department of Psychology, Justus-Liebig-University Giessen, [2]Bradford School of Optometry and Vision Sciences, University of Bradford

All established measures for color constancy come with methodological problems or serious constraints. They rarely capture our everyday experience of the phenomena. Here we present a new and intuitive approach that allows us to measure constancy for arbitrary colors without multiple illuminants in the scene. Participants (N=17) were asked to bring a personal object (e.g. scarf) that had for them a well-defined colour that they were confident they could identify in absence of the object. Without the object being present, participants were asked to select from the Munsell Book of Color (Glossy Edition) the chip that best represented the colour of their chosen object. They performed the task first in a room under neutral daylight illumination and in two other rooms that had non-daylight illuminations provided by windows covered with filters. The task was performed twice in each room but always on different days. The filters induced substantial changes in the objects' color coordinates by 24 (purple filter) and 28 (green filter) Lab units. Before selecting the chip, participants adapted to the illumination while performing a color sorting task. Under each of the three illuminations, we measured the Lab coordinates of the objects, the illumination and the selected chips. We also selected the chip that best matched the object in its presence. In this task, our participants were perfectly color constant. The change in the objects' color coordinates under the illumination changes was equalled by the changes in the color coordinates of the chips selected under the different illuminants. On average, 99.2% (+/- 3.6% s.e.) constancy was achieved. There was no significant difference for the two filter conditions. Our results show that perfect color constancy can be achieved in a task and conditions that are highly representative of the uses of color constancy in everyday life.

Acknowledgement: DFG-SFB/TRR135

33.3013 **Brightness induction reveals changes in neural response time to changes in stimulus contrast**

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We explore whether brightness induction can be used to reveal changes in neural response time to changes in stimulus contrast. Brightness induction is a phenomenon in which the brightness of a stimulus is influenced by its surrounding context (e.g., Chevreul, 1839/1987; Shevell, Holliday & Whittle, 1992). For example, a red dot surrounded by the color black appears brighter than a red dot surrounded by the color white when both red dots are the same intensity. Neurophysiological studies (e.g., Shapley & Victor, 1978; Solomon & Lennie, 2005) have shown that as the contrast of a stimulus decreases, the neuronal response time increases. Subjects performed a brightness induction heterochromatic flicker photometry task (HFP, 5Hz; Gunther & Dobkins, 2005) in three conditions: red intense (bull's-eye dot stimulus with a red center [3.5° diameter] and black surround [6° diameter] alternating with a bull's-eye dot with a green center and white surround), green intense (green is paired with black, red with white), and a non-induction control (red and green dots alternating with no inducing annulus). Subjects performed HFP (minimize flicker by adjusting relative red/green luminances) on the red/green central dot for each induction condition. The red/green center dot was presented at seven contrasts (25-60% of the maximum possible on the monitor; 6.99–8.24% root mean square cone contrast), in seven linear steps. The logic of the induction paradigm is that as the contrast of the stimulus decreases, the center should appear to flicker slower, thus becoming perceptually out of phase with the inducing surround. At low enough contrasts, the center may be perceptually 180° out of phase with the inducer, thus appearing as assimilation instead of induction. The HFP settings do show changes in induction magnitude with contrast, reflecting changes in neural response time. Results are not yet statistically significant - data collection continues.

33.3014 **Asymmetries and spatial gradients in color and brightness induction**

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We tackle two issues in color/brightness induction with a new measurement method. First, there are reports of asymmetry in the literature that dark induction is stronger than light induction, but these claims are based on experiments that did not separate adaptation effects from lateral interactions. Second, the magnitude of induction is generally reduced by spatially separating the test and surround, and by decreasing the physical contrast between them, so blurring the edge between the test and the surround should reduce the magnitude of induction, but this has not been tested experimentally. In our method, observers viewed a centrally fixated annulus (0.66° to 2.0°) surrounded by a 12° square. The edges between the annulus and its surrounds had either a square (sharp) or sinusoidal (blur) gradient. The color of the square was modulated for 0.5 seconds as a half-sinusoid between mid-Grey and one of the six poles of DKL space, roughly Light, Dark, Red, Green, Yellow, Blue. When the annulus was steady at mid-Grey, observers perceived an induced color/brightness shift towards the complementary pole. The magnitude of the perceived shift was measured as the amplitude of real modulation needed to null it, using a double-random 2AFC staircase-procedure. Each block of trials alternated surround modulation between complementary poles to keep adaptation at the mid-Grey. This method estimates stronger induction effects than any other method. Across 2 observers, there were no consistent asymmetries in induction along any of the 3 color axes, suggesting that previously reported asymmetries reflect adaptation effects rather than lateral interactions. Spatial blur did not reduce the magnitude of induction, and in some cases seemed to increase the effect. The lack of effect of moderate blur on induction magnitude, suggests that neural models pooling the outputs of spatial filters may be a better representation than models incorporating edge detection.

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33.3015 **Adapting to an "aged" lens** Katherine Tregillus[1] (kemtregillus@gmail.com), John Werner[2], Michael Webster[1]; [1]Department of Psychology, University of Nevada, Reno, [2]Department of Ophthalmology & Vision Science Department of Neurobiology, Physiology & Behavior, University of California, Davis

Color appearance is effectively compensated for the progressive yellowing of the lens with age, but the time course and mechanisms of these adjustments remain poorly understood. We examined how observers adapted to the sudden introduction of an "aged lens" by wearing glasses with yellow filters that approximated the average lens transmittance of a 70 year old at shorter wavelengths. The glasses were worn over a period of 5 days for 8 hours per day while the individuals (4 young adults) pursued their normal activities. Achromatic settings were measured before and after each daily exposure with the glasses on or off, with each setting preceded by 5 minutes of dark adaptation to remove biases owing to short-term chromatic adaptation. Stimuli were 2 deg fields shown for 250 msec with 1.5 sec intervals and displayed on a CRT. The chromaticity varied in a staircase and was confined to the axis extending through a nominal white point of Illuminant E with or without the glasses. Over repeated days there was a weak but progressive drift of the achromatic settings toward blue, consistent with a partial renormalization for the yellow lens. By the 5th day this averaged roughly 40% of complete compensation. This drift was also evident in the settings made at the beginning versus end of each daily session when the glasses were on, which again showed partial compensation. Surprisingly, the adaptation build-up on each day was not accompanied by an aftereffect when the glasses were removed (and after dark adapting) at the end of the day. This could reflect a contribution of a context-specific adaptation contingent on wearing the glasses. Our results are consistent with evidence (e.g. Delahunt et al. Visual Neuroscience 2004) pointing to a very sluggish mechanism underlying renormalization of color appearance as the spectral characteristics of the lens change.

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33.3016 **Perceiving the average color** Siddhart Srivatsav[1], Jacquelyn Webster[1], Michael Webster[1]; [1]Department of Psychology, University of Nevada, Reno

The average color in a scene is a potentially important cue to the illuminant and thus for color constancy, but it remains unknown how well and in what ways observers can estimate the mean chromaticity. We examined this by measuring the variability in "achromatic" settings for stimuli composed of different distributions of colors. The displays consisted of a 15 by 15 palette of colors shown on a gray background on a monitor, with each chip subtending 0.5 deg. Individual colors were randomly sampled from varying contrast ranges along the luminance, S and LM cardinal axes. Observers were instructed to adjust the chromaticity of the palette so that the mean was gray, with variability estimated from 20 or more repeated settings. This variability increased progressively with increasing contrast in the distributions, with large increases for chromatic contrast but also weak effects for added luminance contrast. Signals along the cardinal axes are relatively independent in many detection and discrimination tasks, but showed strong interference in the white estimates. Specifically, adding S contrast increased variability in the white settings along both the S and LM axes, and vice versa. This "cross-masking" and the effects of chromatic variance in general may occur because observers cannot explicitly perceive or represent the mean of a set of qualitatively different hues (e.g. that red and green hues average to gray), and thus may infer the mean only indirectly (e.g. from the relative saturation of different hues).

Acknowledgement: Supported by EY-10834

33.3017 **Effect of achromatic afterimage on spatial chromatic induction** Guillaume Riesen[1] (guillaume.riesen@gmail.com), Gennady Livitiz[1], Rhea Eskew[2], Ennio Mingolla[1]; [1]Computational Vision Laboratory, Department of Communication Sciences and Disorders, Northeastern University, [2]Department of Psychology, Northeastern University

It is known that visual stimuli with luminance contrasts produce afterimages of opposite contrast following adaptation. A bright figure on a dark surround gives an afterimage of a dark figure on a bright surround. However, the exact nature of these afterimages is unclear -- does the visual system treat them the same as it does luminance contrasts from real light? We used spatial chromatic induction to explore this question. Spatial induction occurs when a colored surround induces its complement into a figure. This effect is maximized at equal brightness, and is eliminated when there are high-contrast edges between the figure and ground. Could brightness contrast from an afterimage be used to cancel the luminance contrast in a test display, thereby producing equiluminant conditions and restoring spatial chromatic induction? We used neon color spreading stimuli (grids of colored lines over achromatic backgrounds) to allow for fine control of luminance independent of hue - the luminances of the backgrounds can be manipulated separately from the grids themselves, which provide chromaticity. Participants were presented with a test stimulus which showed little chromatic spatial induction due to luminance contrast between the figure and background. This stimulus was then alternated with an adaptation stimulus which moved from uniform gray to a maximum contrast, under participants' control via a knob. Participants were instructed to find the adaptation stimulus which resulted in the strongest perception of hue within the figure region of the test stimulus. Results suggest that the afterimage integrated with the test stimulus, reducing the edge contrast and enhancing spatial chromatic induction. This would indicate that the integration of an afterimage with real light precedes the neural computations that determine the strength of color induction. This method also offers a potential way to quantify the luminance contrast in an afterimage.

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33.3018 **Canceling a Hue of a Negative Afterimage in Solid and Perceptually-Filled Color Images** Gennady Livitz[1] (glivitz@gmail.com), Guillaume Riesen[1], Ennio Mingolla[1], Rhea Eskew[2]; [1]Computational Vision Lab, Department of Communication Sciences and Disorders, Bouvé College of Health Sciences, Northeastern University, [2]Psychology Department, Northeastern University

A negative afterimage is perceived as having a color "opposite" to those of the adapting stimulus. We investigated the effects of afterimages on the perception of color stimuli, as well as their effects on spatial chromatic induction. Anstis et al. (1976) showed that the effects of direct light stimulation could be integrated with the chromatic perception resulting from temporal (color adaptation) and spatial color contrast. This could be an additive interaction, meaning that a negative afterimage could be canceled either by light of the same chromaticity or by a complementary surround. In a series of hue cancellation experiments, observers judged the chromatic neutrality of a test after adapting to a colored image. In the experiments with direct light stimulation, observers were instructed to change the saturation of the test stimulus, which had the same hue as the adapting light, until the test figure appeared chromatically neutral. The spatial contrast procedure was similar except that observers adjusted the surround of the test stimulus to cancel the afterimage using spatial chromatic induction; in this case, the surround hue was complementary to the adapting stimulus. Results show that afterimages are either not complementary, do not mix additively with color stimuli, or both. For many of the adapting colors, the hue of the subsequent test did not appear neutral at the observer's settings; observers were able to reduce the saturation of the test but not make it look grey. This non-complementarity was most pronounced in the afterimage of a blue stimulus.

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However in afterimages caused by perceptually-filled (neon color) stimuli, the interactions were more like additive mixing and the final percept came closer to chromatic neutrality. This difference may be related to the tendency of afterimages to be perceived as filters over solid stimuli while additively mixing with perceptually-filled surfaces from neon stimuli.

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33.3019 Illumination discrimination depends on scene surface ensemble

Avery Krieger[1] (krave@sas.upenn.edu), Hilary Dubin[1], Bradley Pearce[2], Stacey Aston[2], Anya Hurlbert[2], David Brainard[1], Ana Radonjić[1]; [1]Department of Psychology, University of Pennsylvania, USA, [2]Institute of Neuroscience, Newcastle University, UK

The ability to discriminate between scenes under different illuminations may provide insight into how the visual system represents and perhaps discounts changes in illumination (Pearce et al. 2014). Here we examine whether there is an interaction between sensitivity to illumination changes in different chromatic directions and the chromaticity of the surfaces in the scene. Simulated stimulus scenes were rendered hyperspectrally using RenderToolbox3 and displayed stereoscopically. Each scene was specified as a room covered with rectangular, uniform matte surfaces of widely different colors. Across the three surface ensembles used, the shape and position of surfaces was fixed but their assigned surface reflectance varied. Under simulated illuminant D67, one surface ensemble was roughly 'neutral' in average chromaticity (mean xy: [0.32, 0.35]), while the other two were 'reddish-blue' ([0.36, 0.34]) and 'yellowish-green' ([0.39, 0.42]) relative to it. For each ensemble we measured illumination discrimination thresholds along four different chromatic directions ('blue', 'yellow', 'red' and 'green') using a staircase procedure. The subjects viewed the target scene (simulated illuminant D67) and two comparison scenes — one identical to the target and another rendered under the test illuminant — and judged which of the comparison scenes matched the target. Varying average scene chromaticity had an effect on illumination discrimination thresholds, and that effect was different for different illuminant-change directions. Notably, thresholds for the 'blue' illumination-change direction were higher for the 'yellowish-green' surface ensemble than for the 'neutral' (+5.6ΔE) and 'reddish-blue' (+6.1ΔE) ensembles, while thresholds for the 'red' illumination change-direction were lowest for the 'reddish-blue' ensemble (-3.7ΔE relative to the 'neutral'; -4.1ΔE relative to the 'yellowish-green' ensemble). Our results show that characterization of illumination discrimination must take the scene surface ensemble into account, and that the relative discriminability of illumination changes in different chromatic directions is influenced by the average chromaticity of the surface ensemble.

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33.3020 Spatial ratios of cone excitations from natural scenes over the course of the day

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The light reflected from natural scenes varies markedly during the day. In addition to spectral changes in the illumination on a scene from the sun and sky, the geometry of the illumination alters with the sun's elevation and cloud cover and with changes in local surface shadow, mutual reflection, and haze. One low-level visual signal that offers an invariance to spectral changes in illumination is the spatial ratio of cone photoreceptor excitations generated in response to light reflected from points or surfaces in a scene. Such a signal may indeed provide a basis for several kinds of color judgments. But it is not obvious that these ratios are also invariant under geometric changes in illumination. The question of this invariance was addressed here by analyzing sequences of time-lapse hyperspectral radiance images from five outdoor rural and urban scenes. The images were acquired with a hyperspectral camera with spatial resolution 1344 x 1024 pixels and line-spread function that was approximately Gaussian with standard deviation 1.3 pixels at 550 nm. In each scene, 10,000 pairs of points were sampled randomly and for each pair the deviation in spatial cone-excitation ratios were estimated at successive times of day. Averaged over scenes, time intervals, spacings of the pairs of points, and cone classes, the mean relative deviation in ratios (i.e. the symmetric mean absolute percentage error) was more than 20%, much greater than the 4% found with pure spectral changes in illumination. But when time intervals were restricted to about an hour or less and pair spacings to 4 pixels or less, the mean relative deviation fell to 7% and for four of the five scenes to 5%. For cone signals adjacent in time and space, spatial ratios may provide a reliable cue for making visual judgements even in a varying natural environment.

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33.3021 Adaptation and compensation in anomalous trichromacy

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Anomalous trichromats have two similar longer wave pigments and thus reduced sensitivity to the reddish-greenish chromaticities carried by their differences. However, a number of studies have found that in some anomalous observers the salience of these hues is much greater than predicted by their sensitivity losses, consistent with a compensatory mechanism that tends to normalize the gamut of their perceptual color space. We explored the possibility that this could result in part from normal processes of contrast adaptation, by examining how normal trichromats would adapt to the reduced range of color signals available to color deficient observers. Images were 1/f noise with perceptually equated random variations in luminance and chromatic (S and LM) contrast. These images were then filtered with the spectral sensitivities of a deuteranomalous observer, and were adjusted for von Kries adaptation so that the mean chromaticity remained gray. Chromatic variations in the resulting images varied primarily in S-cone contrasts. Observers adapted to a rapid sequence of the filtered images shown in a 4-deg field for 5 minutes, and then interleaved with briefly presented test stimuli shown in the same field. The test images had the same luminance contrast but a fixed chromaticity spanning the S vs LM space at 22.5 deg intervals. The hue of the test was matched by adjusting the hue angle of a comparison image presented in an unadapted field to the other side of fixation. Adaptation to the biased chromatic contrasts in the anomalous images produced systematic biases in the perceived hue of the test images, consistent with a selective loss in sensitivity to the adapting colors. Our results suggest that in anomalous trichromats the losses in color contrast may lead to selective contrast adaptation which may act to rebalance and thus partly discount their sensitivity losses from their phenomenal color percepts.

Acknowledgement: Supported by EY-10834

33.3022 Robust color constancy with natural scenes in red-green dichromacy

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Color discrimination in dichromats is impaired but the extent to which their color constancy is affected remains unclear. This work compares color constancy for red-green dichromats with normal observers. Stimuli were generated using spectral reflectance data of natural scenes obtained from hyperspectral imaging. Two scenes of rural and two of urban environments were selected from the database of Foster et al. (2006, J. Opt. Soc. Am. A, 23, 2359). Each scene was rendered with correlated color temperature (CCT) in the range 4012-40231K (steps of 23.3 MK-1) along the daylight locus. In this condition of pure illuminant change average luminance was 10 cd/m2. Thresholds for detecting a change in CCT were estimated with a 2AFC experiment with the stimuli presented on a calibrated CRT controlled by a ViSaGe MKII (Cambridge Research Systems) in 24-bits-per-pixel true-color mode. Similarly to Pearce et al. (2014 PLoS ONE 9(2): e87989), observers viewed the scene illuminated by 6700K and then two images, one illuminated by either a higher or lower CCT. The observers had to identify the image that looked different. Thresholds for a pure luminance change were also estimated with similar methodology but varying only the average luminance of the scenes. Four normal observers, two protanopes and one deuteranope were tested. Four mixed-model ANOVA analyses didn't reveal any significant main effect of scene or of its interactions with group of observers (all $P > 0.05$). However, a group effect was found for changes towards lower CCT [$F(2,4) = 8.29$, $P < 0.05$] but indicating slightly higher color constancy for dichromats. These results suggest that for red-green dichromats color constancy mechanisms along daylight locus are at least as efficient as for normal observers.

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33.3023 Lightness filling-in as a mechanism for achieving lightness constancy

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In a series of recent publications, I have proposed a neural model of lightness computation in which large cortical receptive fields spatially integrate the outputs of oriented contrast detectors in V1/V2 (Rudd, 2010, 2013, 2014). The model explains quantitative data on perceptual edge integration in lightness, as well as matching data from the staircase-Gelb and Gilchrist dome paradigms. Here I demonstrate with computer simulations how lightness filling-in results from this same computational model. The filling-in produced by the model differs from that of previous filling-in models in which regions lying between surfaces boundaries are 'colored in.' The current model instead envisions filling-in as a 'trans-object' mechanism that supports lightness constancy by establishing a unitary lightness scale that applies to multiple surfaces and objects within the visual scene. I demonstrate how a spreading achromatic color signal that is not stopped by object boundaries can support constancy and at the same time appear—but only appear—to be contained by object borders. The effect is achieved through the spatial interaction of spreading of separate lightness and darkness signals that combine like waves to either reinforce or cancel. A spreading darkness signal that encounters a luminance boundary can be partially cancelled by a lightness signal on the other side of the border, thus producing the perceptual impression that the darkness signal was stopped at the border. The model also accounts for Gilchrist's Area Rule, according to which larger area regions that are not the highest luminance appear lighter than smaller regions having the same luminance. The geometrical patterns of lightness spreading produced by the model depend on the shapes of the model receptive fields. I present simulations produced under different assumptions about these receptive field shapes and explain how they reflect the properties of neural connections within the feedforward ventral pathway of visual cortex.

Perception and Action: Driving and navigating

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

33.3024 Easter Egg Hunt Winners use Competition-Density Minimizing Foraging Strategy to "Bring Home the Bacon" (and Eggs)

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This study examines foraging strategy in the ecologically-valid, real-world setting of a competitive Easter Egg Hunt. Foraging studies often test marginal value theorem (MVT), an optimality model that describes ideal foraging behavior in patchy environments with diminishing returns. A typical setting for studying MVT is picking in an apple orchard. Here, a forager balances pursuit of nearby, smaller, lower-density reward trees with pursuit of more distant, larger, higher-density reward trees. The optimal MVT apple-picking tactic has been shown to utilize a cost-benefit analysis of these two pursuit strategies. However, such models omit the real-world role of competitor behavior which complicates modeling but improves ecological validity. To address this issue, we examined foraging behavior in an Easter Egg Hunt. We analyzed competitive foraging behavior of 64 adults in an egg hunt with patchy egg distribution. We found that the most successful hunters initially ignored nearby patches with densely distributed eggs when those patches were crowded with competitors. Instead, top hunters favored running to distant patches with less dense egg-distributions and scant competition. Best performers also exhibited distinct strategy stages, reorienting after the initial scramble removed easily visible eggs, and, then, methodically exploring crowded but difficult areas that novices treated more cursorily. In contrast to apple orchards without dynamic competition, the best strategy was not dominated by MVT planning phases of shortest-routes-to-densest-egg-distribution areas. Rather, it was dominated by taking advantage of behavioral tendencies of competition and systematically changing strategies when the competitive environment fundamentally changed. Our findings support that standard traveling salesman route-length minimization models, like MVT, can be improved by incorporating dynamic competition variables that are fundamental to many real-world foraging tasks. Egg hunters who initially minimize density of competition and later brave crowds to persistently scour tougher terrains prove to be the ones who "bring home the bacon" (and eggs)!

Acknowledgement: None

33.3025 Neighbor influence on evacuation behavior in virtual and real environments

Max Kinateder[1] (max_kinateder@brown.edu), William Warren[1]; [1]Brown University

Virtual reality (VR) enables the study of visually-guided behavior in situations that are otherwise not amenable to laboratory research. An example is a fire evacuation scenario, in which building occupants have to find their way to safety through smoke and flames, identify safe egress routes, and avoid threats. First, however, it must be determined whether evacuation behavior in VR is comparable to that in a real environment. We are thus initially studying participant responses to a fire alarm in matched virtual and real environments. The present experiment investigates how the decision to evacuate is influenced by visual cues about a neighbor's behavior. In the Control group, a lone participant is exposed to a fire alarm while performing a bogus task. In the Passive group, a participant performs the same task with a confederate who ignores the fire alarm. In the Active group, the confederate immediately leaves the room when the fire alarm sounds. The gender of the participant is crossed with the gender of the confederate. 75 participants experience the scenario in a real environment (25 per group), and 75 others in a matched virtual environment presented in a wireless head mounted display (HMD), with avatars of the confederates. In the real environment, two-thirds of participants in the Control group evacuated the room. In the Active group, nearly all did so, whereas in the Passive group all but one did. More female than male participants evacuated in the Control group, but there were no other gender effects. Data collection in the virtual environment is in progress, and will be completed by spring. The findings thus far demonstrate a very strong influence of neighbor behavior on a participant's evacuation decision. The results will provide answers to the much-debated question of whether evacuation behavior is similar in virtual and real environments.

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33.3026 The surprising utility of target drift in natural heading judgements

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Gibson (1950) proposed that optic flow provides information about the direction of self-motion (heading) relative to objects in the environment. Llewellyn (1971) pointed out that the change in egocentric direction of an object, "drift", also provides information about whether an observer is passing to the left or right of the object. We compared the precision of heading judgements with flow and drift cues, presented in isolation, and together. With flow alone, observers were quite precise (< 1°), but observers were more precise with drift, and equally precise with drift alone and with both flow and drift. Next we examined how precision changed with display duration (0.2-1.6s). There was evidence of cue-combination at 0.2s but at longer durations the precisions for the drift and both cue conditions were similar and lower than for the flow condition. To explore whether flow contributes at all with display durations longer than 0.2s, we replicated the 0.4s condition and also measured reaction times. Lower reaction times when flow was available suggested that flow does contribute. We next checked to see whether poorer precision in the flow condition was due to the fact that the object probe was presented after the stimulus display. We ran an experiment in which we added simulated gaze rotation noise in the range between -1 and +1°/s in the display to perturb the drift signal. This led to a drop in the precision of heading judgements. We then added a simulated gaze rotation at +1 or -1°/s. This led to not only a larger reduction in the precision but also a large systematic difference in the accuracy of heading judgments between the two rotation rates, suggesting drift dominating flow. We conclude that target drift is a surprisingly powerful cue for the perception of naturalistic object-relative heading.

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33.3027 Distinct spatial and temporal discounting during decision making in humans

James Thompson[1] (jthompsz@gmu.edu), Martin Wiener[1], Kelly Michaelis[2]; [1]Department of Psychology, George Mason University, Fairfax, VA, [2]Interdisciplinary Program In Neuroscience, Georgetown University, Washington, DC

When given the choice between a smaller reward now and a larger reward at some time in the future, individuals discount the delayed reward as a function of the delay, and choose the more immediate option. Less commonly studied in humans is the effect of spatial discounting, where one must choose between a close reward and a farther one. In general, people

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tend to give less weight to geographically distant effects than to local effects – for example, the willingness to pay to live further away from undesirable facilities decreases exponentially as a function of distance. So-called spatial discounting has been harder to demonstrate in the lab: a target's distance is often confounded by the time it will take to reach it. Across two experiments using a virtual environment, we compared spatial and temporal discounting (Experiment 1) and designed a spatial discounting task in which we isolated the effects of distance on discounting (Experiment2). Our first experiment (n=22) replicated previous findings of a hyperbolic discounting effect in the temporal domain. We also observed the same finding in the spatial domain, with longer/farther rewards progressively discounted. In the second experiment (n=21), subjects again performed the spatial discounting task, but this time the walking speed varied between trials. We found that participants discounted rewards that were farther away relative to those that were closer, even when the time taken to reach the two rewards was the same. These results demonstrate spatial discounting in humans that is distinct from temporal discounting, suggesting a coding of reward distance that is distinct from the time taken to travel to the reward. These results have important implications for understanding spatial decision making in individuals in relation to their environmental surrounds.

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33.3028 Anchoring the internal compass: The role of geometry and egocentric experience Nicole Paul[1] (paulnic@sas.upenn.edu), Steven Marchette[1], Russell Epstein[1]; [1]Department of Psychology

The ability to represent one's orientation (i.e. heading) relative to a fixed reference frame is an essential component of spatial cognition. In a previous study (Marchette et al., 2014), we found that subjects use local environmental boundaries (i.e. walls) to anchor their sense of direction when they re-instantiate spatial views from a newly-learned environment. Here we investigate the role of egocentric experience in shaping this anchoring process. In three experiments, subjects learned virtual environments containing several target objects. On test trials, they re-instantiated views from the environment and reported the locations of target objects. To assess heading codes, we analyzed priming for repetition of imagined heading across successive trials. Exp. 1 tested whether egocentric experience could "break" geometric symmetry by training subjects in a symmetric (rectangular) room but beginning every learning trial with the subject facing the same direction. Priming was observed for views facing the same direction but not for views facing geometrically identical corners, indicating that the egocentric orientation during learning had an effect. In Exp. 2, geometry and egocentric experience were put into conflict using a "hairpin" maze consisting of rectangular corridors linked together to form a single path. Once again, egocentric experience broke the geometric symmetry: priming was obtained between views facing the same direction along the path of travel during learning but not between views facing the same absolute direction. Exp. 3 tested whether egocentric experience alone sufficed to anchor heading codes even in the absence of geometric boundaries by using an environment in which travel was constrained by "moats" rather than by walls. In this case, we observed no heading priming. Taken together, these results suggest that environmental boundaries are essential for anchoring one sense of direction, but that egocentric experience plays an important role in distinguishing between headings when geometry is ambiguous.

33.3029 Predicting Steering Control Performance from Coherent Motion Performance Bobby Nguyen[1] (bhnguyen@wichita.edu), Rui Ni[1], John Plummer[1]; [1]Psychology Department, Wichita State University

Integrating visual information spatially and temporally is important in motion perception and in many daily activities, such as steering in a driving task. Our recent research showed that reduced optic flow quality and quantity impaired steering performance under reduced visibility conditions. However, it is not clear how spatial and temporal integration of visual information is related to steering control under low visibility conditions. In the current study we examined whether spatial and temporal integration performance on coherent motion tasks under low visibility could predict performance on a steering control task under low visibility for younger drivers. In the coherent motion task, displays consisted of either a 2D or 3D array of dots, in which a portion of the dots moved in a uniform direction (i.e., coherency) and the remaining dots moved in random directions (i.e., noise). Participants were asked to identify the perceived direction of the coherent dots (in 2D displays) or to identify the perceived moving direction of the viewer (in 3D displays). Dot density and dot lifetimes were manipulated while coherency threshold was measured using the best BEST procedure. In the steering control task, participants viewed a 3D array of moving random dots and were asked to respond to a sinusoidal perturbation to their lateral position, simulating a driving behavior. Forty participants performed the coherent motion task and the steering control task. We found that temporal and spatial integration of the stimuli, and not display type, affected performance on the coherent motion task. A structural equation model revealed that coherent motion performance accounted for nearly 30% of steering control performance. These results suggest that under reduced visibility conditions, temporal and spatial integration of visual information may play an important role in certain aspects of driving, such as steering control.

33.3030 Prospective steering control is influenced by retinal flow Richard Wilkie[1] (r.m.wilkie@leeds.ac.uk), Callum Mole[1], George Kountouriotis[2], Jac Billington[1]; [1]School of Psychology, University of Leeds, [2]Institute of Transport Studies, University of Leeds

Both retinal flow and visible road edges are potentially useful sources of information when steering down a road. Influential models of driving have identified a role for "near" and "far" road edge components, but it has been shown that flow is used even when complete road edges are present (Kountouriotis et al., 2013). The aim of the present study was to assess whether flow is used when different road edge components were available. We tested 20 participants steering through a virtual reality computer simulated environment while fixating a point on the road ~2s ahead. Flow was systematically manipulated independent of the veridical road edges, so that use of flow would lead to predictable understeer or oversteer (the flow speed was altered proportional to veridical flow by: .5, .75, 1, 1.25, 1.5). We also varied road edge information by using 7 combinations of Near road ('N': up to .5s ahead), Middle road ('M': from .5s to 1s ahead) and Far road ('F': from 1s to horizon) information. As predicted, steering systematically changed according to flow speed, but the magnitude of the flow-induced bias varied depending on the road-edge components that were visible. The presence of Far road increased the influence of flow, with flow bias most evident in F and N+M+F conditions. Similar results were observed when participants were free to look where they preferred. It seems that flow predominantly interacts with prospective steering control rather than the immediate correction of steering errors.

33.3031 Steering control using feedback from near road edges does not rely upon retinal flow. Callum Mole[1] (ps09c2m@leeds.ac.uk), Georgios Kountouriotis[2], Jac Billington[1], Richard Wilkie[1]; [1]School of Psychology, University of Leeds, [2]Institute for Transport Studies, University of Leeds

There are two potentially useful sources of information when steering along a road: retinal flow and road edges. Influential models of driving have examined the distinct roles of "near" and "far" road edge components, but it has been recently shown that flow is used even when road edges should be sufficient to control steering (Kountouriotis et al., 2013). The aim of the present study was to assess the use of flow when different road edge components were present. Participants steered along a computer simulated road on a textured ground plane, travelling at a constant speed (generating retinal flow). Flow was manipulated independent of the veridical road edges, so that use of flow would cause systematic changes to steering. Additional translation components were added to flow by moving the ground (at a speed of .75ms or 1.5ms) perpendicular to the ideal direction of travel towards the outside of the bend (predicted understeer; Fig 1A), towards the inside of the bend (predicted oversteer; See Fig 1B), or flow remained veridical (no additional translation). We also varied road edge information by displaying 7 combinations of Near road ('N': up to .5s ahead), Middle road ('M': from .5s to 1s ahead) and Far road ('F': from 1s to horizon) information. As predicted, steering systematically changed across the flow manipulations, however, the magnitude of the flow-induced bias varied depending on the road edge components that were visible. The presence of N seemed to decrease the influence of flow: flow bias was weakest for N+M+F (complete road), N, N+M conditions, and strongest for F conditions (see Fig 2). While these findings confirm previous observations that the visual-motor system uses flow despite the presence of veridical road edge information, it appears that flow is less influential when the immediate error correction signal is being used.

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33.3032 Steering along curved paths is influenced by global flow speed not speed asymmetry Georgios Kountouriotis[1] (g.kountouriotis@leeds.ac.uk), Callum Mole[2], Natasha Merat[1], Peter Gardner[2], Richard Wilkie[2]; [1]Institute for Transport Studies, University of Leeds, [2]School of Psychology, University of Leeds

Retinal flow, the pattern of motion caused by self-motion through a textured world, is used to control steering. Our previous work has shown that flow asymmetries influence humans steering along demarcated paths, with different textures on either side of the path causing biases consistent with participants reducing flow asymmetries (Kountouriotis et al., 2013). To test whether asymmetries in speed also bias locomotor control, participants were asked to steer a series of curved trajectories in a virtual reality simulated environment. Regions of the ground plane either side of a visible bounded path were rotated at different speeds to create flow asymmetries. The manipulation varied (i) Asymmetry Direction: whether the ground to the inside of the bend moved slower or faster than the outside of the bend, (ii) Asymmetry Size: whether the difference in speeds of the two regions was a small gap or a large gap, and (iii) Global Flow Speed: whether the average speed across both regions was slower than, the same as, or faster than the actual locomotor travel speed. The results suggest that participants did not simply equalise the flow vectors (i.e. steer towards the slower-moving region) since asymmetry size and direction did not systematically alter steering. Instead, participants were influenced by the global flow speed, whereby faster global flow led to greater oversteer (towards the inside of the bend) and vice versa. Importantly, steering biases occurred despite the visible path providing splay angle information across all conditions. We conclude that global flow speed is used to control locomotor steering even when travelling along visible paths that provide alternative useful sources of information

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33.3033 Visual Perception and Illusions in a Driving Simulator - Little Cars, Big Signs

Stacy Balk[1] (Stacy.balk.ctr@dot.gov), Vaughan Inman[1], William Perez[1]; [1]Transportation Solutions and Technology Applications Division, Leidos

One of the tools that the United States Federal Highway Administration uses to evaluate highway infrastructure—signs, roadway markings, and geometric features—is a driving simulator. The nature of the research necessitates that important visual information is perceived similarly in the simulated world as in the real-world. Perceptual mismatches can lead to incorrect assumptions about driver behaviors and understanding of new or novel roadway designs. Because of limitations in simulator projector technology, and the lack of true depth in images projected onto a cylindrical scene, it is often necessary to adjust the size of projected objects. The objects may need to be scaled up or down relative to 1:1 equivalence of image projected on the retina in order to produce a detectable object or a desired apparent distance. For example, to achieve an appropriate legibility distance for highway signs, signs are scaled up to achieve a mean legibility distances of 1 inch of letter height per 60 feet of (simulated) viewing distance. On the other hand, to attain a 1:1 correspondence with real-world following distances between the subject vehicle and the vehicle ahead, simulated vehicles are scaled down to 75 percent of the correct retinal image size. The methods and theories for arriving at these scale factors are described. The need to scale up highway signs is believed to be related to resolution and contrast limitations of current technology projectors. The need to scale down vehicle sizes may be the result of a Ponzo illusion, in which the converging lines of highway lane markings distort the apparent size of vehicles ahead. Before using a driving stimulator to conduct studies of driver perception or behavior in response to out of vehicle stimuli, it is important to examine assumptions concerning the size of projected images and their detectability and perceived distance.

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Face Perception: Mechanisms and models

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

33.3034 Object constancy from view-based models of the face.

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Recognising a familiar face in various poses is a challenging computational task that the human visual system can solve with remarkable ease. Current theory favours a view-based approach to object constancy over an object-centred approach but are different views of an object only related through association? We investigated whether it is possible to reconstruct a view of the face from another viewpoint. We recorded high quality, high frame rate videos of the moving human face, simultaneously from six cameras separated by 19 degrees in a horizontal arc around the face. The videos sequences from each perspective view were converted into separate image files and concatenated to form a sampled panoramic view of the face for each time point. We then expressed each multi-view image in terms of the vector field required warp the multi-view frame onto a reference multi-view frame and the resulting warped multi-view image. Principal components analysis (PCA) was used model the variation in these vectors. A PCA model can be cast as a content addressable memory. From the multi-view vector we removed the data from all but one view, setting the values for those other views to zero. We projected this partial representation back into the principal component model, regenerating the other views. We found that the reconstruction was effective, although there were some differences from the ground truth (reconstruction using all views). We found that summing up loadings for the partial representations projected into the space gave the loading for the full view representation (ground truth). We were able to substantially improve the single view reconstruction by multiplying the resulting loadings by a scale factor. The scale factor differed over views but was consistent over frames. Object constancy for the face may therefore be achieved through the mapping of relative information between view based-models.

33.3035 A neurocomputational account of the magnitude of face composite effects

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Identical top halves of two faces are more likely to be perceived as different when their different bottom halves are aligned rather than offset. Here, we demonstrate that the magnitude of the offset effect for each face can be predicted from a model of overlapping receptive fields with tuning profiles similar to the hypercolumns of simple cells in V1, although the cells are likely in face-selective areas. Importantly, a single face part (e.g. the left eye) is coded by multiple large receptive fields centered at a distance from the face part (Fig. 1). When different bottom halves are aligned to the identical top halves of faces, the large receptive fields centered on the top half of the face will extend to the differing bottom halves, thus making the top halves of the faces more dissimilar. By offsetting the differing bottom halves from the identical top halves of two faces, the features of the bottom halves no longer activate the large receptive fields centered on the top half of the face, leading to more accurate judgments of the identical top halves as the same (Fig. 2). The retention of early-level visual coding (Yue, Tjan, & Biederman, 2006; Xu, Biederman, & Shah, 2014) and the retinotopic representation of a face template in FFA (de Haas et al., 2014) may explain why the offset effect is unique to faces rather than the parts-based representation of objects.

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33.3036 Bubble-Warp: a New Approach to the Depiction of High-Level Mental Representation

Daniel Gill[1] (daniel.gill@glasgow.ac.uk), Lisa DeBruine[1], Benedict Jones[1], Philippe Schyns[1]; [1]Institute of Neuroscience and Psychology, University of Glasgow

Humans have the ability to process facial stimuli and compare them with facial information retrieved from memory. Cues from an input can provide information that enables the observer to infer bits of information about the signaller's identity, age, gender and other characteristics. Reverse correlation methods can reveal the memorized information content, formed as a classification image, that enables the perceiver to resolve these categorization tasks. The most typical method adds white noise to a fixed template serving as a basis. Though powerful, its main drawback is that it typically produces a low resolution greyscale classification image with configural cues restricted to those of the basis image. Here we present a novel method to reveal a colourful high resolution classification image with no configural limitation. We demonstrate the feasibility of the method with two different categories: (i) facial untrustworthiness and (ii) identity. A set of 40 color-calibrated images of female faces served as a 'face basis set'. All faces were delineated by 189 landmarks on a fixed set of salient facial locations. On each trial, the observer saw a set of masked and randomly chosen images. The masked image comprised a pixel-wise multiplication of a randomly drawn image from the face basis set with a two-dimensional mixture of randomly placed Gaussians (a.k.a. 'Bubbles', Gosselin & Schyns, 2001). Observers were instructed to select, from the masked images, the one that best fitted the target category (Untrustworthiness in experiment 1 and identity in experiment 2). To reconstruct the classification images, we first computed the average template of the landmarks of the positively identified images (weighted by the height of the sampling Gaussians). We then warped the positively identified masked images to that average template. Finally, we averaged and scaled the warped images to produce a colored classification image with no configural limitation.

33.3037 **Predicting face dissimilarity judgements from Basel Face Space** Jonathan O'Keeffe*[1] (jonathan.okeeffe@hotmail.co.uk), Kamila Jozwik*[1,2], Stephen Engel[3], Nikolaus Kriegeskorte[1]; [1]Medical Research Council Cognition and Brain Sciences Unit, Cambridge, UK, [2]Cambridge Research Institute, The University of Cambridge, UK, [3]Department of Psychology, University of Minnesota, Minneapolis, Minnesota

*contributed equally What makes two faces appear similar to each other? We examined how the dissimilarity of pairs of faces depend upon the faces' features. We used the Basel Face Space (BFS), a high dimensional coordinate system where axes control facial features and each point is an individual face, to synthesize photorealistic faces. We generated pairs of faces that varied systematically in the angle separating them in the space (θ), and in their distances from the average face (r1 and r2). We used a novel method to collect dissimilarity judgments, in which subjects (n=26) placed each pair of faces vertically on a large touch screen to indicate how dissimilar the two faces appeared. The vertical axis was anchored by reference points denoting identicality and total dissimilarity: pairs of identical face at the bottom of the screen, and pairs of BFS antifaces at the top. We asked to what extent different functions of the BFS coordinates of two faces can predict face dissimilarity judgements. Candidate functions for predicting perceived dissimilarity included (a) linear and (b) sigmoid functions of (1) the BFS Euclidean distance between two faces and (2) linear combinations of the polar angle between faces (θ), and the two eccentricities (r1, r2) of the faces. We fitted models with half the data and compared their predictive performance on the other half. A sigmoid function of Euclidean distance in BFS provided a reasonable approximation to dissimilarity judgments. However, preliminary evidence suggests that similarity does not fall off exactly isotropically in face space as we move away from a reference face in different directions. We relate the results to predictions of alternative models of neuronal coding, including norm-based and exemplar-tuning models. Our results show that BFS provides a useful quantitative model for investigating the representation of faces and predicting perceptual judgments.

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33.3038 **Using structural and semantic voxel-wise encoding models to investigate face representation in human cortex** Alan Cowen[1] (alan.cowen@berkeley.edu), Samy Abdel-Ghaffar[1], Sonia Bishop[1,2]; [1]Psychology, University of California, Berkeley, [2]HWNI Neurosci., University of California, Berkeley

Face perception plays a vital role in human social interaction. Psychologists have previously theorized that a hierarchy of brain regions process low- to high-level visual information about faces. Gallant and colleagues have demonstrated that large-scale stimulus sets and extended data collection can be combined with multi-feature encoding models and use of regularized regression to investigate the neural representation of natural images [1]. Here we applied this approach to conduct a detailed investigation of the voxelwise representation of natural face stimuli within brain regions across all stages of the visual processing stream. Low- and high-level structural (Gabor wavelet pyramid, fiducial point, etc.) and semantic encoding models were fit to estimation data (27 runs each of 4.5min duration, 864 face stimuli from the LFW database, each shown twice) and used to predict voxelwise BOLD responses to novel faces at validation (9 runs of 8min, 99 stimuli, each repeated 11 times). In line with previous findings, the Gabor wavelet pyramid model showed good prediction in early visual cortex. In contrast, semantic face features were primarily encoded in and around face-selective regions (OFA, FFA, pSTS). Structural face features (e.g. location of mouth and eyes) predicted voxelwise responses in early visual regions—in particular, near-foveal early visual cortex—and, to some extent, in high-level face regions. Selectivity differences between classical face-selective regions were more nuanced than previously suggested. This work illustrates how through use of naturalistic face images, extensive data acquisition, and advanced modeling techniques it is possible to interrogate the extent to which the representation of facial features changes across the cortical visual processing stream. [1] T. Naselaris, R. J. Prenger, K. N. Kay, M. Oliver, J. L. Gallant. Bayesian reconstruction of natural images from human brain activity. Neuron 63:902-915 (2009).

Face Perception: Neural mechanisms

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

33.3039 **Comparing the functional profile of face-selective regions with the amygdala at 7 Tesla** David Pitcher[1] (david.pitcher@nih.gov), Leslie Ungerleider[1]; [1]Laboratory of Brain and Cognition, National Institute for Mental Health

Prior fMRI studies have identified multiple face-selective regions in the human cortex but the functional division of labor between these regions is not yet clear. One hypothesis that has gained some empirical support is that face-selective regions in the superior temporal sulcus (STS) preferentially respond to the dynamic aspects of faces, whereas the fusiform face area (FFA) computes the static or invariant properties of faces (Pitcher et al., 2011). We further tested this hypothesis by examining how face-selective regions in the occipitotemporal cortex and the amygdala respond to dynamic and static face stimuli. High-field strength (7 Tesla) and high resolution (1.25 mm isotropic) scans allowed us to functionally define face-selective voxels in the amygdala in almost all participants. Preliminary analyses from 17 healthy adult subjects indicated that the right FFA and right occipital face area (OFA) responded equally to dynamic and static faces. Similarly, the amygdala showed a comparable response to dynamic faces, as compared to static faces. Conversely, a two-fold increase in response to dynamic faces was seen in the right posterior STS region. This pattern of responses in the amygdala, right posterior STS, right OFA, and right FFA suggests that the posterior STS may be preferentially involved in computing changeable aspects of faces, compared to the amygdala, FFA and OFA.

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33.3040 **The FFA can process a non-face category of objects as robustly as faces.** Valentinos Zachariou[1] (zachariouv@mail.nih.gov), Zaid Safiullah[2], Leslie Ungerleider[3]; [1]Laboratory of Brain and Cognition, NIMH, NIH

The FFA is a functionally defined, domain specific brain region in the service of face perception. It has also been shown that the FFA may also subserve the perception of other categories of objects, namely objects of expertise. Here, we present evidence that the FFA, defined using a standard face localizer task (faces > houses), can respond to a non-face category equivalently to faces even when participants are not experts on the non-face category. We demonstrated the above in human adults who performed same-different judgments on two object categories (faces & chairs) while undergoing fMRI. In each category, two exemplars differed in terms of the shape or spatial configuration of their features (featural/configural differences) and the difficulty of the tasks was a priori matched, separately for each participant, in terms of reaction time and accuracy. The functional contrast of faces vs. chairs yielded no significant activation within right FFA, neither at the group nor the individual level. A closer investigation within each individually defined FFA revealed the existence of two overlapping activation peaks of equivalent magnitude: one for faces and another for chairs (mod/mean Euclidian distance: 2.4/3.6mm; EPI: 3.2mm isotropic). To assess the specificity of the face peak, the ten most significantly active voxels comprising the peak were used to train pattern classifiers to differentiate between chair configural and featural trials. The pattern classifiers performed well above chance (60% accuracy), and their performance was comparable to that of differentiating between face configural and featural trials from the same peak voxels (63% accuracy). We conclude that under certain conditions the FFA can respond as strongly to a non-face category as it does for faces and the pattern of activity associated with the non-face category contains sufficient information, even within the most face selective voxels, to differentiate between different attributes of the category.

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33.3041 **Neural correlates of processing elastic moving faces: A functional near-infrared spectroscopy (fNIRS) study** Naiqi Xiao[1] (naiqi.xiao@mail.utoronto.ca), Qiandong Wang[2], Guowei Chen[2], Genyue Fu[2], Kang Lee[1]; [1]University of Toronto, [2]Zhejiang Normal University

Recent behavioral studies showed that moving faces optimize face processing efficiency by facilitating part-based face processing as opposed to static faces (Xiao et al., 2012 & 2013). However, the mechanism of this facial movement facilitation effect is less clear. This study using functional near-inferred spectroscopy (fNIRS) methodology explored the neural mechanisms underlying this moving face effect. Thirty-one adults participated in the current study. The classic Composite Face Effect was used to examine holistic versus part-based face processing. In the dynamic condition, participants first learned a 2-second silent moving face video, depicting chewing and blinking movements in the learning phase. In the testing phase, a static composite face was presented. The test face consisted of upper and lower face halves from different people, displayed either aligned or misaligned. Participants decided whether the upper half was the same person as the one they just learned. The static condition was identical to the dynamic one, except that the learned faces were static pictures. NIRS data were acquired in the temporal and occipital regions. A functional connectivity analysis indicated that learning moving faces led to significantly more positive and negative functional connectivities between brain regions than learning static faces. GLM results revealed a significant greater cortical [deoxy-Hb] response in the middle temporal gyrus for watching moving faces than static faces. In addition, learning moving faces led to decreased [deoxy-Hb] responses to process aligned composite faces (beta = -0.08) but increased responses to misaligned composite faces (beta = 0.11). However, static faces led to similar amount of [deoxy-Hb] activation for aligned (beta = 0.08) and misaligned composite faces (beta = 0.06). This face motion effect in neural activities suggests that facial movement might exert a top-down influence on the primary visual cortex by inhibiting holistic processing when viewing aligned composite faces.

33.3042 An image-invariant representation of familiar faces in the human medial temporal lobe

Katja Weibert[1] (kw783@york.ac.uk), Richard Harris[1], Alexandra Mitchell[1], Hollie Byrne[1], Timothy Andrews[1]; [1]Department of Psychology and York Neuroimaging Centre, University of York

The ability to recognize familiar faces across different viewing conditions contrasts with the inherent difficulty in the perception of unfamiliar faces across similar image manipulations. It is believed that this difference is based on the neural representation for familiar faces being less sensitive to changes in the image than it is for unfamiliar faces. Here, we used a fMR-adaptation paradigm to investigate neural correlates of familiar face recognition in face-selective regions of the human brain. 80 participants viewed faces presented in a blocked design. Each block contained different face images from either the same identity or different identities. Faces in each block were either familiar or unfamiliar to the participants. First, we defined face-selective regions by comparing the response to faces with the response to scrambled faces. This revealed the core face-selective regions (fusiform face area (FFA), occipital face area (OFA) and superior temporal face area (STS)), along with regions of the amygdala, hippocampus, middle temporal gyrus (MTG), precuneus and medial frontal gyrus (MFG). Next, we asked whether any of these regions responded more to familiar faces compared to unfamiliar faces. Higher responses to familiar faces were evident in the FFA, hippocampus, MTG, precuneus and MFG. No face-selective regions responded more to unfamiliar compared to familiar faces. Finally, we tested whether any of these regions showed image invariant adaptation to faces. We found a higher response to different identity compared to same identity familiar faces (adaptation) in the hippocampus. However, there was no adaptation to unfamiliar faces. These findings are consistent with electrophysiological studies that have found identity-invariant neuronal responses in the medial temporal lobe (Quiroga et al., 2005, Nature, 435: 1102-1107). Taken together, our results suggest that the marked differences in the perception of familiar and unfamiliar faces may depend critically on neural representations in the medial temporal lobe.

33.3043 Classifying neural responses to familiar and unfamiliar people over viewing distances in face and body selective areas

Carina Hahn[1] (achahn30@gmail.com), Alice O'Toole[1], P. Jonathon Phillips[2]; [1]The University of Texas at Dallas, [2]National Institute of Standards and Technology

The visual quality of face and body information varies continually as we observe a person approach from a distance. We investigated whether and when neural responses to familiar and unfamiliar people could be discriminated in face- and body-selective brain regions during an approach. Participants were familiarized with identities using close-up and distant videos of the individuals. Next, in an fMRI scanner, they viewed 8s videos of familiar and unfamiliar people approaching from a distance (13.6m). Multi-voxel pattern analysis (MVPA) was applied to classify the neural activity patterns elicited in response to familiar and unfamiliar people in three ROIs: face-selective voxels, body-selective voxels, and a broader area of ventral temporal cortex defined by significant differences in responses to faces, bodies, and objects ("FBO voxels"). Using cross-validation, we computed classifier accuracy (d') for discriminating neural responses to familiar and unfamiliar people at different times (i.e., viewing distances) in the video. Each 8s video scan time was divided into 4 TRs, each capturing 2s of video time, yielding four "distance windows." Beginning by classifying neural activity collected across the entire video, we were able to discriminate responses to familiar and unfamiliar people in 10 of the 12 participants, for at least one of the ROIs. For these participants, the classifier was applied independently within the four distance windows. Classification accuracy depended jointly on the viewing distance window and the ROI, $F(6,54)=2.73$, $p=.02$, with no main effects of ROI or distance. In FBO and body-selective voxels, classification accuracy peaked in the third distance window (d'=0.88 and 0.64, respectively). In the face-selective ROI, accuracy peaked in the closest distance window (d'=0.56), when the face was most prominent in the video. The degree of neural response separation in response to familiar and unfamiliar people reflects the relative quality of face and body information over varying distances.

33.3044 Cortical Thickness in Fusiform Face Area Predicts Face and Object Recognition Performance

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The response to non-face objects in the face selective fusiform face area (FFA) can predict behavioral performance for these objects, but such results are often disregarded because experts may pay more attention to objects in their domain of expertise. We report an effect of expertise with objects in FFA that cannot be explained by differential attention. We relate regional cortical thickness (rCT) of FFA to face and object recognition using the Cambridge Face Memory Test (CFMT) and Vanderbilt Expertise Test (VET). Object performance in the VET was summarized using two PCA factors, one for living objects (VET-LV) and one for non-living objects (VET-NL). Using high-resolution structural data, we measured rCT in individually defined FFA1 and FFA2, OFA and PHG, in twenty-seven men recruited to vary in expertise for cars. The only significant correlations with behavioral performance were found in the FFAs. In right FFA2, rCT was positively correlated with performance on VET-NL (r=.42). This was supported by a correlation with an independent matching task with cars and planes (.43). In contrast, rCT was negatively correlated with performance on the VET-LV in left FFA1 (-.50) and FFA2 (-.68), and with performance on the CFMT in right FFA1 (-.46). Multiple regression revealed that performance with faces and objects together accounted for ~40% of the variance in rCT in several FFA patches. While men with a thicker FFA cortex performed better with non-living objects, those with a thinner FFA cortex performed better with faces and living objects. Performance with these different categories may reflect experience that is acquired during different phases of brain development (arguably faces earlier than vehicles), with different mechanisms of plasticity operating at these different times. The results point to a domain-general role of FFA in object perception, one that cannot be explained by attention to objects of expertise.

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33.3045 Rubin-vase illusion perception is predicted by prestimulus activity and connectivity

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The Rubin's vase illusion evokes a bistable perception that alters between a pair of faces or a vase. In this study we looked at the oscillatory and network level effects that could differentiate between these two perceptions. Thus, tackling the issue of what leads to conscious access and, thus resulting in perceptual dominance between two competing signals. We conducted a study within the MEG, during which participants observed a brief presentation (150msec) of the Rubin's vase illusion, and subsequently reported the dominant percept. Behavioral results indicated a stochastic trial-by-trial report of the vase or faces. Contrasts in the prestimulus period yielded significant results between the perceptual reports, whereby there was an increase in low-frequency power (12-17Hz) for the report of faces. Source analysis revealed the main locus of this effect to be in the "object-sensitive" right lateral occipital area (LO). In the evoked response a stronger late-processing (350msec-375msec) effect was observed for the face report, with source analysis indicating a locus of this effect in the right "face-sensitive" occipital face area (OFA). Using these two source effects (i.e. LO and OFA) as seeds we conducted a connectivity analysis within source space using the imaginary coherence measure. Connectivity analysis revealed a variant connectivity to right inferior frontal gyrus (IFG), whereby for the LO seed there was greater connectivity for vase vs. faces reports, conversely for the OFA seed there was greater connectivity for face vs. vase reports. This connectivity effect is an important finding within the theory of consciousness, and adds more support to a recent framework (WIN2CON) that predicts that not only is it the local effects that are sufficient for conscious access (e.g. LO and OFA) but it is the state of open connections to frontal regions (IFG) that results in the perceptual dominance.

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33.3046 A gradual increase of face-selectivity along the human ventral visual pathway: evidence from intracerebral recordings with fast periodic visual stimulation

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Face perception involves a large set of regions distributed along the ventral temporal cortex and thus represents an interesting model to help understanding how visual information is processed along the ventral visual pathway. Here we shed light on the functional organization of this cortical network by recording focal intracerebral electroencephalogram in 20 epileptic patients implanted with depth electrodes. We objectively defined and quantified face-selective responses in the frequency domain by means of fast periodic visual stimulation with natural images (Rossion et al., in press, JOV). Patients were presented with various object categories (houses, animals, plants, etc.) at a base frequency of 6 Hz (6 images/second) with variable face stimuli interleaved in this sequence at regular intervals of 5 stimuli (face frequency = 6 Hz/5 = 1.2 Hz) (Figure 1A). They were instructed to detect colour changes of the fixation cross. Robust face-selective responses occurring exactly at the 1.2 Hz oddball frequency and its harmonics (2.4, 3.6, etc.) were found in the lateral occipital cortex and in the fusiform gyrus (FG), but also in the antero-inferior temporal cortex (AIT: anterior collateral and occipito-temporal sulci) and in the temporal pole (TP). Interestingly, there was a posterior-anterior gradient of face-specificity: face/base frequency ratio increased along the ventral temporal regions (see Figure 1B for typical responses in 3 patients). Although the magnitude of the face-selective responses were the largest in regions that also responded to all visual stimuli (FG), "pure" response to faces (oddball responses in the absence of any 6 Hz general visual responses) were observed only in the AIT and in the TP (e.g., patients 2 and 3, Figure 1B). These findings point to a sharpening of face-selectivity along the ventral visual pathway and reveal that exclusive response to faces can be found at a macroscopic (cell populations) level of cortical organization.

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33.3047 Neural correlates of own- and other-race face processing in infants: A near-infrared spectroscopic study

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Human adults show better face recognition for own-race faces than other-race faces (e.g., Feingold, 1914; Meissner & Bringham, 2001). Developmental studies revealed that this recognition bias for own-race faces emerges in infancy (for a review, see Lee et al., 2011). At three months of age, infants can discriminate as readily between two own-race faces as between two other-race faces (Kelly et al., 2007, 2009). However, 9-month-old infants can only distinguish between own-race faces, whereas they have difficulty discriminating other-race faces. In this study, we examined the neural correlates for the development of own- and other-race face processing in infants aged 5 to 9 months using near-infrared spectroscopy (NIRS). We hypothesized the different patterns of hemodynamic responses to own-race and other-race faces between younger and older infants, paralleling the existing behavioral findings. We measured Japanese infants' hemodynamic responses in the bilateral temporal regions during the presentation of East-Asian faces (own-race condition) and Caucasian faces (other-race condition). In each trial, infants were presented sequence of five color photographic images of different female faces (Figure 1). The hemodynamic responses to the faces were contrasted against the activation during the baseline period where five color images of vegetables were shown. We found that at 5 months, infants' hemodynamic responses were higher for other-race faces than for own-race faces (Figure 2). In contrast, 8- and 9-month-olds showed the higher activation for own-race faces than other-race faces in the right temporal area. These results indicate that due to differential exposure to own- versus other-race faces, infants show differentiations in neural response between own- and other-race faces; this differentiation also undergoes developmental change, likely due to the increased exposure to own-race faces with increased age. Thus, early asymmetry in experience with own- and other-race faces has early impact on not only infants' behavior but also neural activities.

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33.3048 Effects of TMS to occipital face area on the perception of face viewpoint cued only by shape changes in the external contour of the face

Samuel Lawrence[1] (sjl510@york.ac.uk), Bruce Keefe[1], Richard Vernon[1], André Gouws[1], Holly Brown[1], Alex Wade[1], Declan McKeefry[2], Antony Morland[1,3]; [1]York Neuroimaging Centre, Department of Psychology, University of York,, [2]University of Bradford School of Optometry and Vision Science, University of Bradford, [3]Centre for Neuroscience, Hull-York Medical School, York

Changes in the outer contour of a face act as a cue to face viewpoint, and these changes can be captured using radial frequency (RF) pattern stimuli (Wilson et al., 2000). The face viewpoint aftereffect (FVA) is a visual illusion where adaptation to a left-facing face causes a front-facing face to appear as right-facing and vice versa (Fang and He, 2005). The occipital face area (OFA) has been implicated in both the FVA (Fang et al., 2007) and early face processing (Haxby et al., 2000; Pitcher et al., 2007). We replicated the FVA using synthetic head outline RF pattern stimuli. We then applied transcranial magnetic stimulation (TMS) to OFA and a nearby shape processing area, LO2 (Silson et al., 2013), during viewpoint discriminations of the same stimuli following adaptation to a forward- or lateral-facing stimulus. TMS to OFA resulted in significantly worse viewpoint discrimination than TMS to LO2, however neither condition was significantly different from control conditions. It was therefore impossible to determine whether our effect of TMS on discrimination was attributable to a facilitation of performance from TMS to LO2, or an inhibition of performance from TMS to OFA. In addition we found no effect of TMS to any brain regions on the magnitude of the FVA. We conclude that our differential effect of TMS to LO2 and OFA on viewpoint discrimination likely indicates a causal role for OFA in the processing of shape cues to viewpoint, however more data will be acquired to further clarify our results. This would be consistent with Silson et al.'s (2013) suggestion of parallel mechanisms for orientation and shape processing in LO1 and LO2, respectively. We add a potential third parallel mechanism for shape information that is relevant to face processing in OFA.

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33.3049 Neural Representations of Expression and Viewpoint Information in the Temporal Cortex

Tessa Flack[1,2] (tessa.flack@york.ac.uk), Andrew Young[1,2], Timothy Andrews[1,2]; [1]Department of Psychology, University of York, [2]York Neuroimaging Centre, University of York

Movements of the face play an important role in social communication. For example, changes in facial expression provide information on emotional state, whereas changes in viewpoint convey information about the direction of attention. Our aim was to determine whether there are distinct neural representations for different types of facial movement and whether these representations interact. We used fMRI to investigate the neural representations underlying the perception of changes in facial viewpoint or facial expression. In the first experiment, participants (n=20) viewed sequences of faces that varied in viewpoint direction (0º. 45º, 90º, 135º, 180º). Using MVPA, we found distinct patterns of response within face-selective regions for each of the different viewpoints. In the second experiment, we asked whether the patterns of response to different viewpoints were distinct from the patterns of response to facial expression. Participants (n=24) viewed faces from 3 different viewpoints (45º, 90º, 135º) with 3 different facial expressions (fear, disgust, happy). We found distinct patterns of response to different viewpoints and to different facial expressions within face-selective regions. The patterns of response were dominated by changes in viewpoint, presumably reflecting the larger image changes caused by these movements. However, there was no interaction between the patterns of neural response to expression and viewpoint. Together, these results show topographically distinct neural patterns of response to viewpoint and expression that are consistent with the distinct social information conveyed by these different movements.

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33.3050 **The reorganization of extrastriate cortex in patients with lobectomy** Tina Liu[1] (tinaliu@cmu.edu), Adrian Nestor[2], Christina Patterson[3], Marlene Behrmann[1]; [1]Carnegie Mellon University, [2]University of Toronto Scarborough, [3]Children's Hospital of Pittsburgh of UPMC

The recovery of perceptual functions that occur following cortical damage can offer key insights into the nature and plasticity of brain organization. In this respect, studies of individuals post-lobectomy/hemispherectomy offer a unique window into the nature and extent of cortical plasticity. First, in contrast with more common lesions, the extent of the damage in such patients can be extreme (i.e. an entire hemisphere in some cases) yet, at the same time, very well controlled - both cortical and subcortical structures of the remaining hemisphere are typically intact. Second, the extent of the recovery is often disproportionate relative to the extent of the damage - many compromised functions are regained partly or even completely. Using fMRI, our present work characterizes the changes in topography in extrastriate cortex in children who have undergone surgical lobectomy or hemispherectomy of ventral cortex in either hemisphere (compared with control participants who have undergone resections to other areas such as dorsal cortex). We also map language areas in each individual as an anchor for hemispheric dominance. We uncover atypicalities in the selectivity maps to common visual categories (face, object, and word) in the ventral patients and show changes in their development/reorganization over time. Overall, the current results suggest that extensive removal of visual cortex lead to atypical/diminished selectivity for common visual categories despite the absence of major recognition difficulties and that, in some cases, reorganization may result in somewhat more typical selectivity maps.

Attention: Cueing and inattention

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

33.4001 **fMRI-based Functional Localization of the Ventral Attention Network in Individual Subjects** Kathryn Devaney[1] (kdevaney@bu.edu), Emily Levin[1], Maya Rosen[1], Samantha Michalka[1], David Somers[1]; [1]Department of Psychological and Brain Sciences, Boston Universtiy

Two well-known cortical networks support attention function – a dorsal attention network (DAN) for sustained, goal-directed attention and a ventral attention network (VAN) responsible for transient attentional shifts (Corbetta & Shulman, 2002). While the DAN is readily localizable in the brains of individual subjects by any of a number of attentionally demanding paradigms, the components of the VAN are more elusive, perhaps due to the transient nature of its function, and it is typically only described via large group averages. Group averaging methods for identifying regions of the VAN are potentially problematic due to the high intersubject anatomical variability and functional heterogeneity of those regions of the cortex. Here, we developed a rapid fMRI localizer (4 runs, 24 minutes) leveraging a modified Posner task and an oddball paradigm to identify the VAN in individual subjects. Participants (n=12) performed a 6-location variant of the Posner cueing task, with infrequent oddball images interspersed. Participants were required to discriminate between two highly similar targets, which could appear either at the cued location (valid 80%) or one of the other locations (invalid). Following the target phase, a standard mask appeared on 5/6th of the trials, however, on 1/6th of the trials, a rapid sequence of vivid trial-unique scene images (a.k.a. oddballs) appeared in a RSVP stream (5 images, 100ms per image) during the mask phase. Behaviorally, the expected reaction time cost of an invalid cue was observed (57ms). The fMRI contrast of oddball to non-oddball Posner trials successfully localized areas, in individual subjects, that have been identified as part of the VAN in many previous group-averaged analyses. This novel localizer will enable rapid progress towards pinpointing the explicit functional role of the VAN at the individual subject level.

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33.4002 **Additivity of prioritizing selection for new objects by onset capture and visual marking** Takayuki Osugi[1,2], Daisuke Hayashi[1,2], Ikuya Murakami[1]; [1]Department of Psychology, The University of Tokyo, [2]JSPS

When certain distractors (old items) appear before others (new items) during an inefficient visual search task, observers exclude the old items from the search if the target always appears as a new item (preview benefit). This effect is said to occur because of inhibitory visual marking (VM) for old objects in addition to attentional capture (AC) to new objects (Watson & Humphreys, 1997). However, another view claims that the preview benefit simply reflects AC (Donk & Theeuwes, 2001). To address the question of whether VM plays any role in addition to AC, we compared search performances for the target always appearing as a new item ("AC+VM"), for the target equally appearing as a new or old item ("AC"), and for the target among simultaneously presented items in a halved set size ("Half"). VM should not occur in the AC condition because there is no benefit in inhibiting old items. Furthermore, to standardize stimulus shape, we used letter stimuli made of parts of a digital symbol "8" (Yantis & Jonides, 1994) and orthogonally manipulated the shape changes in old distractors and the configuration of search items. No difference in slope was found among the conditions irrespective of changes in old items when items were arranged circularly, negating contribution from VM. In contrast, when items were presented at random positions within an invisible 7 x 7 matrix, the AC+VM condition's slope was shallower than the AC condition's, favoring the involvement of VM, and these slopes were higher than the Half condition's irrespective of changes in old items. These findings suggest that 1) the effect of VM depends on the configuration of search items and 2) with complex displays, prioritizing selection for new objects is more effective if coupled with deprioritized selection for old objects.

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33.4003 **Examining the Relative Strength of Attentional Cues and the Time Course of Exogenous Orienting** Gerald McDonnell[1] (gmcdonnell@huskers.unl.edu), Michael Dodd[1]; [1]University of Nebraska-Lincoln

The current study examined the relationship between endogenous, exogenous, and symbolic attention as it relates to working memory and attentional allocation. Previous research has established that exogenous cues result in early facilitation and later inhibition at cued locations (Posner & Cohen, 1984). In contrast, endogenous cues result in long-lasting facilitation, but not IOR, when responding to the location of a target. This pattern of results remain consistent even when participants are required to hold nonpredictive arrow cues in working memory (McDonnell & Dodd, 2013). The present experiments examined the characteristics of these attentional effects when the irrelevant spatial cue is relevant to a secondary memory task, requiring it to be processed. In Experiment 1, participants completed a standard Posner cueing task while holding in memory a colored placeholder that either matched or did not match the subsequent color of the exogenous cue. This is a departure from previous research where normally participants are instructed to ignore the exogenous cue or that it is irrelevant. Surprisingly, no facilitation was observed at early SOAs (200ms), but was followed by standard IOR at intermediate SOAs (500ms) and late SOAs (800ms; these effects replicated when decreasing the difficulty of the memory test). In Experiment 2, when participants maintained in memory an irrelevant arrow cue while responding to a target preceded by an exogenous cue, standard exogenous IOR effects were observed at intermediate and late SOAs, but once again no facilitation at early SOAs (presumably due to the attentional demands of the working memory load), independent of the nonpredictive arrow cue (25% or 50% predictive). However, when the arrow cue was made 75% predictive, exogenous inhibition was not observed at intermediate SOAs when the arrow cue was valid. The present experiments provide important insight into the interaction between working memory and attentional orienting.

33.4004 **Title: Drop the beat & miss T2: How various dimensions of music influence attentional failures** Jessica Madrid[1] (cyrene@nmsu.edu), Arryn Robbins[1], Michael Hout[1]; [1]New Mexico State University

It is well established that emotional distractors enhance attentional control in demanding tasks such as the classic attentional blink paradigm (Olivers & Nieuwenhuis, 2005; Sussman, Heller, Miller, & Mohanty, 2013). By inducing a range of moods using music and memory generation, it has also been shown that the interaction of emotional valence and level of arousal have unique effects on second-target accuracy detection in the attentional blink (Jefferies, Smilek, Eich, & Enns, 2008). However, it is unclear how the specific type of music used to induce mood alters an individual's attention capabilities. While previous research has focused largely on coarse emotionality of musical selections, the interplay of rhythm and arousal (which can interact to sway emotional reactions) on attention has yet to be addressed. In this investigation, we sought to tease apart how various features of music affect attention by manipulating the accompanying musical selection during an attentional blink task. Our participants were randomly assigned to one of eight experimental conditions in which musical selections encompassed a factorial combination of emotional valence (positive or negative), arousal (high or low), and rhythm (rhythmic or non-rhythmic). Participants were asked to detect two digits in a stream of rapidly presented letters. Our findings replicate prior work (Olivers & Neiuwenhuis, 2005, Jeffries et al., 2008) showing that music has a beneficial effect on attention; participants committed fewer attentional failures while listening to music, relative to a (counterbalanced) no-music baseline block. More importantly, we found that the rhythmicity and valence of music had no affect on attention, but that the level of arousal of the piece, has a negative effect on attention; arousing music increases the size of the attentional blink. This suggests that a wide range of music types may have beneficial effects on attention, with less arousing music providing the attentional benefit.

33.4005 A dissociation between conscious perception and stimulus processing: the effects of prior exposure to high-visibility stimuli

Dominique Lamy[1] (domi@post.tau.ac.il), Ziv Peremen[1]; [1]Psychological Sciences department, Tel Aviv University

Recent research has shown that discrimination of a barely visible stimulus is greatly enhanced following exposure to a clear version of this stimulus (Ahissar & Hochstein, 2004; Lin & Murray, 2014). However, whether such enhancement affects only conscious perception of the critical stimulus or also the extent to which it is processed and can indirectly affect behavior has not been addressed. Here, we presented a small prime arrow followed by a larger target arrow that served as backward pattern mask. Observers responded to the direction of the target. We manipulated the stimulus-onset asynchrony (SOA) between the prime and mask either by randomly mixing them or by presenting them in separate blocks of increasing durations (i.e., decreasing mask effectiveness). Conscious perception of the prime was assessed either using the 4-level Perceptual Awareness Scale (subjective measure) or as forced-choice discrimination performance (objective measure). Processing of the prime was measured as the effect on performance of the compatibility between the prime and target arrows. The results show that for short exposure durations, both subjective and objective awareness of the prime were dramatically lower in the blocked than in the mixed condition. However, compatibility effects were unaffected by the blocked vs. mixed SOA manipulation. Thus, prior exposure to high-visibility primes affected conscious perception but not processing of briefly presented primes. The methodological implications of these findings for the study of unconscious processing are discussed.

Acknowledgement: Israel Science Foudation

33.4006 Not So Moving: Irrelevance blindness with moving irrelevant stimuli

Adam Kimbler[1] (adamkmblr@gmail.com), Jason Hays[1], Amanda Renfro[1], D. Alexander Varakin[1]; [1]Eastern Kentucky University

Inattentional blindness is the failure to notice unexpected objects when attention is occupied by a demanding cover task (Mack & Rock, 1998). It was widely assumed that a demanding cover task was necessary for inattentional blindness to occur. However, recent research (Eitam, Yeshurun, & Hassan, 2013) suggests that even under minimal attentional load, observers have reduced awareness of objects that are not related to the cover task. This effect is called irrelevance blindness, because visual features escape awareness due to irrelevance, not limited attentional resources. Previous research on irrelevance blindness demonstrates reduced awareness of visual features like color. The purpose of the current study is to examine whether irrelevance blindness occurs when irrelevant objects are moving. Observers (n = 80) were instructed to identify the color of a rectangle that was presented centrally on a display and surrounded by a field of 250 moving dots (each 10 pixels in diameter) all moving in the same direction (either up, down, left or right). Participants were not informed about the moving dots at all. Each observer viewed a single 500ms display. Immediately after the display offset, participants were first asked about the features of the irrelevant moving dots' color and direction motion, and then about the color of the relevant central shape. Only individuals (n = 72) who accurately identified the central shape's color were included in the analysis. Of these, 25 participants (35%) failed to identify the color of the dots and 23 participants (32%) failed to identify the direction in which the dot was moving. These results suggest irrelevance blindness can occur even if the irrelevant stimuli are moving.

33.4007 Action video game playing does not reduce inattentional blindness

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

Given the increased attentional and perceptual abilities exhibited by action video game players (AVGPs) (Green & Bavelier, 2003; Clark, Fleck, & Mitroff, 2011), it seems reasonable to expect them to perform differently on an inattentional blindness (IB) task from a non-gaming population. We explored whether this was the case. Using the Mack & Rock (1998) IB cross procedure, AVGPs (n=15) and non-video game players (NVGPs, n=14) reported the longer arm of a cross presented for 200 ms parafoveally on 7 trials. An unexpected word was presented at fixation with the cross on the 4th (critical inattention), 7th (critical divided attention), and 11th (critical full attention) trials. Participants were asked whether they had seen anything other than the cross on these critical trials and, if so, what. To establish that our populations were like those others had sampled, we included a change detection task, since others have found that AVGPs outperform NVGPs on change detection (Clark et al., 2011). We used the Rensink, O'Regan, & Clark (1997) flicker procedure; participants were asked to detect and identify changes in natural scenes repeatedly presented for up to 75 s (240 ms scene, 80 ms ISI). Our change detection data were consistent with that of others. AVGPs detected significantly more changes than NGVPs (p=.034) and correctly identified more of the changes (p=.047). Therefore, we were able to assume that we tested representative samples. In contrast to change detection, we found no significant differences in the frequency of IB between the groups (p=.359), suggesting that IB is impervious to the benefits of action video game playing, which is consistent with findings that meditators who also outperform controls on change detection do not do so with IB (Hodgins & Adair, 2010). Further research is required to determine what accounts for this difference.

33.4008 It's all relative: Attentional set for target distractor relations in inattentional blindness

Rebecca Goldstein[1] (rgolds5@tigers.lsu.edu), Melissa Beck[1]; [1]Louisiana State University

Most et al. (2001) demonstrated that an unexpected object (UEO) is noticed when it is similar to the target but dissimilar to the distractors. The authors concluded that inattentional blindness is influenced by attentional sets based on relationships among targets and distractors (e.g., lighter or darker). The present study further examined the role of relational attentional sets in inattentional blindness. In experiment one, participants monitored gray letters while ignoring either black or white distractors. The UEO was black, gray, or white. Participants were least likely to report seeing UEOs that matched the distractor color. Furthermore, UEOs that were in the opposite direction of the relationship between the target and the distractors (e.g., white UEO when the distractors were darker than the targets) were noticed either more often or equally as often as UEOs that matched the target. In experiment two, we examined whether this finding would generalize to relationships among colored targets and distractors. Participants either monitored dark orange targets with light orange distractors or light orange targets with dark orange distractors. Therefore, an attentional set could be created for "redder" or "yellower" and the UEO was either red, dark orange, light orange, or yellow. The results supported a relational attentional set when the targets were light orange and the distractors were dark orange (reporting of the UEO was highest for yellow UEOs > light orange > red > dark orange). However when participants should have been set for redder because the targets were dark orange and the distractors were light orange, reporting of the UEO was still high for the yellow UEO (red > dark orange = yellow > light orange). Overall, these results are consistent with previous research showing that attentional sets can be relational. However, there are also instances where saliency may override a relational attentional set.

33.4009 Searching for Feature-Based Surround Suppression in Inattentional Blindness

Trafton Drew[1] (trafton.drew@psych.utah.edu); [1]Department of Psychology, University of Utah

When engaged in an attention-demanding task, Observers (Os) often miss stimuli that would otherwise be perfectly obvious, like a dancing gorilla or a clown on a unicycle, a finding known as Inattentional Blindness (IB). Previous work has shown noticing rates for unexpected stimuli increase as the similarity to the target increases: when tracking white items, Os are much more likely to notice an unexpected white stimulus than a black one. Most and colleagues (2001), showed that noticing rates follow a simple linear relation with the similarity of the attended stimulus, even for unexpected items of novel color (e.g. a grey item when tracking white items and ignoring black items). We wondered whether the presence of distractors in these intermediate positions would change the pattern of results. The presence of the distractors that share a similar color to the attended objects may result in this color being inhibited in feature space. Recent behavioral and electrophysiological work has suggested that feature-based suppression operates on colors that are similar (~30° in hue space) to the attended color (Störmer et al., 2014). For example, visual search performance for two colors separated by 30° in hue space was worse than performance for two colors separated by 75°. Os in the current study attended objects colored X while ignoring an equal number of distractors colored X+30° and X+180°. We measured IB rates for unexpected items of attended, near-attended and far from attended colors in different Os. Inconsistent with the predictions of surround suppression, IB rates were inversely proportional to similarity to the attended

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color. The results suggest that while we may use feature-based suppression to inhibit near-target colors under some circumstances, this does not manifest itself in reduced noticing rates during Inattentional Blindness.

33.4010 Relating sustained attention to visual long-term memory
Megan deBettencourt[1] (debetten@princeton.edu), Kenneth Norman[1,2], Nicholas Turk-Browne[1,2]; [1]Princeton Neuroscience Institute, Princeton University, [2]Department of Psychology, Princeton University

Attention naturally fluctuates when it needs to be sustained for long periods of time. These fluctuations have immediate consequences for performance on current tasks, but their consequences for the encoding of current information into visual long-term memory (VLTM) are less well understood. In particular, although the effects of selective attention and divided attention on memory have been explored, the relationship between sustained attention and memory is less clear. We hypothesized that, in a sustained attention task, being in an attentive state just prior to the presentation of an image would lead to better subsequent VLTM for that image. Based on previous studies of sustained attention, we operationalized attentiveness as slower and less variable response times (RTs). In a first incidental encoding phase of the experiment, observers categorized trial-unique pictures of scenes as indoor or outdoor by pressing one of two buttons. Critically, the scenes were selected to be 90% from one subcategory and 10% from the other, which encouraged observers to lapse into making the more frequent response habitually, thereby inducing fluctuations in sustained attention. In the second phase of the experiment, observers performed a surprise recognition memory test in which they were shown old images (that had appeared in the first phase) and new images. They were asked to decide whether they had seen each image before, as well as to report their confidence. Using these memory responses, we returned to the sustained attention task data and found that stimuli that were subsequently remembered vs. forgotten were indeed preceded by trials with slower and less variable RTs. These results suggest that the dangers of attentional failures may not only be realized in the moment, but also in the future when we need to access memories from those episodes.

33.4011 Previewing Distractors Improves Change Detection in a Change Blindness Paradigm
Monique Daignault[1] (daignau3@gmail.com), Mark Becker[2], Devin McAuley[3]; [1]Psychology, Social Science, Michigan State University, [2]Psychology, Social Science, Michigan State University, [3]Psychology, Social Science, Michigan State University

Abstract When a change occurs during steady viewing it produces a transient that attracts attention, thereby allowing an observer to notice the change. If, however, a change occurs simultaneously with the onset of a set of distractors, the distractors also produce transients that compete for attention, the change becomes difficult to detect resulting in "change blindness" (Rensink, O'Regan, & Clark, 1999). Becker and Vera (2007) found that change blindness is dramatically reduced if the distractors flash many times before appearing with the change. In their experiments the distractors always flashed 14 times before appearing with the change. Here we present a paradigm similar to Becker and Vera's but vary the number of flashes that precede the change. It is possible that multiple flashes are required to create and/or strengthen an attentional filter to improve change detection. However, it is also possible that a single preview of distractors visually mark the distractors resulting in improved change detection (Watson and Humphreys, 1997). Participants detected a single letter change among a circle of letters. In control trials there were no distractors, in experimental trials the letter changed with a simultaneous flash of distractors. Experimental trials also varied in the number of preceding flashes: zero (classic change blindness situation), one, two, four, or eight. Consistent with previous work, having a simultaneous flash of distractors disrupted change detection and preceding flashes improved change detection compared to no previous flashes. Importantly, only a single preceding flash was required to see the dramatic improvement in change detection rates, and a single preceding flash was roughly as effective as eight preceding flashes. That is, the effect did not build up over multiple flashes. This pattern of results suggests that participants visually mark the distractors after a single previous presentation and are then able to ignore the subsequent distractor onsets.

33.4012 Target template precision is unaffected by target-distractor similarity
Hannah Wyland[1] (Hannah-Wyland@uiowa.edu), Shaun Vecera[2]; [1]Psychology Department, University of Iowa, [2]Psychology Department, University of Iowa

It is well supported that target templates held in visual short-term memory guide visual search (Desimone & Duncan, 1995; Wolfe, 1994). We investigated how template precision is affected by search context. Following previous research, participants searched RSVP streams for an orange letter and reported its presence or absence (Anderson, 2014). In different blocks, distractor letters were either similar to the target color (red, gold, green and blue) or dissimilar to the target color (white, purple, green and blue). If template precision is affected by search difficulty, accuracy differences should be found between the two distractor conditions. In Experiments 1-3, the RSVP stream consisted of eight frames of four letters each. Targets in Experiment 1 could appear at any location on the 2nd-6th frames. Compared to the distractor dissimilar condition, accuracy in the similar distractor condition was significantly worse. This difference, however, may reflect insufficient time for selection and consolidation processes, not template precision. To test this, targets in Experiment 2 appeared on screens 4-8. While subsequent displays may interrupt processing of the 4th-7th screens, the 8th (final) screen allows adequate time for selection and consolidation. Here, a significant interaction was found between distractor color and target position with follow-up tests indicating significantly better performance at the 8th position in the similar distractor condition. For Experiment 3, additional time was added between each RSVP display to allow selection and consolidation of each display. Although the main effect of distractor color was significant, the accuracy difference between the conditions was greatly reduced. To remove the need for selection processes, Experiment 4 presented a single stream of 16 frames. Accuracy for this experiment did not differ between conditions. The results of these experiments suggest that target identification is limited by selection, consolidation, and comparison processes, but not by template precision.

Sunday AM

33.4013 Looking for neural correlates of sustained inattentional blindness with single trial per subject design in fMRI
Ekaterina Pechenkova[1,2] (evpech@gmail.com), Maria Kuvaldina[3], Liudmila Litvinova[2], Alena Rumshiskaya[2], Polina Iamshchinina[4], Valentin Sinitsyn[2]; [1]Institute of Practical Psychology and Psychoanalysis, Moscow, Russia, [2]Radiology Department, Federal Center of Treatment and Rehabilitation, Moscow, Russia, [3]Saint-Petersburg State University, Saint-Petersburg, Russia, [4]Vrij University of Amsterdam, Amsterdam, Netherlands

An inability to notice an extra salient item once the attention is engaged in some other task, called Inattentional Blindness (IB; Mack & Rock, 1998), is widely used in research on visual awareness. However, the neuroimaging of IB is limited due to technical issues, including the possible number of trials per subject. Since the IB decreases once the participant is informed about the effect, a single trial per subject design is usually implemented in psychophysics. FMRI studies of IB so far have either substantially changed the original paradigm (Thakral, 2011) or didn't measure the IB effect while scanning (Todd et al., 2005; Matsuyoshi, Ikeda, 2010). Our research aimed at investigating the neural correlates of IB in multiple object tracking (MOT) task preserving the design of a single trial. In the scanner participants traced eight moving white and black circles and counted bounces of the white circles off the edges of the screen. In experimental group an extra item (a dark grey square) traveled across the screen for 7 seconds. It was neither verbally reported nor recognized by 69% of 23 observers (the IB effect). BOLD signal evoked by the unnoticed stimulus in 16 IB subjects was compared with the signal in 16 control subjects who were not presented with an extra item. Greater activation ($p< 0.001$ uncorrected, k=3 voxels) was found in both left and right FEF in the control condition. Separate analysis of the activation in experimental and control group demonstrated clear and significant ($p< 0.05$ FWE corrected) neural signature of the MOT task (Howe et al., 2009; Culham et al., 2001) including the bilateral V5, IPS, SPL and PMA/FEF areas. Thus our results advocate the feasibility of a single trial per subject design in fMRI and its potential use for research on the unconscious information processing in IB.

Acknowledgement: RFHS N-06-00947

Attention: Reward

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

33.4014 Reward modulates orienting and reorienting in exogenous cueing.
Berno Bucker[1] (berno.bucker@vu.nl), Jan Theeuwes[2]; [1]Vrije Universiteit, Amsterdam, Netherlands, [2]Vrije Universiteit, Amsterdam, Netherlands

It is well know that rewards influence attentional selection, so that we may adapt our behavior to maximize reward rate. Both reward-signaling cues and exogenous cues capture attention automatically and cause changes in performance at their location. The typical time course of changes due to exogenous cues shows an initial facilitation effect at the cued location

that is followed by inhibition after 200-300 ms. For reward-signaling cues facilitation is typically known to last longer. However, the extent to which reward and exogenous cueing effects interact remains largely unexplored. In a series of experiments, an abrupt onset (50% valid) was followed by two colored circular stimuli presented on the left and right of fixation. Observers performed a location-discrimination task on dots presented in these circular stimuli. The color of the circular target stimulus indicated whether a high or low reward could be obtained for that trial. To investigate the different temporal phases of exogenous cueing effects, short and long stimulus onset asynchronies (SOAs) were used. On both validly and invalidly cued trials, responses were faster when the target was presented in the high compared to the low reward-signaling stimulus. This might imply that observers orient and reorient faster towards high reward-signaling stimuli, or that they disengage more easily from low reward-signaling stimuli. In a second experiment, we presented the exogenous cue in the high or low reward-signaling color. The high reward cue elicited faster responses at the cued location for both the short and long SOA, whereas the low reward cue elicited faster responses at the uncued location for both the short and long SOA. These results indicate that high reward-signaling exogenous cues can capture and maintain attention beyond the typical 200-300 ms window, whereas low reward-signaling exogenous cues seem to promote fast reorienting towards the uncued location.

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33.4015 **Reward Alters Perception of Time** Michel Failing[1] (michel.failing@vu.nl), Jan Theeuwes[1]; [1]Department of Cognitive Psychology, Vrije Universiteit

Classic studies have demonstrated an important role of attention in perception of time. Which stimuli enjoy attentional priority has also been shown to be affected by reward. For instance, recent studies showed that stimuli associated with relatively high reward are attentionally prioritized over stimuli associated with low or no reward. The question we addressed in the present study is whether a reward association also affects perception of time. Here participants had to perform a prospective timing task using temporal oddballs. In this task six standard stimuli (e.g. black circle) each displayed for a fixed duration (500 ms) and one colored oddball (e.g. red circle) displayed for varying durations (350-650 ms), were shown in succession at the center of fixation. Participants had to indicate whether they perceived the oddball to last shorter or longer in time than the standard stimuli. In three experiments we manipulated whether the color of the oddball (exp 1 and 3) or the color of the standard (exp 2) signaled whether reward could be earned for a correct response. The color indicated how much reward could be earned (high, low or no). To assess how reward affects the temporal perception of the oddball, psychometric curves were estimated. The results showed that participants perceived an oddball signaling relatively higher reward to last longer than the standards compared to when the oddball signaled lower reward. However, when reward was signaled by the standards and not by the oddball, the duration perception of the oddball remained unaffected. We argue that by signaling a relatively higher reward, a stimulus becomes more salient thus modulating attentional deployment towards it and distorting how it is perceived in time.

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33.4016 **Positive affect reduces visual crowding** Ariana Familiar[1] (ariana.familiar@dartmouth.edu), Stefan Uddenberg[2], Won Mok Shim[1]; [1]Dartmouth College, Department of Psychological and Brain Sciences, [2]Yale University, Department of Psychology

Positive mood has been shown to both broaden the scope of visual attention (Rowe, Hirsh & Anderson, 2006), and facilitate a broad or narrow focus depending on whichever mode is currently dominant (Huntsinger, Clore & Bar-Anan, 2010). Here we investigate whether positive affect influences the spatial extent of peripheral feature integration. Using short film clips to induce positive (happy), negative (fear), and neutral affect, we measured the effect of visual crowding in each mood condition. A Gabor patch (diameter: 1o, eccentricity: 8o) surrounded by six equally spaced 'flanker' Gabors (diameter: 1o) at one of eight possible distances (1.5o, 2o, 2.5o, 3o, 3.5o, 4o, 4.5o, 5o) from the central patch was briefly presented in the right visual field. Subjects' task was to report whether the central patch was tilted left or right of the vertical meridian, and the detection threshold was measured at each flanker distance. Average critical spacing across subjects was significantly smaller when in a positive mood compared to both neutral and negative conditions, which did not significantly differ. Thus, under positive affect the spatial scope of feature integration was narrowed, allowing for better identification of a crowded feature in the periphery. This supports the notion that positive affect influences the spatial envelope of attention in a flexible manner (Huntsinger, 2013), and modulates this scope depending on the default mode necessitated by current task demands.

Acknowledgement: Rockefeller Research Grant at Dartmouth College to Won Mok Shim

33.4017 **Reward vs. Emotion in Visual Selective Attention** Takemasa Yokoyama[1, 2, 3] (yokoyama@lit.kobe-u.ac.jp), Srikanth Padmala[1, 4], Luiz Pessoa[1]; [1]Department of Psychology, University of Maryland, [2]Graduate School of Environmental Studies, Nagoya University, [3]Japan Society for the Promotion of Science, [4]Neuroscience and Cognitive Science program, University of Maryland

Learned stimulus-reward associations influence how visuospatial attention is allocated, such that stimuli previously paired with reward are favored in situations involving limited resources and competition. At the same time, task-irrelevant emotional stimuli grab attention and divert resources away from tasks resulting in poor behavioral performance. However, investigations of how reward learning and negative stimuli affect visual perception and attention have been conducted in a largely independent fashion. We have recently reported that performance-based monetary rewards reduce negative stimuli interference during visual perception. Here, we investigated how stimuli associated with past monetary rewards compete with negative emotional stimuli during a subsequent visual attention task when, critically, no performance-based rewards were at stake. We conducted two experiments to address this question. In Experiment 1, during the initial learning phase, participants selected between two stimulus categories that were paired with high- and low-reward probabilities. In the test phase, we conducted an RSVP task where a target stimulus was preceded by a task-irrelevant neutral or negative image. We found that target stimuli that were previously associated with high reward reduced the interference effect of potent, negative images. In Experiment 2, with a related design, this response pattern persisted despite the fact that the reward manipulation was irrelevant to the task at hand. Similar to our recent findings with performance-based rewards, across two experiments, our results demonstrate that reward-associated stimuli reduce the deleterious impact of negative stimuli on behavior.

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33.4018 **Exploring Value-Driven Attention: Evidence for a Domain-General Mechanism of Selection** Brian Anderson[1] (bander33@jhu.edu); [1]Department of Psychological & Brain Sciences, Johns Hopkins University

When visual features are learned to predict a reward outcome, stimuli possessing these reward-associated features automatically capture attention. This consequence of reward learning on attention has only been examined under conditions in which visual features (e.g., color, orientation) are associated with tangible, extrinsic rewards such as money and food. In the present set of experiments, I examine how an irrelevant reward-associated sound affects visual processing and whether positive social feedback produces attentional biases for associated visual stimuli. In one experiment, participants first performed a training phase comprising a sound identification task in which certain sounds were associated with a monetary reward outcome. In a subsequent test phase, participants completed a visual search task while trying to ignore task-irrelevant sounds, certain of which were previously associated with reward. Visual search performance was impaired in the presence of the previously high-value sound, demonstrating cross-modal attentional capture. In another experiment, participants first performed a training phase comprising visual search for a color-defined target. Trial-by-trial feedback consisted of a face exhibiting either a positive (smile) or neutral expression. Participants were told that these faces would "react to what happened on that trial." One color target was more likely than the other to be followed by a positive expression; the feedback participants received was unrelated to their actual performance. Then, in a subsequent test phase, former-target-color stimuli were presented as distractors in a visual search task for a shape-defined target. Distractors rendered in the color previously associated with a high probability of positive social feedback impaired search. The findings support the domain generality of value-driven attention, with a range of positive outcomes biasing information processing across and between different sensory systems.

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33.4019 Distractor inhibition in visual search can be facilitated by value salience
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Visual attention can be biased by value salience and cause maladaptive behaviors. Here we test whether the distractor with value salience can be effectively suppressed by selection of a target that categorically conflicts with it (i.e., steep vs. shallow in orientation). In Experiment 1, we trained observers to associate high and low reward with two steep bars (±30° from the vertical). Before and after the training, we tested the reward effect using a visual search task where steep was defined as the categorical feature of the target or distractor. The search display consisted of eight bars tilted to the same direction (left or right). The target (e.g., 30°) and distractor (e.g., 60°) bars were two singletons presented along the diagonal line, among six 45° tilted bars around the fixation. Observers were asked to look for the steep (and ignore the shallow) bar or look for the shallow (and ignore the steep) bar in separate blocks. The results showed significantly larger improvement in search RT for item associated with high reward than low reward ($p< 0.05$). Notably, this facilitation was evident when the reward-associated items were either to be detected (search for steep block) or ignored (search for shallow block), indicating the reward influences on target selection and distractor suppression, respectively. In Experiment 2, we confirmed that the suppression effect ($p< 0.05$) was unaffected by factors such as stimulus type (use Gabor pattern), presentation time, target-distractor distance (1 or 3 intervening items), and training category (associate the shallow with reward). These findings suggest that distractor inhibition in visual search can be facilitated by value salience.

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33.4020 What's that smile worth? Social reward influences spatial orienting
Dana Hayward[1] (dana.hayward@mail.mcgill.ca), Effie Pereira[1], Todd Vogel[1], Kathleen Stewart[1], Jelena Ristic[1]; [1]Department of Psychology, McGill University

A wealth of recent research indicates that rewarded singletons capture attention. However, it is unclear whether reward may also lead to the development of spatial associations between neutral cues and corresponding target locations, resulting in spatial orienting. Furthermore, reward-mediated capture has mostly been demonstrated using monetary reward, opening up the possibility that this finding may not generalize to other types of rewards. To test this, we used a social reward and examined performance in Baseline, Learning, and Test conditions. Participants performed a four location cuing task, in which one of two bicolored circles (orange-yellow; blue-green) shown at fixation indicated a target on the left, right, top, or bottom with equal probability. In the Baseline condition, participants completed a target detection task. In the Learning condition, they performed a target identification task. Implicit social reward (i.e., "points" towards the researcher's project) was administered for correct identification of a target that was spatially congruent with one half of one bicolored cue (e.g., orange left, target left; +5 points). Incorrect identification of a target that was congruent with the other half of the bicolored cue accrued negative points (e.g., yellow left; target left; -5 points). No reward was given for the other cue. Rewarded cue type was counterbalanced between participants. In the Test condition conducted one day later, participants performed the same task as Baseline. The data indicated that social reward influenced learning of spatial relations. In contrast to Baseline, where no facilitation of RTs was found, in the Test condition, participants were significantly faster at detecting targets congruent with the rewarded color. This shows that in addition to modulating attention to singletons, reward also modulates the learning of spatial associations, and furthermore suggests an important role of social reward for the development of human social attention.

33.4021 The role of sensory cortex and cortical "hubs" in category-specific executive function
Thomas James[1,2] (thwjames@indiana.edu), Lindsay Arcurio[2,3], Anastasia Nikoulina[1]; [1]Cognitive Science Program, Indiana University, [2]Department of Psychological and Brain Sciences, Indiana University, [3]Section on Clinical Psychoneuroendocrinology and Neuropsychopharmacology, National Institute on Alcohol Abuse and Alcoholism

Human executive functions are sensitive to visual cues that make up the environmental context, but there are few research programs that study this influence or study the impact of changes in sensory neural signals on frontal cortical function. In this talk, I will present findings from studies of people with alcohol use disorders (AUD) that implicate the lateral occipital cortex (LOC) and its connections with the anterior insular cortex (AIC) in impulsive decisions-to-drink when exposed to visual alcohol cues. Specifically, 31 women (15 AUD) were scanned using fMRI while performing a decisions-to-drink task. In that task, they were presented with alcohol and food cues that were normed for attractiveness/desirability. They were asked to imagine themselves in a situation where deciding to drink had a high or low probability of a negative consequence and were asked to rate their likelihood of drinking (or eating) on a 4-point scale. AUD women endorsed alcohol cues more than non-AUD, but not food cues – a category-specific effect on decision making. Differences in BOLD signal between AUD women and non-AUD for alcohol vs food cues were widespread and always greater for AUD. This finding suggests that there was no single neural system (e.g., cognitive control) that accounts for the group difference in behavior. Comparing high- to low-risk scenarios highlighted differences between AUD and non-AUD in the LOC and AIC. A task-based functional connectivity analyses provided further support for the role of LOC and AIC in AUD women producing more impulsive category-specific decisions. In conclusion, widespread differences in decision-related BOLD signal between AUD and non-AUD may originate in the visual cortex (LOC) and cascade throughout the brain by way of network "hubs" such as the AIC. These results highlight the important (but underappreciated) role of sensory cortices in decision making and other executive functions.

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33.4022 Estimates of human subjective utility from early visual responses
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In motivated behavior, attention can be directed towards objects or locations associated with economic gains or losses. We investigated whether information about potential gains and losses affects visual sensitivity and cortical activity (BOLD fMRI) in a manner akin to that of spatial attention. While in the scanner, subjects performed a contrast discrimination task at one of four possible locations. On half of the trials, subjects expected to earn monetary rewards as a result of correct responses – no loss possible. On the other half of the trials, subjects expected to lose accrued rewards upon incorrect response – no gain possible. We presented cues before trial onset that were 100% informative about the potential gains or losses at each location, but provided no information about the location of the stimulus to be discriminated. We measured contrast-discrimination thresholds concurrently with fMRI responses in early visual cortex (V1-hV4) to stimuli that predicted for high- or low-gains, and high- or low-losses. We used visuocortical responses to estimate subjective utility associated with expected gains and losses. Discrimination sensitivity and visuocortical activity was higher at locations of high-gain and -loss stimuli. Discrimination thresholds and cortical activity were similar for gain and loss trials. But estimating subjective utility associated brain responses to gains and losses showed that activity for losses increased twice as fast as that for gains. We conclude that maximizing gains and minimizing losses generates effects closely resembling the spatial allocation of attention. These findings support the predictions of modern economic theories in which prospective losses outweigh gains.

33.4023 Relating BOLD and ssVEPs during visual aversive conditioning using concurrent EEG-fMRI recordings
Nathan Petro[1] (npetro@ufl.edu), L. Forest Gruss[1], Siyang Yin[2], Haiqing Huang[2], Mingzhou Ding[2], Andreas Keil[1]; [1]Department of Psychology, College of Arts & Sciences, University of Florida, [2]Department of Biomedical Engineering, College of Engineering, University of Florida

Functional and electrophysiological measures indicate visual cortical responses evoked by emotionally arousing versus neutral stimuli are amplified, a process thought to be mediated by re-entrant projections from anterior cortical and subcortical structures. In healthy human observers, neuroimaging techniques with high temporal and spatial resolution are necessary to test such hypotheses. Here, blood-oxygen level dependent (BOLD) data and EEG data were collected simultaneously during a classical conditioning paradigm in which the orientation of grating stimuli (the conditioned stimuli, CS) predicted the presence/absence of a cutaneous electric shock (i.e., the unconditioned stimulus). Gratings were phase-reversed for a duration of 5 seconds, at a fixed rate (10/sec), evoking steady-state visual evoked brain potentials (ssVEP). In addition to considering the ssVEP and fMRI data separately, electrophysiological indices of single-trial visual engagement were extracted from ssVEP data and used to construct a predictive model for BOLD activation. BOLD and ssVEP data converged to show specific engagement of circumscribed areas in the calcarine fissure and occipital pole, in response to the phase reversal. Across experimental phases, BOLD in regions such as middle-temporal cortex, anterior insular cortex, and frontal cortical regions related to trial-by-trial fluctuations in ssVEP amplitude.

33.4024 **Exogenous cueing modulates preference formation**

Giulia Rampone[1] (giulia@liverpool.ac.uk), Alexis Makin[1], Marco Bertamini[1]; [1]University of Liverpool

Attentional shifts can be produced by external (exogenous) cues. Here we focus on whether a shift of attention modulates affective responses. In five experiments, the peripheral onset of an uninformative cue was followed by a novel abstract pattern. We observed that exogenous cuing enhanced target discrimination (RTs) and preference formation (ratings) (Experiment 1a). We therefore distinguish two validity effects: VE_{RTs} and $VE_{preference}$. Validity effects are measured by the difference between valid and invalid conditions. Interestingly, $VE_{preference}$ was sensitive to several parameters. When oculomotor responses were inhibited, cuing induced VE_{RTs} but not $VE_{preference}$ (Experiment 1b). Also the cue-to-target (inter-stimulus interval, ISI) interval was critical. By increasing ISI we eliminated both VE_{RTs} and $VE_{preference}$ (Experiment 2a and 2b). Further investigation revealed that the $VE_{preference}$ originates from a combination of a validity benefit and an invalidity cost (Experiment3). We also investigated whether $VE_{preference}$ indirectly results from the experience of fluency on valid conditions. The target in Experiment 4 was a simple circle and participants responded to its location. After this response, a non-target pattern appeared at fixation and was evaluated. Although VE_{RTs} was present for target detection, $VE_{preference}$ for non-target patterns at fixation was absent. In Experiment 5 the non-target patterns were presented at the peripheral location of the target. Both VE_{RTs} and $VE_{preference}$ were observed. Preference modulation may thus be determined by a sense of fluency associated with the cue-to-target contingency. However, reorienting attention with an additional saccade can reset the effect. Overall these studies document the relationship between exogenous attention and preference. Our results highlight the important role of attention and oculomotor responses in the mechanism that links visual and emotional responses.

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33.4025 **Coping with Conflicts Improves Under Threat: Evidence from a Simon and a Visuo-Auditory Stroop Tasks**

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A large body of research has suggested that our attentional system is distinctively sensitive to threat-related stimuli in the environment (for reviews see, Bar-Haim et al., 2007; Yiend, 2010). Recently, Chajut, Schupak, & Algom (2010) introduced a new paradigm in which changes in Stroop dilution effects (Kahneman & Chajczyk, 1983) are used to gauge the power of emotional (vs. neutral) words to bias attention. In this color naming task, a colored emotional or neutral word to be named (e.g. Death vs. Chair colored in blue) is accompanied by a color-word (e.g. Red) printed in black. The results showed that the Stroop effect (RT of incongruent trials minus RT of congruent trials) was smaller with emotion than with neutral words. This finding suggests that emotion words bias attention to a greater degree than do non-emotion ones, and is termed an emotional dilution of the Stroop effect (EDSE; Chajut et al., 2010). In this research we investigated whether the improved ability to cope with conflict observed in the EDSE is a viso-spatially biased phenomenon, namely a spatial allocation of attention that is biased toward emotional content, or an example of a general impact of threat on our basic ability to cope with conflicts. Two experiments recorded a dilution of conflict effect in conditions where conflict was dissociated from the visual stimuli of the color to be named: First, by deploying Stroop congruency conflict in an auditory modality (Experiment 1); and second, by implementing the setting of a Simon conflict (Experiment 2). The results indicate an improvement of participant's ability to cope with Stroop and Simon conflicts under threat condition, supporting the general impact of threat hypothesis.

Attention: Tracking

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

33.4026 **An Eye for Detail: Attentive States Modulate the Social Gaze-Cue Effect in Multiple Object Tracking**

Alisa Brockhoff[1] (alisa.brockhoff@uni-tuebingen.de), Markus Huff[1]; [1]University of Tuebingen

Behavioral and electrophysiological studies on bistable images helped to trace the boundary between what perception owes to early visual processing, and what cognition adds to it. They demonstrated that passive sensory processing can be actively modulated in a top-down manner. For example, knowledge and intentional control has been shown to alternate percepts of the same stimulus. One reason for this phenomenon to occur is a change in the allocation of attention in the visual display. How does this affect a task whose successful completion already requires permanent re-allocation of attention? Here, we use the multiple-object tracking (MOT) paradigm to study influences of participants' knowledge on stimulus behavior to demonstrate that top-down processes affect sensory visual processing of dynamic stimuli. In MOT tasks, participants track and identify a specified set of target objects that move among identical looking distractors. Using pairs of cartoon eyes as stimuli, we integrated a strong exogenous cue that works independently of top-down control. In an experimental series, participants either tracked without further knowledge or were asked to identify the four conditions they were informed about beforehand. The gaze-cue effect was either implemented by the objects constantly "staring" or randomly "flirting" with a single other object (either a target or a distractor). Results: (1) only with explicit explanations about the eyes' behavior, perception shifts were observed (measured in how often participants marked the gaze-cued object), (2) even when observers failed to identify the eyes' behavior, the impact of the gaze cue was still strong, and (3) it is not tracking experience per se that enhances the gaze-cue processing. These results not only show that cognitive processing modes determine visual perception in attention-demanding dynamic tasks, but also serve as an approach to explain existing, contradicting results of past research.

33.4027 **Influence of Negative Emotion over Attention Allocation in Multiple Objects Tracking**

Huanyu Lei[1] (lhy5658692@126.com), Dongyuan Duan[1,2], Xuemin Zhang[1,3,4], Xiaoqian Yan[1,5]; [1]School of Psychology, Beijing Normal University, [2]College of Urban and Environmental Science, Northwest University, [3]National Key Lab of Cognitive Neuroscience and Learning & IDG/McGovern Institute for Brain Research, [4]Center for Collaboration and Innovation in Brain and Learning Sciences, Beijing Normal University, [5]Department of Psychology, University of York

Our visual system processes massive information in the everyday life, and most of the information is dynamic instead of static. A large amount of studies have been done to explore the underlying cognitive and neural mechanism behind this process. Studies have shown that the limitation on tracking mainly depends on allocation efficiency of attentional resources. The number of targets and the maximum speed that could be tracked are both inversely related to the resource demands for each tracking object. In present study, we used electrophysiological (Event-Related Potentials, ERP) measures to further investigate effect of negative emotions on tracking performance in twenty participants. Since studies suggested that negative emotions like anxiety and depression could engage more cognitive resources than positive emotions, we expected that negative emotions, compared to neutral ones, would have negative effect on attention allocation during tracking. Our behavioral results showed that the difference of tracking accuracy between negative emotion condition and neutral condition was not notable. Our ERP results showed that: 1) Probes on target position elicited stronger N2 (200~300ms) than did probes on space position (baseline condition) during neutral emotion induction condition, indicating target enhancement.2) N2 amplitude elicited at target condition decreased significantly in negative emotion condition than that in neutral, which was due to more attentional resource engaged under negative emotion.3) Probes on distractor condition elicited weaker P3(200~300ms) than target position, similar to space position. This might suggested weak distractor suppression mechanism. The present study indicated that negative emotions could affect attentional resource allocation during MOT task. The relevant region was located in the right prefrontal cortex, which was responsible for both negative emotion processing and attention control.

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See page 3 for Abstract Numbering System

33.4028 Multiple object tracking explained with neither fixed nor flexible resources

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In the multiple object tracking task an observer tracks moving targets within a set of featurally identical objects. Because error rates increase as target load (number of tracked targets) increases, the task is frequently cited as evidence of commodity-like resources that limit attention and working memory, with ongoing debates focused on whether resource allocation is fixed or flexible. Here we challenge the common assumption that resources limit tracking performance in the first place, adducing evidence from eye tracking experiments and a probabilistic model. The model infers the positions of targets on the basis of noisy samples received at a rate of 12Hz (similar results obtain at 20Hz), and it uses a nearest-neighbor algorithm to address correspondences between tracked targets and packets of unlabeled samples (including from nontargets). The noise in received samples depends on the distance of the relevant object from fixation (following Bouma's law). As a result, fixation position greatly impacts performance. 20 participants completed tracking trials with loads between three and eight and several speed settings. The model then simulated each participant, assuming his or her actual fixations. Without fitting parameters and with the same settings (apart from fixations) under all conditions, the model produced speed and load effects that were significantly correlated with those of human observers. The model also captured trial-by-trial performance variance (controlling for load). And most strikingly, it accounted for between-subject variance, ranking participants as they ranked in practice. In summary: A model with a limited sampling rate and eccentricity dependent noise —but with neither fixed nor flexible resource limits— produces the typical load and speed effects taken as evidence of resources. Incorporating inter-observer fixation differences accounts for inter-observer differences in performance. These results suggest that MOT capacity limits are effective, not inherent, arising because of interactions between task parameters, fixation, and correspondence computations.

33.4029 The limitations of attentional resources across developmental groups: A three-dimensional multiple object tracking study

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This study investigated the resource limits for dynamic visual attention across development using a three-dimensional multiple object-tracking (3D-MOT) task. Previous studies exploring such attentional limits were restricted by (i) the assessment of MOT in two dimensions, and (ii) categorical speed manipulations. 3D-MOT was used to measure attentional processing capacity when manipulating the number of target items and trial speed. Twenty-one participants grouped by age: school-aged (6-12 years), adolescent (13-18), or adult (19-30) group; were asked to follow 1 through 4 target spheres (separate conditions) among 8 total spheres, which moved randomly in a virtual volumetric space during an 8 second trial. The speed of the spheres changed for subsequent trials until threshold performance was attained, defined as the average speed at which all target spheres for each condition (1 through 4) could be tracked. All participants were able to track up to four items successfully; however, school-aged children were limited to slower trial speeds compared to the adolescent and adult groups ($p < .001$) across all conditions (i.e., 1 through 4 items). The decreasing trend in speed threshold scores at increasing levels of target items resembled a logarithmic function for all age groups ($r2 = .983$, $p = .008$). This finding describes the deployment of attentional resources, where an upper limit of object capacity (when speed is close to motionless) was 6.48 for adults, 7.12 for adolescents, and 5.42 for school-aged, differing from limits described by two-dimensional paradigms (Alvarez & Franconeri, 2007). The decreasing trend is representative of the flexible-resource model, where in this case resource allocation is a function of trial speed and number of target items. These preliminary findings suggest that 3D-MOT can be used for characterizing the development of resource allocation in attentional processes through the use of a measure that best approximate real-world conditions.

33.4030 MOT Capacity is Compromised in Ecological 3D Environments

Brad Weber[1] (bradweberwsu@gmail.com), Rui Ni[1]; [1]Department of Psychology, Wichita State University

Multiple object tracking (MOT) has been used extensively in studies on visual attention and working memory in a dynamic environment. However, the majority of findings of MOT research have been collected using two dimensional (2D) displays. Given the lack of ecological connection between 2D MOT displays and 3D real-world visual scenes, the current study aims to investigate the effect of 3D depth information on tracking multiple moving objects in 3D environments. Specifically, the MOT displays were generated in a way to simulate different viewing positions from an observer's perspective. In the first experiment the stimulus was manipulated to simulate 4 viewing angles, 30º, 50º, 70º, and 90º. No significant effect was found for the changes in viewing angle. This could be due to that fact that, even for the shallowest viewing angle - 30º, it's still unrealistically too steep for most real-world tasks. Thus, in experiment 2 we examined a shallower angle of 15º in the MOT task, which is more similar to a viewing angle that an individual may experience in watching/playing sports such as soccer or driving a vehicle. With this more ecological manipulation we found significant decrements in tracking capacity under 15º as compared to 90º viewing angle conditions. Consistent with previous research, it was also found in both experiments that the MOT tracking capacity significantly decreased with increased target number. The results suggest that the current 3D MOT program could be a better indicator of cognitive capacities in 3D real-world conditions.

Sunday AM

33.4031 Simulating multiple object tracking performance using a Kalman filter model

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Although previous work has debated whether motion extrapolation is used in multiple object tracking (MOT), here we show that a Kalman filter-based model of motion prediction can simulate tracking accuracy on a trial-by-trial basis. Behavioral data were collected in two experiments manipulating trial duration (exp 1; 4-12s at 8°/s) and item speed (exp 2; 5-11°/s at 8s). In each experiment observers tracked 4 of 10 moving discs. Consistent with previous findings, tracking performance was found to vary with both speed and duration (both $p < .001$). Our model attaches an independent Kalman filter to each target disc at the start of a motion sequence. At each time step of the simulation, each filter predicts the position and velocity of its associated disc, then decides new assignments of filters to discs probabilistically based on predicted positions and velocities and all observed disc positions. We define a 2D Gaussian distribution per filter, with the mean equal to the predicted position, and a covariance matrix that maximizes the probability-density-function in the direction of the predicted velocity. A disc is attached to the filter with a probability based on the pdf evaluated at the disc's position, with tracking errors resulting when a filter becomes incorrectly attached to a non-target. The disks associated with filters at the end of each simulation are considered the items selected as targets. Accuracy is defined as the percentage of correctly selected targets. The model captured the behavioral decrease in tracking accuracy with both increasing trial duration (exp 1; $p < .001$) and increasing disc speed (exp 2; $p < .001$), although predicted accuracy in exp 2 was slightly higher than what was found in the behavioral data ($p = .05$). We conclude that motion prediction, simulated here by simple Kalman filters, can describe tracking accuracy in two widely-studied MOT tasks.

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33.4032 Four theoretical dichotomies in the motion extrapolation literature

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People can estimate the current position of an occluded moving object. The laboratory version of this task is called 'motion extrapolation'. Participants typically press a button when they estimate the moving object has arrived at the end of the occluder. The literature is fragmented, and there is no consensus on how people produce accurate responses. This complex topic can be understood by framing four theoretical dichotomies, and considering tentative resolutions. Dichotomy 1: Does mental imagery or visuospatial tracking mediate motion extrapolation? Resolution: A rate control mechanism 'does the work' in both accounts, by either updating position of spatial attention, or the position of the imaginary target, at the right speed. Dichotomy 2: Cognitive clocking or visuospatial tracking? Do people obtain a representation of time-to-contact, then count this down, or do they track across the occluder with the spotlight of spatial attention? Resolution: These accounts are not mutually exclusive, while anti-clocking conclusions are premature. Dichotomy 3: One or many rate controllers? People

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can extrapolation through other 'spaces', such as colour space or abstract number space. So, do all forms of extrapolation require a common rate controller, or does each dimension have a separate rate controller? Resolution: Current evidence supports the common rate control model. Dichotomy 4: Common rate controller or a common clock? Resolution: New evidence shows that multidimensional rate control is possible. In summary, diverse motion extrapolation papers from the last 60 years can be organized under the new four dichotomies framework. Recent evidence points to a centralized rate controller for updating all dynamic mental representations.

Acknowledgement: Leverhulme Trust (ECF 2012 721)

Spatial Vision: Models and mechanisms

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

33.4033 Diagonal Stretch Illusion: the distance between dots appearing longer when surrounded by circles

Daisuke Hayashi[1,2] (daisuke@fechner.c.u-tokyo.ac.jp), Masahiko Terao[1], Lin Cai[1], Takayuki Osugi[1,2], Ikuya Murakami[1]; [1]The University of Tokyo, [2]Japan Society for the Promotion of Science(JSPS)

We found a new illusion that makes the distance between two small dots appear longer. When two of the four dots comprising a square shape are surrounded by thick circles, the diagonal distance between the two dots (length of the "test" diagonal) subjectively becomes longer than the distance between the dots without surrounding circles (length of the "comparison" diagonal). We named this phenomenon 'Diagonal Stretch Illusion'. Several important characteristics of this phenomenon are listed as follows. (1) The degree of this illusion is higher when the test diagonal is horizontal rather than vertical, opposite to the prediction from the vertical-horizontal illusion. (2) Stimulus duration for 100 ms is sufficient. (3) This illusion is observed in both foveal and peripheral vision. (4) As the surrounding circles become thinner and/or smaller, the illusion becomes weaker. In contrast, a strong illusion is obtained from dots superimposed upon large disks rather than surrounding circles. (5) The longer absolute distance between dots makes the illusion weaker. (6) The illusion is robust even when surrounding circles are contrast-defined or when circles and dots are color-defined. (7) To produce this illusion, surrounding stimuli can be circles, squares, or even illusory-contour squares. The last observation rules out accounts in terms of depth perception because dots on the illusory-contour squares should appear nearer than dots on the background, and Emmert's law dictates that nearer objects should appear closer to each other. (8) After adaptation to a subjectively stretched shape, an isotropic shape appears to be stretched along an orthogonal axis. From these observations, we propose that the visual system possesses some distance estimation mechanism that produces a systematic bias in the presence of surrounding stimulus patterns in addition to localized points of interest, and that such a mechanism is located early enough to be adaptable following prolonged observation.

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33.4034 Greater benefits of collective integration in visual search

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Perceptual accuracy can improve by combining multiple people's judgments into a group decision. Assuming that internal observer responses are Gaussian and Independent (GI), a classic prediction by Signal Detection Theory (GI-SDT) is that the maximum possible group-d' is equal to the square root of the sum of individual's squared d-primes (Sorkin & Dai, 1994). When observers scrutinize images limited by external noise (e.g., medical, satellite, aerial imagery), judgments are typically correlated across observers, and the benefits from optimal collective integration are lower than that predicted by GI-SDT (group-$d'_{observed}$ / group-$d'_{GI\text{-}SDT}$ < 1). Exp1 demonstrates the typical reduced benefits of collective integration (i.e., d'_{ratio} < 1) using a single location, noise limited, yes/no task. Fifteen observers responded on an 8-point rating scale whether a Gaussian luminance signal was embedded in white noise at a known location (signal present 50%). Group d-primes obtained using an optimal linear combination model were significantly larger than individual d-primes, but significantly lower ($p < .01$; bootstrap resampling) than that predicted by GI-SDT (d'_{ratio} = .86 for groups of 2; d'_{ratio} = .79 for groups of 3). In contrast, Exp2 demonstrates that visual search tasks can lead to large increases in the benefits of collective integration. Fifteen observers searched (2 second time limit) for a target (target present 50%) in a random and unknown location within a white noise field (28 x 22.5 degrees). Observers responded using an 8-point rating scale about the presence of the target. Group d-primes obtained for the search task achieved benefits comparable or larger than that predicted by GI-SDT (d'_{ratio} = 1.25 for groups of 2; d'_{ratio} = 1.09 for groups of 3). Conclusion: Search with spatial uncertainty in noise limited tasks results in collective integration benefits that are significantly larger than single location perceptual judgments, and can approach or exceed the predictions of GI-SDT.

33.4035 Dipper functions for second-order modulation of contrast, orientation, and motion

Yi Gao[1] (adelegaoyi@gmail.com), Alex Baldwin[1], Robert Hess[1]; [1]McGill Vision Research, Department of Opthalmology, McGill University

The human visual system can detect not only modulations in luminance (first-order stimuli), but also modulations of these modulations (second-order stimuli). For example modulations in the contrast, orientation, or motion of a first-order "carrier" stimulus. Second-order modulations are substantially more difficult to detect than equivalent first-order modulations. This difference would be explainable if we understood the processing mechanisms of second-order stimuli, however these are not yet clear. In order to compare the different types of second-order processing and allow comparisons to be made against first-order, we used the pedestal masking method to measure dipper functions for three types of second-order stimuli: contrast-, orientation- and motion-modulated. The contrast-modulated stimuli are constructed by modulating a 45°, 4 c/d sinusoid grating carrier with a horizontal sinusoid grating envelope with a spatial frequency of 0.5 c/d. The orientation-modulation stimuli are made by adding two contrast-modulated stimuli with perpendicular carrier gratings and opposite envelope phases together. The motion-modulation stimuli are made by adding two contrast-modulated stimuli with opposite envelope phases but the same orientation drifting in perpendicular directions. The data are fit using maximum likelihood with a modified version of the Legge & Foley (1980) contrast response function. We find the dipper shapes similar to first order (same exponents) for the contrast, orientation and motion stimuli. Compared to contrast-modulation (from which the other stimuli are constructed) both the orientation- and motion-modulation conditions show an increased saturation constant (8 and 2 times higher respectively) consistent with increased divisive suppression. The motion-modulation condition also has an increased internal noise about 1.2 times that for contrast-modulation. In comparison with first-order results from previous studies we find all three second-order conditions have increased internal noise and greatly increased saturation constants. We consider preliminary designs for model architectures that may account for our results.

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33.4036 Detection of blur gradients: its relationship with blur discrimination.

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Blur gradient is acknowledged as an important cue for relative distance. A number of studies examined detection and discrimination of blur, but no study to date has directly examined human performance of gradient detection per se. In this study we examined gradient detection by using filtered random patterns. Blur gradient was generated by applying low-pass filters with varied cut-off frequencies to random dot patterns. The random dot pattern was comprised of 10 x 10 min cells, and extended 5 x 5 deg. The cut-off frequency at the center of the pattern was either 1.6, 3.2, 6.4, or 12.8 c/deg, and it was gradually increased or decreased along the horizontal axis to generate a blur gradient. Observers were asked to detect the direction of the gradient either to the right or to the left. It was found that the visual system is very sensitive to blur gradient. The lowest threshold of 0.016 octave/deg was found for the center frequency of 3.2 and 6.4 c/deg. The threshold increased at both 1.6 and 12.8 c/deg. These results were compared to the blur-discrimination performance obtained with two 5 x 5 deg homogeneously blurred patterns placed side by side with a 1 deg gap in between. The same four cut-off as the main experiment was used for the standard stimulus. It was found that the gradient threshold is almost comparable to that of discrimination if the gradient detection is based on the comparison between two extreme positions within a pattern, although it is not likely that such extreme positions are used for gradient detection. In addition, the discrimination threshold increased monotonically as cut-off was increased whereas the gradient threshold followed a U function. These results, thus, suggest that gradient detection is based on a mechanism separate from that for blur detection.

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33.4037 Estimating cortical reorganization and neural fill-in using fMRI population receptive field (pRF) mapping. Jessica Thomas[1] (jmthomas@uw.edu), Erik Runeson[1], Ione Fine[1], Geoffrey Boynton[1]; [1]Department of Psychology, University of Washington, Seattle, WA

Introduction: There is substantial interest in the use of population receptive field (pRF) 1 modeling to examine cortical reorganization after vision loss. Our lab has been developing methods for quantifying bottom-up changes in population receptive fields that are independent from the effects of spatio-temporal BOLD nonlinearities and various top-down influences including neural 'fill-in'. Previously we demonstrated how estimates of cortical reorganization can be biased by either not modeling scotomas appropriately 2, or by using a predictable stimulus 3. Here we examine how these phenomena interact with the fixation instability typical of individuals with low vision. Methods: In normally sighted individuals, we measured fMRI responses in cortical areas V1-V3 with a 2x2 stimulus design: Drifting bar vs. multifocal: stimuli were either predictable drifting bar sequences or unpredictable multifocal sequences; and Full-field vs. scotoma: stimuli were either full-field or contained a central mask simulating a foveal scotoma. Throughout each condition the fixation spot moved in a periodic pattern designed to simulate a typical form of nystagmus. Data were analyzed in a 2x2 design: Scotoma modeled or not modeled: stimuli containing scotomas were modeled either with or without the inclusion of the scotoma. Eye-movements modeled or not modeled: the moving fixation point was either modeled according to eye-tracker data or assumed to be static. Results: We found that unbiased pRF estimates can be obtained as long as an unpredictable stimulus is used, scotomas are modeled, and eye-movements are compensated for. Failing to compensate for any or all of these parameters will result in biased pRF estimates resembling cortical reorganization; including increased receptive field size and eccentricity values, particularly for pRFs near the scotoma. Finally, we show that unbiased pRFs can accurately estimate the neural "fill-in" elicited by predictable stimuli.

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33.4038 Modeling Strategic Optimization Criteria in Spatial Combinatorial Optimization Problems Brandon Perelman[1] (bperelman@gm.slc.edu), Shane Mueller[1]; [1]Michigan Technological University

In many real-world route planning and search tasks, humans must solve a combinatorial optimization problem that holds many similarities to the Euclidean Traveling Salesman Problem (TSP). The problem spaces used in real-world tasks differ most starkly from traditional TSP in terms of optimization criteria – Whereas the traditional TSP asks participants to connect all of the nodes to produce the solution that minimizes overall path length, real-world search tasks are often conducted with the goal of minimizing the duration of time required to find the target (i.e., the average distance between nodes). Traditional modeling approaches to TSP assume that humans solve these problems using intrinsic characteristics of the brain and perceptual system (e.g., hierarchical structure in the visual system). A consequence of these approaches is that they are not robust to strategic changes in the aforementioned optimization criteria during path planning. To investigate performance in these tasks, 28 participants solved 18 randomly-presented computer-based combinatorial optimization problems with two sets of task instructions, one designed to encourage shortest-path solutions and the other to encourage solutions that minimized the estimated time to find a target hidden among the nodes (i.e., locations). The node distributions were designed to discriminate between these two strategies. In nearly every case, participants were capable of strategically adapting optimization criteria based on instruction alone. These results indicate the importance of modeling cognition in behaviors that are traditionally thought to be driven automatically by perceptual processes. In addition, we discuss computational models that we have developed to produce optimization criteria-specific solutions to these combinatorial optimization problems using a strategic optimization parameter to guide solutions using a single underlying mechanism. Such models have applications in approximating human behavior in real-world tasks.

33.4039 Modelling probability summation for the detection of multiple stimuli under the assumptions of signal detection theory Frederick Kingdom[1] (fred.kingdom@mcgill.ca), Alex Baldwin[1], Gunnar Schmidtmann[1]; [1]McGill Vision Research, Dept. Ophthalmology, McGill University

In general there are two ways in which multiple stimuli can sum to threshold: by probability summation or by additive summation (of which linear summation is a special case). Probability summation (PS) is still often modelled using the long-refuted High Threshold Theory (HTT), in spite of the fact that most researchers believe that Signal Detection Theory (SDT) is the better model. Studies which do model PS under SDT often use Monte Carlo simulations to perform the calculations, but this method is prohibitively slow when many thousands of calculations are required, as when fitting psychometric functions with PS models and estimating bootstrap errors on the fitted parameters and model goodnesses-of-fit. We provide numerical integration formulae for calculating, on the assumptions of SDT, the proportion correct detections for n independently detected stimuli, each subject to a non-linear transducer τ, while Q channels are being monitored, and for an M-AFC task. We show how the equations can be used to simulate psychometric functions in order to determine how parameters such as the Weibull threshold and slope vary with n, τ and Q. We also show how the equations can be used to fit actual psychometric functions from a binocular summation experiment in order to obtain estimates of τ and to determine whether probability or additive summation is the better model of the data.

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33.4040 Psignifit 4: Pain-free Bayesian Inference for Psychometric Functions Heiko Schütt[1] (heiko.schuett@uni-tuebingen.de), Stefan Harmeling[5], Jakob Macke[2,4], Felix Wichmann[1,2,3]; [1]Neural Information Processing Group, Faculty of Science, University of Tübingen, Germany, [2]Bernstein Center for Computational Neuroscience, Tübingen, Germany, [3]Empirical Inference Department, Max Planck Institute for Intelligent Systems, Tübingen, Germany, [4]Max Planck Institute for Biological Cybernetics, Tübingen, Germany, [5]Institut für Informatik, Heinrich-Heine-Universität Düsseldorf, Germany

Psychometric functions are frequently used in vision science to model task performance. These sigmoid functions can be fit to data using likelihood maximization, but this ignores the reliability or variance of the point estimates. In contrast Bayesian methods automatically calculate this reliability. However, using Bayesian methods in practice usually requires expert knowledge, user interaction and computation time. Also most methods---including Bayesian ones---are vulnerable to non-stationary observers (whose performance is not constant). For such observers all methods, which assume a stationary binomial observer are overconfident in the estimates. We present Psignifit 4, a new method for fitting psychometric functions, which provides an efficient Bayesian analysis based on numerical integration, which requires little user-interaction and runs in seconds on a common office computer. Additionally it fits a beta-binomial model increasing the stability against non-stationarity and contains standard settings including a heuristic to set the prior based on the interval of stimulus levels in the experimental data. Obviously all properties of the analysis can be adjusted. To test our method it was run on extensive simulated datasets. First we tested the numerical accuracy of our method with different settings and found settings which calculate a good estimate fast and reliably. Testing the statistical properties, we find that our method calculates correct or slightly conservative confidence intervals in all tested conditions, including different sampling schemes, beta-binomial observers, other non-stationary observers and adaptive methods. When enough data was collected to overcome the small sample bias caused by the prior, the point estimates are also essentially unbiased. In summary we present a user-friendly, fast, correct and comprehensively tested Bayesian method to fit psychometric functions, which handles non-stationary observers well and is freely available as an MATLAB implementation online.

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33.4041 Psychophysical Calibration of Mobile Touch-Screens for Vision Testing in the Field Jeffrey Mulligan[1] (jeffrey.b.mulligan@nasa.gov); [1]Human Systems Integration Division, NASA Ames Research Center

The now ubiquitous nature of touch-screen displays in cell phones and tablet computers makes them an attractive option for vision testing outside of the laboratory or clinic. Accurate measurement of parameters such as contrast sensitivity, however, requires precise control of absolute and relative screen luminances. The nonlinearity of the display response ("gamma") can be measured or checked using a minimum motion technique similar to that developed by Anstis and Cavanagh (1983) for the determination of isoluminance. While the relative luminances of the color primaries vary between subjects (due to factors such as individual differences in pre-retinal pigment densities), the gamma nonlinearity can be checked in the lab using a photometer. Here we compare results obtained using the psychophysical method with physical measurements for a number of different devices. In addition, we present a novel physi-

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cal method using the device's built-in front-facing camera in conjunction with a mirror to jointly calibrate the camera and display. A high degree of consistency between devices is found, but some departures from ideal performance are observed. In spite of this, the effects of calibration errors and display artifacts on estimates of contrast sensitivity are found to be small.

Acknowledgement: NASA Engineering & Safety Center

33.4042 The FechDeck: a hand-tool for exploring psychophysics

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The FechDeck is an ordinary deck of playing cards modified to support exploration of psychophysical methods. Card backs are printed with noise textures that span a range of densities. Faces are augmented with line segments arranged in "L" patterns. Jokers are printed with ruled faces and with backs that serve as noise standards. The FechDeck allows users to conduct threshold experiments using Fechner's methods of adjustment, limits, and constant stimuli, and scaling experiments using Thurstone's ranking, pair comparison, and categorical rating methods, and Stevens' partition and magnitude estimation methods. Instructions and spreadsheets support clear use and efficient data processing. For example, for the method of adjustment, the user selects a card containing an "L" pattern, and places the joker face down on top. They then slide the top card until the arms of the exposed L match in length. Flipping the two cards and reading the ruler value indicates the accuracy of the match. Entering repeated measures into the spreadsheet estimates the psychometric function, the discrimination threshold, and the point of subjective equality. Similarly, for pair comparison scaling, the user separates the deck into suits, shuffles each suit and turns the piles face down. Using the spades as standards, they then repeatedly compare the other cards with the standards, sorting into piles of greater and lesser noise density. Turning the piles face up and entering their values in the spreadsheet populates the frequency matrix used by Thurstone's law of comparative judgment to derive an interval scale of perceived density. Additional instructions and analysis tools are provided for the other methods. Thus the FechDeck enables hands-on exploration and learning of the psychophysical methods. Finally, in addition to its valuable didactic purpose, the FechDeck, can be used for a serious round of Poker or a relaxing game of Hearts.

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33.4043 Efficient implementations of the adaptive PSI procedure for estimating multi-dimensional psychometric functions

Christopher DiMattina[1] (cdimattina@fgcu.edu), Kechen Zhang[2]; [1]Department of Psychology, Florida Gulf Coast University, [2]Department of Biomedical Engineering, Johns Hopkins University

Numerous psychophysical studies have considered how subjects combine multiple sensory cues to make perceptual decisions, or how contextual information influences the perception of a target stimulus. In cases where cues interact in a linear manner, it is sufficient to characterize an observer's sensitivity along each individual feature dimension to predict perceptual decisions when multiple cues are varied simultaneously. However, in many situations sensory cues interact non-linearly, and therefore quantitatively characterizing subject behavior requires estimating a complex non-linear psychometric model which may contain numerous parameters. In this computational methods study, we analyze three efficient implementations of the well-studied PSI procedure (Kontsevich & Tyler, 1999) for adaptive psychophysical data collection which generalize well to psychometric models defined in multi-dimensional stimulus spaces where the standard implementation is intractable. Using generic multivariate logistic regression models as a test bed for our algorithms, we present two novel implementations of the PSI procedure which offer substantial speed-up compared to previously proposed implementations: (1) A look-up table method where optimal stimulus placements are pre-computed for various values of the (unknown) true model parameters and (2) A Laplace approximation method using a continuous Gaussian approximation to the evolving posterior density. We demonstrate the utility of these novel methods for quickly and accurately estimating the parameters of hypothetical nonlinear cue combination models in 2- and 3-dimensional stimulus spaces. In addition to these generic examples, we further illustrate our methods using a biologically derived model of how stimulus contrast influences orientation discrimination thresholds. Finally, we consider strategies for further speeding up experiments and extensions to models defined in dozens of dimensions. This work is potentially of great significance to investigators who are interested in quantitatively modeling the perceptual representations of complex naturalistic stimuli like textures and occlusion contours which are defined by multiple feature dimensions.

33.4044 Autistic and neurotypical subjects extract spatial frequencies differently

Laurent Caplette[1] (laurent.caplette@umontreal.ca), Philippe Desroches[1], Bruno Wicker[2], Frédéric Gosselin[1]; [1]Département de psychologie, Université de Montréal, [2]Institut de Neurosciences de la Timone, CNRS UMR 7289 & Aix-Marseille Université

When recognizing an object, low spatial frequencies (LSFs) are processed before higher spatial frequencies (HSFs), presumably through the faster magnocellular pathway. People suffering from autism spectrum disorders (ASD) however may not benefit from such a precedence of LSF information, several studies indicating a deficit in processing related to the magnocellular pathway (e.g., Sutherland & Crewther, 2010) and a preference toward HSFs rather than LSFs (e.g., Deruelle, Rondan, Gepner, & Tardif, 2004). Our study compared the time course of spatial frequency (SF) use in object recognition in neurotypical and ASD subjects. Forty-five neurotypical and 18 ASD subjects participated to the study. On each trial, a short video (333 ms) was presented to subjects. This video was created by selecting one of 86 object images, all equalized in SF content, and by sampling randomly its SFs across time. An object name immediately followed and subjects had to indicate if it matched the object (it did on half the trials) as quickly as possible without making too many errors. We then performed multiple linear regressions on SF x time sampling planes and accuracy. Most SFs between 0.08 and 4.42 cycles per degree (cpd) during almost all stimulus presentation (0 to 325 ms) led to more accurate responses for both groups ($p< 0.05$; Z_{max}=7.10). Interestingly, SFs between 3.75 and 4.33 cpd in the 58-100 ms time window ($p< 0.05$; Z_{max}=4.03) and SFs between 5.00 and 5.58 cpd in the 67-100 ms time window ($p< 0.05$; Z_{max}=3.99) led to more accurate responses for autistic subjects than for neurotypical subjects. These results indicate that while both groups use LSFs and intermediate SFs throughout object recognition, autistic subjects use more HSFs at a shorter latency. This suggests a different time course of SF extraction for autistic subjects.

Motion Perception: Neural mechanisms and models

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

33.4045 Anticipation of an approaching bar by neuronal populations in awake monkey V1

Giacomo Benvenuti[1] (giacomox@gmail.com), Sandrine Chemla[1], Arjan Boonman[2], Guillaume Masson[1], Frédéric Chavane[1]; [1]Team InVibe, Institut de Neurosciences de la Timone, CNRS and Aix-Marseille Université, France, [2]Department of Zoology, Faculty of Life Sciences, Tel Aviv University, Israel

Visual motion integration in area V1 is traditionally investigated with local stimuli drifting over many cycles within a fixed aperture. However, psychophysical studies have suggested that motion signals can be optimally integrated along the trajectory of a single, translating dot. High detection performance can be explained by the propagation of information between adjacent detector units (Verghese et al., 1999). Such propagation mechanism was proposed to take place within the retinotopic cortical map in area V1 where each local input along the trajectory will elicit a spread of activity that can pre-activate future locations. To test this hypothesis, we recorded single-unit responses (n=80 cells) in area V1 of 2 fixating monkeys when presented with a small bar (4°) always drifting along the same direction (rightward, 6.6°/s) but with three different trajectory lengths (1.5, 3 and 6°). We found in 47% of the neurons an anticipatory build-up of spiking activity for long motion paths, starting as far as 2-4° from the RF center. This activity was not due to eye movements and was abolished when the order of the stimulus sequence was randomized. To probe the origin of such anticipatory responses, we recorded both LFP signals using multi-electrode-arrays and sub-threshold synaptic activity using voltage-sensitive-dye-imaging (VSDI). LFP responses showed a very early anticipatory signal that could be attributed to a fast feedback signal from higher areas. The dynamics of VSD sub-threshold anticipatory responses matched the spatiotemporal properties of the horizontal connectivity underlying propagation of neural activity within V1 retinotopic maps. Thus, anticipatory spiking response in V1 neurons is probably subtended by a combination of intra and inter-cortical signals converging onto V1 cells. These results highlight the complex, predictive integration of visual motion in primate area V1.

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33.4046 V1 population activity represents global motion velocity of long-range apparent motion in the awake monkey Sandrine Chemla[1], Alexandre Reynaud[1,2], Guillaume Masson[1], Frederic Chavane[1]; [1]Institut de Neurosciences de la Timone (INT), CNRS and Aix-Marseille Université, UMR 7289, Campus Santé Timone, 27 boulevard Jean Moulin, Marseille 13005,France, [2]Current Address: McGill Vision Research, Dept of Ophtalmology, McGill University, Montreal QC, Canada

Two stationary stimuli successively flashed in spatially separated positions generates the so-called apparent motion illusion. The illusion depends on the precise spatial and temporal separations of the stimuli and is called long-range apparent motion (lrAM) for large spatiotemporal(ST) separations[1]. Since these values extend well beyond the typical selectivity of early visual neurons, it is unclear how the visual system computes motion signals from such sequence of static stimuli. We investigated whether a global motion representation could emerge at the level of V1 population in response to a two-stroke lrAM through lateral interactions[2]. We used voltage-sensitive dye imaging[3] to study in real-time the V1 population activity of two fixating monkeys in response to lrAM stimulations, whose velocity(direction and speed) was manipulated. We observe the emergence of a ST representation of the global motion:a cortical correlate of the illusory motion[4]. This ST representation of V1 population is shaped by non-linear interactions:the apparition of the second stimulus generates a spread of suppression in the direction opposite to the AM at a speed compatible with the horizontal propagation, independent of the stimulus' speed. Such spread of suppression acts as a fast normalization[5] that optimally shapes the ST representation of global motion along the AM path, to accurately represent the stimulus velocity. To validate this hypothesis, we applied an opponent motion energy model[6] on the observed and linearly-predicted V1 activity. The model systematically produced the largest energy for the appropriate direction and speed on the observed activity and failed for the linear prediction. Our results suggest that motion signal can emerge at the level of V1 population in response to lrAM, a signal that could then be decoded by downstream areas. [1] Cavanagh & Mather(1989). Spat.Vis.,4(2-3),2-3. [2] Muller et al.(2014).Nat.Comm.,5. [3] Chemla & Chavane(2010).J.Physiol-Paris,104(1),40-50. [4] Jancke et al.(2004). Nature,428:423-6. [5] Reynaud et al.(2012).J.Neurosci,32(36),12558-12569. [6] Adelson & Bergen (1985).JOpt.Soc.Am.A,2:284-299.

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33.4047 Illusory Motion Perception Is Impaired in individuals with DCDC2 Intron 2 Deletion showing the Selective Role of Magnocellular-Dorsal Stream in Dyslexia Sara Mascheretti[1] (sara.mascheretti@bp.lnf.it), Simone Gori [1,2], Enrico Giora[3], Luca Ronconi[1,2], Milena Ruffino [1], Ermanno Quadrelli[4], Andrea Facoetti[1,2], Cecilia Marino [1,5,6]; [1]Child Psychopathology Unit, Scientific Institute, IRCCS Eugenio Medea, 23842 Bosisio Parini, Lecco, Italy,, [2]Developmental and Cognitive Neuroscience Lab, Department of General Psychology, University of Padua, 35131 Padua, Italy,, [3]Faculty of Psychology,"Vita-Salute" San Raffaele University, 20132 Milan, Italy,, [4]Department of Psychology, University of Milan-Bicocca, 20126 Milan, Italy,, [5]Centre de Recherche de L'Institut Universitaire en Santé Mentale de Québec, Québec, QC, Canada G1J 2G3, [6]Département de Psychiatrie et Neurosciences, Faculté de Médecine, Université Laval, Québec, QC, Canada G1V 0A6

Developmental dyslexia (DD) is a heritable neurodevelopmental reading disorder that seems to arise from auditory, visual, and cross-modal integration deficits. A deletion in intron 2 of the DCDC2 gene (hereafter DCDC2d) increases the risk for DD. First, we show that illusory visual motion perception-specifically processed by the magnocellular-dorsal (M-D) stream- is impaired in children with DD compared with age-matched and reading-level controls. Second, we test for the specificity of the DCDC2d effects on the M-D stream. Children with DD and DCDC2d need significantly more contrast to process illusory motion in comparison to their counterpart without DCDC2d and to age-matched and reading-level controls. Regardless the genetic variant, children with DD perform typically in the parvocellular-ventral task. Finally, DCDC2d influenced illusory motion perception also in adult typical readers, showing that the M-D deficit is a potential neurobiological risk factor of DD rather than an effect of reading disorder. Our findings demonstrate, for the first time, that a specific neurocognitive dysfunction tapping the M-D stream is associated with a well-defined genetic susceptibility.

33.4048 Prefrontal neurons represent comparisons of motion directions in the contralateral and the ipsilateral visual fields
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Neurons in the lateral prefrontal cortex (LPFC) are active when monkeys decide whether two stimuli, S1 and S2, separated by a delay, move in the same or in different directions.Their responses show direction selectivity reminiscent of activity in motion processing area MT, and during S2, their responses are modulated by the remembered direction. A similar modulation, termed comparison effect (CE), has also been observed in area MT. These parallels between the two areas are consistent with their connectivity, although the nature of this connectivity suggests a possibility of asymmetries in the way contralateral and ipsilateral motion is represented in the LPFC during the motion tasks. Specifically, while signals about the contralateral motion reach LPFC directly from MT of the same hemisphere, ipsilateral motion processed by MT in the other hemisphere can only reach the LPFC indirectly via callosal connections from the opposite LPFC. We explored the role of direct and indirect motion signals in the generation of the comparison effects by examining responses of LPFC to contralateral and ipsilateral stimuli during S2. The CE was measured by comparing responses to identical S2 stimuli on trials when S2 was preceded by S1 moving in the same direction (S-trials) with trials when it was preceded by S1 moving in a different direction (D-trials). ROC analysis revealed two distinct groups of neurons preferring either S-trials or D-trials. Although these CE effects were equally likely to occur for ipsilateral and contralateral stimuli, the signals for the contralateral hemifield appeared about 90ms earlier, a likely reflection of direct connectivity with area MT. These results demonstrate that the comparison between the current and the remembered stimulus can be carried out in the LPFC even in the absence of direct inputs from area MT.

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33.4049 Motion encoding in human being and praying mantis investigated with a masking paradigm Jenny Read[1] (j.c.a.read@ncl.ac.uk), Natalie Busby[1], William Herbert[1], Sandra Arranz-Paraíso[2], Lisa Jones[1], Vivek Nityananda[1], Ghaith Tarawneh[1], Ignacio Serrano-Pedraza[1,2]; [1]Institute of Neuroscience, Newcastle University, [2]Departmento de Psicología Básica I, Complutense University of Madrid

The existence of multiple channels selective for spatial frequency in human motion perception has been shown by masking experiments (Anderson & Burr, 1989). We examined this in humans and praying mantises. The "signal" stimuli were vertically-oriented sinusoidal luminance gratings of either Low or High spatial frequency, moving either left or right with a temporal frequency of 8Hz. Signals were masked by temporally broadband noise, with no net energy in either direction. The noise was spatially band-pass, centered on either Low or High spatial frequency. Human subjects pressed a button to report motion direction; for mantises, a human observer blind to the stimulus judged the direction of the mantis optomotor response. The Low and High spatial frequencies were chosen for each species such that contrast sensitivity was roughly equal for both. For mantises, we used 0.04 and 0.2 cpd (2.3 octaves apart); for humans, we used 0.4 and 2 cpd (2.3oct), and also 0.2 and 4 cpd (4.3oct). For humans, at 2.3oct separation, contrast thresholds at both signal frequencies were increased by noise at the other frequency, with the Low threshold increased more by High noise. At 4.3oct, the Low threshold was still affected by High noise, but not vice versa. This implies the existence of at least two mechanisms: a broadband motion sensor which detects both 0.2 and 4 cpd, and a narrower-band, higher-frequency sensor which detects 4cpd but not 0.2cpd. For mantises, at 2.3oct separation, thresholds at both Low and High frequencies were increased by noise at the "other" frequency, but the High threshold was increased more by Low noise: the opposite to humans. Thus if mantises have >1 motion sensor, the lower-frequency sensor is narrower-band. Many aspects of motion perception are surprisingly similar in insects and humans, but this finding represents a novel difference.

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33.4050 A dynamic model for decoding direction and orientation in macaque primary visual cortex Wahiba Taouali[1] (wtaouali@gmail.com), Giacomo Benvenuti[1], Frédéric Chavane[1], Laurent Perrinet[1]; [1]CNRS-Aix Marseille University, Institut de Neurosciences de la Timone

Sunday AM

Using observations of spiking activity in a population of neurons from macaque primary visual area, we studied simultaneously the dynamics of direction and orientation decoding. Stimuli consisted of oriented bars moving in 12 different directions, the orientation being orthogonal to the direction. Bars move from 3 degrees before to 1.5 degrees after the receptive field center (RFc). We first fitted the neuronal responses to the different directions using a modified von Mises tuning function. Then, we extended this fit with respect to time in order to study the dynamics of the orientation and direction tuning. The whole temporal dynamics could be described by a simple temporal tuning model based on the combination of an unselective evoked gain, direction and orientation tuning functions and a temporal Gaussian activation profile. To evaluate this model, we adapted a maximum likelihood decoder as proposed in [Jazayeri et al. Nature Neuroscience 2006] with a leave-one-out cross validation paradigm that allows to decode the direction and the normalized population activation state. The results revealed that at the beginning of the population activation, orientation is significantly decoded but not direction (i.e. the estimated direction corresponds either to the stimulus direction or its opposite). Then, when the activation is maximal, direction is significantly decoded (area under ROC curve >0.7) despite the low values of cells' direction index (only 3% with DI >0.7). Finally, when the activation decreases (i.e. the stimulus leaves the RF), direction selectivity faded first. Our temporal tuning model reveals that the decoding is highly dynamic and evolves with the global population activation state. This is at odds to static decoding commonly used for early visual areas. Our results also show that direction can be decoded accurately from a poorly selective neuronal population.

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Sunday AM

33.4051 **Compound stimuli reveal velocity separability of spatiotemporal receptive fields in macaque area MT** Andrew Zaharia[1] (adz213@nyu.edu), Robbe Goris[1,2], J. Movshon[1], Eero Simoncelli[1,2,3]; [1]Center for Neural Science, New York University, [2]Howard Hughes Medical Institute, New York University, [3]Courant Institute of Mathematical Sciences

What determines the shape of the spatiotemporal tuning curves of visual neurons? In V1, direction-selective simple cells have selectivity that is roughly separable in orientation, spatial frequency, and temporal frequency ("frequency separable"). Models for tuning in area MT predict that signals from V1 inputs with suitable spatial and temporal frequency selectivity are combined to create tuning curves organized around tilted planes through the origin, representing stimuli translating at a particular direction and speed ("velocity separable"). In these models, this transformation is critical to build "pattern selective" neurons, which are neurons that respond best to simple and compound stimuli moving with the preferred velocity. We measured spatiotemporal frequency selectivity in single macaque MT neurons responding to sinusoidal gratings whose drift direction varied while their drift rate was either held constant (frequency separable organization) or varied along the preferred velocity plane (velocity separable). Most MT neurons' grating tuning was fit equally well by both the frequency and velocity separable model, regardless of the degree of pattern selectivity. We also measured responses to plaids (sums of two gratings oriented 120º apart). MT responses to velocity separable plaids were stronger and more broadly tuned than those to frequency separable plaids. Velocity separable model fits to these plaid responses were better than corresponding frequency separable model fits for almost every cell. Fitting the velocity separable model to gratings alone failed to predict pattern selectivity, whereas fitting to plaids alone predicted pattern selectivity well. We conclude that velocity separable models better describe the responses of most MT cells, though this superiority is only evident when complex stimuli are used to expose the nonlinear elements of these models.

33.4052 **Differences in primary visual cortex predict performance in local motion detection in deaf and hearing adults** Alexandra Levine[1] (atl507@york.ac.uk), Charlotte Codina[2], David Buckley[2], Gabriela De Sousa[1], Heidi Baseler[3]; [1]Department of Psychology, University of York, [2]Academic Unit of Ophthalmology and Orthoptics, School of Medicine & Biomedical Sciences, University of Sheffield, [3]Centre for Neuroscience, Hull York Medical School

Background The alteration of sensory experience can result in an enhancement in other sensory modalities. For example, congenitally deaf adults perform better in peripheral motion detection tasks. Recent work has indicated that peripheral motion sensitivity is correlated with structural changes in the retina in deaf and hearing individuals (Codina et al., PLoSOne, 2011). Moreover, electrophysiological signals in peripheral retina and visual cortex are larger and faster in deaf than hearing adults (Baseler et al., SFN 2013). This leads to the prediction that the peripheral representation in primary visual cortex should also reflect differences between deaf and hearing individuals. Methods Participants included eleven congenitally, profoundly deaf adults and eleven matched hearing controls, all without visual deficits. FMRI retinotopic mapping was performed using stimuli extending out to +/-72° to include the far peripheral visual field, where behavioral sensitivity differences are greatest in deaf adults. Motion detection was also measured in the same participants using a 2 AFC task with dot patterns at varying eccentricities.. Structural measurements of the V1 representation at each eccentricity were correlated with performance on the motion detection task in each individual. Results In V1, the ratio of peripheral to central visual field representation (volume and area) is significantly larger in deaf than hearing participants. In addition, the area of the peripheral representation in V1 predicted performance in peripheral motion detection in both deaf and hearing individuals. Conclusions Individual differences in visual maps in V1 appear to influence peripheral motion sensitivity, and these maps may be affected by differences in visual experience brought about by hearing loss.

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33.4053 **Functional interactions of feature-selective responses in MT+ and LOC and primary visual cortex in dynamic feature interpolation during apparent motion** Feilong Ma[1] (feilong.ma.gr@dartmouth.edu), Won Mok Shim[1]; [1]Psychological and Brain Sciences, Dartmouth College

When a static stimulus appears at two locations in succession, one can perceive the illusion of apparent motion (AM) across the two locations. Previous research using fMRI and a forward encoding model shows that intermediate visual features of a transforming object, which are absent in the retinal input but are spatiotemporally interpolated during AM, are reconstructed in population-level feature-selective tuning responses in the region of V1 corresponding to the AM path (Familiar, Chong, & Shim, 2014 VSS). However, little is known about how this interpolated feature information is reconstructed in non-stimulated regions of early visual cortex via top-down processing. Here using fMRI and a novel method of feature channel-based functional connectivity we examined functional interactions between the region of V1 that is retinotopically mapped to the AM path (V1-AM path) and high-level visual areas that are implicated in motion and shape processing (MT+ and LOC) during the perception of AM. Participants viewed rotational AM between two oriented gratings in the periphery and the population-level orientation channel responses in the V1-AM path, MT+ and LOC ROIs were reconstructed. We used the response at each orientation channel as input to compute channel-based inter-area correlations between V1 and each of the higher-level areas. The results showed that correlations between V1-AM path and MT+, as well as V1-AM path and LOC, were higher at orientation channels corresponding to the interpolated orientations on the AM path (0° or 90° depending on AM condition) when AM was perceived compared to when AM was abolished by simultaneously presenting the two gratings. This channel-selective increase in functional connectivity was not evident at other orientation channels. These results suggest that signals from high-level motion and shape processing areas, such as MT+ and LOC, may provide feedback information that mediates dynamic feature reconstruction in early retinotopic cortex during AM.

33.4054 **Asymmetric inhibition: Psychophysical evidence for redundancy reduction of velocity signals along moving edges.** John Perrone[1] (jpnz@waikato.ac.nz); [1]School of Psychology, The University of Waikato, Hamilton, New Zealand

Primate Middle Temporal neurons have been discovered with asymmetric antagonistic surrounds (Xiao et al., 1997). The response rate of such a neuron (e.g., tuned to V deg/s, 0°) is reduced by a small stimulus moving at the same velocity and located either directly above or below the classical receptive field of the neuron. Perrone (JOV, 2012) has argued that this asymmetric inhibition is designed to reduce redundant velocity signals generated along the edges of moving objects. Redundancy reduction and asymmetric inhibition have also been postulated to underlie the motion oblique effect in humans (Perrone, Liston & Stone, VSS, 2014). We therefore sought to find evidence for asymmetric inhibition in humans using a motion detection paradigm. Observers fixated a small central cross while a window (10° wide x 1.4° high) containing a high contrast moving edge was presented in the near periphery (V = 5 deg/s, 0° for 1 sec). Perrone (2012) suggested that MT pattern neurons are the target of the asymmetric inhibition. Therefore the test stimuli consisted of small Gaussian-windowed patches (SD = 0.25°) of moving 120° plaids (4 c/deg, 5 deg/s, 0°) designed to isolate pattern neurons. The targets were located above or below the moving edge and appeared for 200 msecs. They had to be dis-

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criminated from 'static' plaids (sum of two counter-phase gratings) as the contrast was reduced. Motion detection thresholds were measured using a 2AFC staircase for cases in which the edge was moving (M) and when it was static (S). The threshold ratio (M/S) was used to probe for evidence of inhibitory processes. We have isolated a number of locations where the threshold value below the edge was significantly higher than that above it and vice versa, supporting the idea of an asymmetric inhibitory mechanism designed to 'thin' the velocity signals along moving edges.

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33.4055 **Two Mechanisms Determine the Barber-Pole Illusion**

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In the Barber-Pole Illusion (BPI), a diagonally moving grating is perceived as moving vertically because of the narrow, vertical, rectangular shape of the window through which it is viewed. This strong shape-motion interaction persists through a wide range of parametric variations in the shape of the window, the spatial and temporal frequencies of the moving grating, the contrast of the moving grating, complex variations in the composition of the grating and window shape, and the duration of viewing. It is widely believed that end-stop-feature (third-order) motion computations determine the BPI, and that Fourier motion-energy (first-order) computations determine failures of the BPI. Here we show that the BPI is more complex: (1) In a wide variety of conditions, weak-feature stimuli (extremely fast, low contrast gratings, 21.5 Hz, 4% contrast) that stimulate only the Fourier (first-order) motion system actually produce a slightly better BPI illusion than classical strong-feature gratings (2.75 Hz, 32% contrast). (2) Reverse-phi barberpole stimuli are seen exclusively in the forward (feature, third-order) BPI direction when presented at 2.75 Hz and exclusively in the opposite (Fourier, first-order) BPI direction at 21.5 Hz. (3) The BPI in barber poles with scalloped edges (Badcock, McKendrick, and Ma-Wyatt, VisRes, 2003) is much weaker than in normal straight-edge barber poles for 2.75 Hz stimuli but not in 21.5 Hz stimuli. Conclusions: Both first-order and third-order stimuli produce strong BPIs. In some stimuli, local Fourier motion-energy (first-order) produces the BPI via a subsequent motion-path-integration computation (Peng, Chubb,and Sperling, JOV, 2014); in other stimuli, the BPI is determined by various feature (third-order) motion inputs; in most stimuli, the BPI involves combinations of both. High temporal and spatial frequencies, low contrast, and peripheral viewing, all favor the first-order motion-path-integration computation; low spatio-temporal frequencies, high contrast, and foveal viewing favor third-order motion computations.

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33.4056 **Boundary information is insufficient for direction and shape perception in short-range motion**

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Investigators have focused on the visual system's ability to exploit edge information in order to establish border-ownership and correctly perceive the motion of a surface across a background. (Layton, Mingolla, & Yazdanbakhsh, 2012). The random dot cinematogram is often used as a benchmark stimulus to explore the perception of motion when a sector of the cinematogram becomes a coherently displaced surface across frames (Braddick, 1979; Sato, 1989). The discrimination of motion direction and the shape of the displaced surface has been shown to depend on the detection of counterchange (Norman, Hock, Schöner, 2014); i.e. motion is signaled by the simultaneous decreases in local activation at one location and increases at another (Hock et al. 2002; Hock, Schöner & Gilroy, 2009; Norman, Hock, Schöner, 2014). METHOD: The current experiment separated the contribution of surface boundaries from the contribution of the information enclosed by the boundaries to the perception of motion for a random checkerboard. The central portion of a coherent moving surface was replaced with randomly arranged light and dark checks, as if a hole exposed the background, leaving only a thin coherent figure boundary. RESULTS: Observers reliably detected the direction of motion and surface shape when the central portions of the figure had not been removed, but subjects could not detect motion direction or figure shape when the central portion of the surface was made incoherent. The presence of an incoherent hole could not be detected even at the smallest displacements. The results indicate that boundary information is insufficient for direction and shape perception in short-range motion.

33.4057 **The use of graphical user interfaces (GUIs) to analyze motion and temperature**

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The recent revolution in wearable sensors poses new problems to develop analytics that handle large volumes of rapidly accumulating data from continuous recordings. We develop new analytical techniques to handle big data to process various physiological signals such as motion and temperature output from wearable sensor technology. Subjects performed tasks including dancing, walking, sleeping, performing decision-making tasks, and tasks in response to perceptual stimuli, while wearing sensors on various parts of the body. Sensors that register motion and surface skin temperature are worn for up to 15 hours. Inertial measurement units recorded acceleration, gyration, and temperature. A graphical user interface (GUI) was designed and implemented to automatically process large amounts of data and to provide longitudinal tracking of the subjects' physiological signals. A GUI is a human-computer interface wherein users give commands to electronic devices using visual indicators such as push buttons, drop-down menus, etc. They can be designed to show outputs in the form of text or visual graphs based on parameters input by the user. Using GUIs to analyze large volumes of data creates ease and efficiency. We paired the GUI with 6 inertial measurement units, IMUs (APDM 128Hz, Oregon). A Matlab program was designed to analyze data captured from the IMUs. In addition to the use of the GUI in typical populations, here we demonstrate the use of this GUI in a variety of clinical populations with neurological disorders and mental illnesses. The latter include schizophrenia, bipolar disorder, and general executive dysfunction. The former included autism, sensory processing disorder, and a genetic disorder that causes a deletion in SHANK-3, resulting in the presence of autistic traits in some cases). We propose the use of the GUI interface to characterize bodily responses during the performance of perceptual tasks to provide real-time, objective read-outs of a subject's perceptual state.

Motion Perception: Biological motion

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

33.4058 **Biological motion: At what age do we recognize boys and girls?**

Michael Bach[1] (michael.bach@uni-freiburg.de), Vanessa Frommherz[1], Wolf Lagrèze[1], Nikolaus Troje[2]; [1]Section for Visual Function, Eye Center, Freiburg University, Germany, [2]Queen's University, Kingston, Ontario, Canada

Biological motion is a fascinating phenomenon: Not only can we recognize walking with impoverished information, but also species identity, and in humans mood and sex. We here look at a developmental aspect, namely at which age gender recognition becomes successful. Based on a data set by Troje (2002, J Vision, doi:10.1167/2.5.2), we created three sex-neutral walkers for one task: front, left-walking and right-walking. For another task we created male and female walkers with three different levels of "gender strength". Each stimulus was presented twice in a blocked randomized fashion. Children in the age range 3 to 6 years participated; their parents had been fully acquainted with the study and signed a written agreement. In their kindergarten environment, the children were first familiarized with biological motion using the neutral front walker. When they understood the situation and were ready to participate further, two kinds of tasks were presented: Task 1 was to recognize direction of a point walker (right→left vs. left→right), here called "walking recognition". The second task was to recognize the sex of a point walker ("girl" vs. "boy"), here called "gender recognition". The task outcome could be "non-compliant", "correct" or "incorrect". We found that the youngest age group (2–3 years) reported walking direction at chance level. This rose only slightly for 3–4. Above 4 years of age walking direction was reported correctly. For gender recognition, there was a significant effect of age ($p < 0.01$), but gender was recognized one year later than walking direction. There was no significant effect of "gender strength" for the values we had chosen. Our results suggest: During their kindergarten period, children still develop their biological motion capability; by school age, gender recognition has matured.

Sunday AM

33.4059 How different is Action Recognition across Cultures? Visual Adaptation to Social Actions in Germany vs. Korea
Dong-Seon Chang[1] (dong-seon.chang@tuebingen.mpg.de), Uijong Ju[2], Heinrich Buelthoff[1,2], Stephan de la Rosa[1]; [1]Dept. of Human Perception, Cognition and Action, Max Planck Institute for Biological Cybernetics, 72076 Tübingen, Germany, [2]Dept. of Brain and Cognitive Engineering, Korea University, 136-713 Seoul, Korea

The way we use social actions in everyday life to interact with other people differs across various cultures. Can this cultural specificity of social interactions be already observed in perceptual processes underlying the visual recognition of actions? In the current study, we investigated whether there were any differences in action recognition between Germans and Koreans using a visual adaptation paradigm. German (n=24, male=10, female=14) and Korean (n=24, male=13, female=11) participants first had to recognize and describe four different social actions (handshake, punch, wave, fist-bump) presented as brief movies of point-light-stimuli. The actions handshake, punch and wave are commonly known in both cultures, but fist-bump is largely unknown in Korea. In the subsequent adaptation experiment, participants were repeatedly exposed to each of the four actions as adaptors (40 seconds in the beginning, and 3 times before each trial) in separate experimental blocks. The order of actions was mixed and balanced across all participants. In each experimental block, participants had to categorize ambiguous actions in a 2-Alternatives-Forced-Choice task. The ambiguous test stimuli were created by linearly combining the kinematic patterns of two actions such as a punch and a handshake. We measured to what degree each of the four adaptors biased the perception of the subsequent test stimulus for German and Korean participants. The actions handshake, punch and wave were correctly recognized by both Germans and Koreans, but most Koreans failed to recognize the correct meaning of a fist-bump. However, Germans and Koreans showed a remarkable similarity regarding the relative perceptual biases that the adaptors induced in the perception of the test stimuli. This consistency extended even to the action (fist-bump) which was not accurately recognized by Koreans. These results imply a surprising consistency and robustness of action recognition processes across different cultures.
Acknowledgement: Max Planck Society

33.4060 Recognition of static and dynamic social actions in the visual periphery
Laura Fademrecht[1] (laura.fademrecht@tuebingen.mpg.de), Isabelle Bülthoff[1], Stephan de la Rosa[1]; [1]Max Planck Institute for Biological Cybernetics, Tübingen, Germany

Although actions often appear in the visual periphery, little is known about action recognition outside of the fovea. Our previous results have shown that action recognition of moving life-size human stick figures is surprisingly accurate even in far periphery and declines non-linearly with eccentricity. Here, our aim was (1) to investigate the influence of motion information on action recognition in the periphery by comparing static and dynamic stimuli recognition and (2) to assess whether the observed non-linearity in our previous study was caused by the presence of motion because a linear decline of recognition performance with increasing eccentricity was reported with static presentations of objects and animals (Jebara et al. 2009; Thorpe et al. 2001). In our study, 16 participants saw life-size stick figure avatars that carried out six different social actions (three different greetings and three different aggressive actions). The avatars were shown dynamically and statically on a large screen at different positions in the visual field. In a 2AFC paradigm, participants performed 3 tasks with all actions: (a) They assessed their emotional valence; (b) they categorized each of them as greeting or attack and (c) they identified each of the six actions. We found better recognition performance for dynamic stimuli at all eccentricities. Thus motion information helps recognition in the fovea as well as in far periphery. (2) We observed a non-linear decrease of recognition performance for both static and dynamic stimuli. Power law functions with an exponent of 3.4 and 2.9 described the non-linearity observed for dynamic and static actions respectively. These non-linear functions describe the data significantly better (p=.002) than linear functions and suggest that human actions are processed differently from objects or animals.

33.4061 Neural representations of human interactions
Alon Hafri[1] (ahafri@sas.upenn.edu), John Trueswell[1], Russell Epstein[1]; [1]Department of Psychology, University of Pennsylvania

A fundamental challenge for the visual system is perception of the social world. A key component of social perception is the ability to categorize human interactions based on bodily form and motion, in a manner that is independent of the particular actors involved, the viewpoint, or setting. Here we use fMRI to identify brain regions that represent human interaction categories. We scanned participants with fMRI while they viewed short video clips of two-person interactions (slap, kick, shove, bite, pull, brush, massage, tap). For each action, several factors were crossed: the actors, their roles (Agent, Patient), the direction of action (left-to-right, right-to-left), and the scene (four indoor backgrounds). We focused on several regions of interest that respond to features relevant for distinguishing actions, such as bodies (EBA and FBA), motion (hMT+), and biological motion (pSTS). We also examined activity in early visual cortex (EVC) and the parahippocampal place area (PPA) as control regions. Multivariate pattern analysis revealed that the action category (e.g. kick) could be decoded from activation patterns in EVC, EBA, FBA, hMT+, and pSTS, but not PPA. Representations of actions in these regions were invariant to changes in actors, roles, and scenes, and invariant to action direction in all regions except EVC. Furthermore, a dissociation between action information (EBA, FBA, hMT+, pSTS) and scene information (PPA) was found, consistent with functional specialization of these regions. In contrast, EVC contained information that distinguished the stimuli on many visual dimensions (action, action direction, and scene). Our results reveal that the neural patterns in brain regions previously shown to respond to bodily form and motion contain information that differentiates categories of actions, invariant to visual elements such as the actors, action direction, and setting.

33.4062 Lighting-from-above prior in the perception of biological motion: new illusion and a neural model.
Leonid Fedorov[1] (leonid.fedorov@cin.uni-tuebingen.de), Martin Giese[1]; [1]Computational Sensomotorics Lab, CIN&HIH, Department of Cognitive Neurology, Univ. Clinic Tuebingen, Germany

The perception of 3D static shapes from 2D images is strongly influenced by surface shading cues (Brewster, 1847; Ramachandran, 1988; Yamane, 2008). Most research on biological motion perception has focused on the influences of 2D motion and form cues and binocular disparity, while the influence of surface shading has only rarely been addressed. We discovered a new visual illusion, where the light source direction flips the perceived walking direction, indicating a lighting from above prior in biological motion perception. METHODS: Our experiments builds on a bistable biological motion stimulus that shows a walker from the front (Vanrie, 2004). Instead of dots we used volumetric conic elements placed at the limb centers. The elevation of the light source direction was varied systematically between 180 degrees (above) to 0 degrees (below). Two stimuli were compared that were derived from the same 3D walker walking either towards or away from the observer. Participants had to report the perceived walking direction. In an additional control experiment we investigated the influence of individual features on the illusion, by removing the gradual shading from all limb segments except for selected subsets. RESULTS: The light source position has a strong influence on the perceived walking directions (for walking away: $F(16,176)=178.9, p< 0.01$; towards: $F(16,176)=154.3, p< 0.01$), where illumination from below results in a flip of the perceived walking direction by 180 deg. The control experiment shows that effect is mainly driven by the shading gradients of the forearms and the thighs. CONCLUSION: Similar to the perception of static shapes, biological motion perception depends on a lighting-from-above prior. We were able to reproduce this effect can by extending a neural model for biological motion perception (Giese, 2003) by an additional shading pathway, which analyzes gradual shading variations within surface elements, while suppressing contrast edges at the borders.
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33.4063 Computational Model of Biological Motion Detection: a path toward view-invariant action understanding
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Understanding actions and intentions of others is at the basis of social communication in humans and relies on our ability to associate the view of other's actions to (the view of) our own motor acts. In this work, we focus on the low level, bottom up, detection and segmentation of biological motion, and present a computational model to extract perspective invariant visual features based on known regularities of body motion trajectories. The segmentation approach presented does not require any a-priori

knowledge of the kinematics of the body and relies on rather coarse early visual features. Specifically we focus on features describing an invariant property of biological movements, known as the Two-Thirds Power Law, which relates the instantaneous velocity and local curvature of the trajectory of moving body parts. Starting from video streams acquired during different kind of motions, the algorithm initially computes the optical flow and detects the regions where the motion is occurring by computing a saliency motion map. Then it describes the regions in the visual stream with low-level features corresponding to the computational counterparts of the quantities involved in the Two-Thirds Power Law. Finally, on the basis of these quantities, we demonstrate the validity of this approach in distinguishing biological motion from dynamic events due to non-biological phenomena. The model proposed represents a pre-categorical biological motion segmentation tool exploiting the regularities of human motion to build and tune low-level visual feature extraction which does not require a priori knowledge of the scene and of the kinematics of the body and guarantees view invariance. Hence it is an ideal tool to support the matching between visual information extracted during action execution and action observation at the basis of human ability to understand others' actions.

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33.4064 Biological motion processing under interocular suppression

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Biological motion processing is crucial for survival, social interaction, and communication. Since ecologically important stimuli can be prioritized in visual processing even when they do not reach awareness, we hypothesized biological motion would also receive preferential processing even when rendered unconscious. In three experiments, we used a stereoscope and the breaking continuous flash suppression (CFS) paradigm, where we gradually increased the contrast of masked point light walker (PLW) stimuli, and measured the time (i.e., contrast) at which the stimuli reached awareness. In Experiment 1, PLWs were presented either intact or spatially scrambled, a manipulation that disrupts the coherent form of the stimuli. We found that intact PLWs reached awareness significantly earlier (i.e., at lower contrast) than their scrambled counterparts. In Experiment 2, we added a speed manipulation. We replicated the results of Experiment 1, intact PLWs reaching awareness earlier. We also observed that faster PLWs broke through significantly earlier than slower PLWs, likely driven by differences in motion energy. There was no interaction between PLW coherence and speed. In Experiment 3, investigated whether the characteristics of the CFS mask would modulate the effect. The mask consisted either of rectangular or circular Mondrians (congruent shape with the dots of the PLW). We again found that intact PLWs broke through suppression earlier. There was also a significant main effect of mask type: circular Mondrians led to significantly greater suppression. There was no interaction with mask type and PLW coherence. Overall, we present evidence that biological information is processed below the threshold of awareness. Specifically, we showed (and twice replicated) an effect of PLW coherence: Intact PLWs reach awareness earlier (at lower contrast) compared with spatially scrambled ones. This coherence advantage was maintained across different levels of PLW speed and for both mask types, demonstrating the importance of biological form during unconscious processing.

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33.4066 Visual Tuning for Perceptual Animacy and its Influence on Multiple Object Tracking

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The ability to distinguish animate from inanimate entities arises very early in human development and is fundamental to our understanding of the physical and social worlds. However, two important questions remain unknown: what spatio-temporal properties in the visual stimuli play an essential role in inducing the impression of animacy, and how animacy perception interacts with other visual processes. To address the first question, subjects were asked to provide animacy ratings for moving displays comprised of Gabor disks that varied in terms of spatial frequency (SF), relative orientation, and global movement patterns. Results revealed band-pass tuning curves across these three dimensions. Animacy was highest for elements with intermediate SF (peak at 0.4 cpd), and reduced for low SF's in which the oriented structure was not evident. Elements changed direction randomly over time as determined by a Gaussian distribution, where standard deviation represented the extent of directional changes. Animacy peaked at intermediate levels of directional change (s.d. = 32 deg). Finally orientation was either co-aligned with the element's heading direction or offset to varying degrees. Animacy was highest with co-alignment and decreased monotonically with increasing offsets up to 90 deg. Importantly, these results enable the generation of displays that vary substantially in the degree of perceptual animacy, but that are well-matched in terms of local stimulus properties. To address the second question, we conducted a multiple-object-tracking experiment using the stimuli and parameters derived from the previous experiments. We found that tracking performance was impaired for visual elements with high levels of animacy. This effect was primarily due to interference from animate distracters in the background, presumably because they instinctively pulled attention away from the tracked targets. These results illustrate the spatio-temporal tuning of human vision to perceptual animacy and the tracking results indicate a significant influence of animacy on attentional processes.

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33.4067 Influence of Form and Motion on Biological Motion Prediction

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In natural vision, although moving objects are often partially or fully occluded, we are able to maintain coherent representations of them and their locations. The form of an object can influence judgments regarding its motion path, especially for the case of biological motion (Shiffrar and Freyd, 1990). Moreover, these effects can be dependent on temporal factors such as exposure duration. Here, we used an occlusion paradigm to investigate how the amount of motion information affects predictions of object movements. We were further interested whether these predictions would also be affected by the biologicalness of the object. The object presented was either biological (hand) or non-biological (oval). The pre-occlusion exposure time (prime duration) was either 100, 500, or 1000 ms, followed by a 500 ms occlusion period. When the object reappeared, the motion continued at an earlier frame (-350, -100, -20 ms), at the correct frame, or at a later frame (+20, +100, +350 ms). Participants were asked to judge whether or not the continuation after occlusion was too late. For both object types, there was a significant difference in the psychophysical curves for 100 and 1000 ms prime durations: when very little motion information was available (100 ms) before occlusion, it is harder to make predictions about the movement of the object. For the hand (biological) object only, prediction performance of biological motion trajectories was also significantly different for the 500 and 1000 ms durations. These data suggest that given sufficient time, hence more information, the visual system can be influenced by high-level constraints such as knowledge of how biological objects move in making predictions about object movement. These data are consistent with Bayesian models of cue integration in perception.

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33.4068 Action prediction and the flash-lag effect

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The flash-lag effect, a misperception of spatial relations between a moving object and a briefly flashed object, has been empirically well-established. However, it remains unknown whether high-level visual representations, such as biological motion, influence this illusion. To address this question, observers viewed a biological motion stimulus (a walker shown in a skeleton display). A stationary dot was briefly flashed (33ms) adjacent to a reference joint (either a hand or a foot joint) of the walker. Participants were asked to judge the relative spatial relation between the flashed dot and the reference limb. We found a strong flash-lag illusion for biological motion: observers perceived a lag between the reference limb and the flashed dot even when they were exactly aligned in space and time. Furthermore, when the actor walked in a natural direction (i.e., forward walking), the flash-lag effect was enhanced compared to the effect for a backward walker. This asymmetry suggests that updating future postures for familiar actions plays an important role in perceiving the relative spatial relation between a moving agent and other objects. When the walker was inverted, the flash-lag difference between the forward and backward walking directions was maintained for hand joints. However, when the flashed dot was adjacent to foot joints in an inverted walker, the flash-lag difference between the forward and backward walking directions was eliminated. This result suggests that action prediction may maintain different degrees of precision for different joints, depending on the functional importance of the joints

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for a particular action (e.g., feet are the most critical joints for a walking action, hence prediction of its future location may be more sensitive to the change of the body orientation). Overall, our findings indicate that the flash-lag effect can provide a powerful tool for studying action prediction.

Acknowledgement: NSF BCS-0843880

33.4069 **Motion-based Attention Underlies the Rehearsal of Biological Motion in Working Memory** Zaifeng Gao[1] (zaifengg@gmail.com), Yangfan Zhao[1], Xiqian Lu[1], Mowei Shen[1], Feng Zhang[2]; [1]Department of Psychology, Zhejiang University, China, [2]Department of Psychology, Ningbo University, China

Holding biological motions (BM) - the movements of animate entities, in working memory (WM) is important to our daily social life. Previous studies have documented that there is a specific buffer dedicated to keeping BM in WM. However, no study has explored the attentional mechanism underlying maintaining BM in WM. Considering that it has been suggested that object-based attention underlies the rehearsal of object information (e.g., color) in object WM, we hypothesized that motion-based attention, instead of object-based attention, underlies the rehearsal of BM in WM. Consequently, we required the participants to memorize colors or BM in different blocks. Moreover, we inserted a secondary motion task to consume motion-based attention, or an object-feature-report task to consume object-based attention. We found a significant larger impairment for BM than for colors with a secondary motion task, yet a significant larger impairment for colors than for BM with a secondary an object-feature-report task. Taken together, these results suggest that motion-based attention plays a pivotal role in maintaining BM in WM. (Acknowledgement: This research is supported by the National Natural Science Foundation of China (No. 31271089,31170975))

33.4070 **Representational similarity analysis of fMRI responses in brain areas involved in visual action processing** Burcu Urgen[1] (burgen@cogsci.ucsd.edu), Ayse Saygin[1,2]; [1]Department of Cognitive Science, UC San Diego, [2]Neurosciences Program, UC San Diego

Over the last two decades neurophysiological and neuroimaging studies have identified a network of brain regions in occipito-temporal, parietal, and frontal cortex that are involved in visual processing of actions. What remains unclear are the neural computations and representational properties in each area. In this study, we investigated the representational content of human brain areas in the action observation network using fMRI and representational similarity analysis. Observers were shown video clips of 8 different actions performed by 3 different agents (actors) during fMRI scanning. We then derived two indices from the representational similarity matrices for each region of interest (ROI): Agent decoding index and action decoding index, which reflect the presence of significant agent and action information, respectively. We found significant agent decoding in early visual areas and category sensitive cortical regions including FFA and EBA, as well as in the action observation network. However, agent decoding index varied across ROIs and was strongest in the right posterior superior temporal sulcus (pSTS), and was significantly greater than the indices in ROIs in the parietal and frontal cortex in the right hemisphere. On the other hand, although we found significant action decoding in all visual areas as well as the action observation network, the strength of action decoding was similar across ROIs. However, the representational structure of action types varies across ROIs as revealed by hierarchical clustering, indicating that action-related information changes along the levels of the cortical hierarchy. These results suggest that during visual action processing, pSTS pools information from the early visual areas to compute the identity of the agent, and passes that information to regions in parietal and frontal cortex that code higher-level aspects of actions, consistent with computational models of visual action recognition.

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33.4071 **Assessment of sport specific and non-specific biological motion perception in soccer athletes shows a fundamental perceptual ability advantage over non-athletes for recognising body kinematics** Thomas Romeas[1] (thomas.romeas@umontreal.ca), Jocelyn Faubert[1]; [1]École d'optométrie, Université de Montréal

With continuous exposure to situations, events or action patterns, we can achieve superior levels of performance. An effective example that highlights this expertise can be described in athletics (sports). A number of studies report perceptual-cognitive expertise in athletes. Interestingly, recent studies have shown that athletes' domain specific expertise can transfer to everyday tasks such as processing socially realistic multitasking crowd scenes, which involve pedestrians crossing a street or processing complex and dynamic visual scenes. In this study we assessed the perceptual-cognitive expertise of athletes and non-athletes using sport specific and non-specific biological motion perception tasks. Using a virtual environment (EON IcubeTM), forty one university-level soccer players and nineteen non-athletes were asked to perceive the direction of a point-light walker and to predict the trajectory of a masked-ball during a point-light soccer kick. Angles of presentation were varied for orientation (upright, inverted) and distance (2m, 4m, 16m). Correct response (%) and reaction time (s) were measured to assess observers' performance. The two tasks revealed distinct level of performance in both groups ($p < 0.001$). Response accuracy ($p < 0.001$) and reaction time ($p=0.002$ for point-light walker only) varied according to the angle of presentation (task difficulty). Varying difficulty throughout biological motion highlighted athletes' superior ability compare to non-athletes to accurately predict the trajectory of a masked soccer ball during the point-light soccer kick task ($p=0.003$ accuracy; $p=0.961$ reaction time). As expected, athletes performed better throughout the domain-specific task (soccer) but more surprisingly, they also displayed greater performance in accuracy ($p=0.002$) and reaction time ($p=0.057$) than non-athletes throughout the more fundamental and general point-light walker direction task. Athletes seemed to demonstrate a general fundamental perceptual-cognitive expertise for biological motion perception.

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33.4072 **Dependence of the perception of emotional body movements on concurrent social motor behavior** Nick Taubert[1,2] (nick.taubert@uni-tuebingen.de), Junru Li[1,2], Dominik Endres[3], Martin Giese[2]; [1]Equal Contribution, [2]Section for Computational Sensomotorics, Dept. for Cognitive Neurology, Hertie Institute for Clinical Brain Research & Centre for Integrative Neurocience, University Clinic Tuebingen , [3]Theoretical Neuroscience, Department of Psychology, Philipps-Universität Marburg

Embodiment theories hypothesize that the perception of emotions from body movements involves an activation of brain structures that are involved in motor execution during social interaction [1,2]. This predicts that, for identical visual stimulation, bodily emotions should be perceived as more expressive when the observers are involved in social motor behavior. We tested this hypothesis, exploiting advanced VR technology, requiring participants to judge the emotions of an avatar that reacted to their own motor behavior. METHODS: Based on motion capture data from four human actors, we learned generative models for the body motion during emotional pair interactions, exploiting a framework based on Gaussian Process Latent Variable Models [3]. Using a head mounted display, participants observed ten angry and ten fearful emotional reactions, each with eight repetitions, of a human-sized virtual agent, who turned towards the subject after being tipped on the shoulder. As control conditions, participants watched exactly the same stimuli without doing any movements. The emotion information of the avatars was controlled using a motion morphing method based on the GP model, using 5 emotional strength levels, which were carefully adjusted based on a pre-experiment for each emotion and actor. Participants had to rate the emotional expressiveness of the stimuli on a Likert scale. RESULTS: Initial data indicates that emotional expressiveness of the stimuli was rated higher when the participants initiate the emotional reaction of the avatar in the VR setup by their own behavior, as compared to pure observation ($F > 6.2$ and $p < 0.03$). This confirms an involvement of representations for the execution of social interactive behaviors in the processing of emotional body expressions, consistent with embodiment theories. [1] Wolpert et al., Science 269, 1995. [2] Wicker et al., Neuropsychologia 41, 2003. [3] Lawrence, ND, Advances in neural information processing, 2004.

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33.4073 **Structural and dynamic factors of female physical attractiveness** Slobodan Markovic[1] (smarkovi@f.bg.ac.rs), Tara Bulut[1]; [1]Laboratory of Experimental Psychology, Department of Psychology, University of Belgrade, Serbia

Judgments of female body attractiveness can be based on both structural and dynamic information. Structural information is specified by sizes of crucial female body characteristics, such as waist-to-hip ratio (WHR), breasts and buttocks: the lower the WHR and the larger the breasts and buttocks, the higher the femininity level. Dynamic information is specified as either implicit dynamics, such as pose, or explicit dynamics, such as walk. The purpose of the present experiment was to investigate

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the effects of both structural and dynamic factors on the judgments of female body attractiveness. Stimuli were generated using the DAZ 3D program for computer animation. In two sessions twenty-five male participants rated the attractiveness of figures with five levels of femininity in a beautiful, a neutral and an ugly pose (session 1) or walk (session 2). Five female figures, poses and walks were specified in preliminary experiments. The main effect of femininity level was significant: post hoc tests indicated that the third (medium) and the forth femininity levels were most attractive, the fifth (highest) and the second femininity levels were less attractive and the first (lowest) femininity level was least attractive. The main effect of pose/walk was obtained as well: post hoc tests indicated that attractiveness increased in an expected way, i.e. ugly-neutral-beautiful pose/walk. However, interactions and post hoc tests indicated that the effects of pose/walk are largest for most attractive figures (medium and higher femininity levels) and then they decrease in both directions (towards highest and lowest femininity levels). In case of the least feminine figure factors pose/walk had no effects on attractiveness at all. These results suggest that beautiful and ugly poses/walks are effective (positively or negatively, respectively) for the attractive figures, whereas they don't change the judgments of the least attractive (least feminine) figure.

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Scene Perception: Neural mechanisms

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

33.4074 Scene-Space Encoding within the Functional Scene-Selective Network

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High-level visual neuroscience has often focused on how different visual categories are encoded in the brain. For example, we know how the brain responds when viewing scenes as compared to faces or other objects – three regions are consistently engaged: the parahippocampal/lingual region (PPA), the retrosplenial complex (RSC), and the occipital place area/transverse occipital sulcus (TOS). Here we explore the fine-grained responses of these three regions when viewing 100 different scenes. We asked: 1) Can neural signals differentiate the 100 exemplars? 2) Are the PPA, RSC, and TOS strongly activated by the same exemplars and, more generally, are the "scene-spaces" representing how scenes are encoded in these regions similar? In an fMRI study of 100 scenes we found that the scenes eliciting the greatest BOLD signal were largely the same across the PPA, RSC, and TOS. Remarkably, the orderings, from strongest to weakest, of scenes were highly correlated across all three regions (r = .82), but were only moderately correlated with non-scene selective brain regions (r = .30). The high similarity across scene-selective regions suggests that a reliable and distinguishable feature space encodes visual scenes. To better understand the potential feature space, we compared the neural scene-space to scene-spaces defined by either several different computer vision models or behavioral measures of scene similarity. Computer vision models that rely on more complex, mid- to high-level visual features best accounted for the pattern of BOLD signal in scene-selective regions and, interestingly, the better-performing models exceeded the performance of our behavioral measures. These results suggest a division of labor where the representations within the PPA and TOS focus on visual statistical regularities within scenes, whereas the representations within the RSC focus on a more high-level representation of scene category. Moreover, the data suggest the PPA mediates between the processing of the TOS and RSC.

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33.4075 Using voxel-wise encoding models to study occipito-temporal representations of the animacy, semantic and affective content of natural images.

Samy Abdel-Ghaffar[1] (samyag1@berkeley.edu), Jack Gallant[1,2,3], Alex Huth[2], Dustin Stansbury[3], Alan Cowen[1], Sonia Bishop[1,2,3]; [1]Department Psychology, UC Berkeley, [2]HWNI Neuroscience Institute, UC Berkeley, [3]Program in Vision Science, UC Berkeley

It has been argued that animate emotional stimuli are biologically prepared. That is, as a result of evolutionary significance, they are processed rapidly, tend to capture attention and are better recalled. Here, we tested the prediction that we may have especially distinct representations of these stimuli. We investigated this by performing voxel-wise modeling on functional magnetic resonance imaging (fMRI) data acquired while participants (n=6) viewed natural images of varying semantic and affective content. Thirty fMRI runs of 7.5min duration (1440 images, each shown twice) per participant were used to estimate voxel-wise models. Twenty fMRI runs of 6min duration (180 images, each repeated 9 times) were used to validate the models and test prediction accuracy. Models coding for animacy, semantic content and the interaction of these features with image valence (negative, neutral, positive) were fit to the estimation data using a regularized ridge regression procedure. This resulted in sets of weights that described how the features in each model influenced Blood Oxygen Level Dependent (BOLD) activity in each voxel, for each individual participant. OT cortex was selected as a focus of investigation given its known semantic selectivity and role in object and scene recognition. Our results indicated that the valence of animate, but not inanimate, stimuli is represented in single voxels within OT cortex. This held even when animate and inanimate images were subdivided down into specific semantic classes (e.g. insects, mammals, human faces etc. versus household objects, indoor buildings etc.) Differentiation of the representation of animate stimuli as a function of affective valence within OT cortex might facilitate recognition and subsequent processing (e.g. action selection, encoding into long-term memory) of stimuli of biological relevance.

33.4076 Neural coding of navigational affordances in the local visual environment

Michael Bonner[1] (michafra@mail.med.upenn.edu), Jack Ryan[1], Russell Epstein[1]; [1]Department of Psychology, University of Pennsylvania

An essential component of visually guided navigation is the ability to perceive features of the environment that afford or constrain movement. For example, in indoor environments, walls limit one's potential routes, while passageways facilitate movement. Here we attempt to identify the cortical mechanisms that encode such navigational features. Specifically, we test the hypothesis that scene-selective regions of the human brain represent navigational affordances in visual scenes. In an fMRI experiment, subjects viewed images of artificially rendered rooms that had identical geometry as defined by their walls, but varied on the number (one to three) and position (left, right, center) of spatial passageways (i.e., open doorways) connected to them. Thus, the layout of these passageways defined the navigable space in each scene. Several versions of each layout were shown, each with the same set of passageways but different textures on the walls and floors. Furthermore, half the rooms were empty except for the walls and passageways, while the other half included visual clutter in the form of paintings along the walls, which were similar in size and shape to the passageways. Images were presented for 2 seconds while subjects maintained central fixation and performed an unrelated color-discrimination task on two dots overlaid on each scene. Using multivoxel-pattern analysis, we sought to identify representations of navigational layout that were invariant to other visual properties of the images. This analysis revealed consistent and invariant coding of navigational layout in the occipital place area (OPA), a scene-selective region near the transverse occipital sulcus. In this region, scenes elicited similar activation patterns if they had similar navigational layout, independent of changes in texture or the presence of visual clutter (i.e., paintings on the walls). These findings suggest that the OPA encodes representations of navigational affordances that could be used to guide movement through local space.

33.4077 Rectilinearity is insufficient to explain category selectivity of the parahippocampal place area

Peter Bryan[1] (pbryan@sas.upenn.edu), Joshua Julian[1], Russell Epstein[1]; [1]Department of Psychology, University of Pennsylvania

Neuroimaging studies have revealed strong selectivity for scenes in the parahippocampal place area (PPA). However, the mechanism of this selectivity remains unknown. One possibility is that scene-selectivity reflects tuning for particular low-level stimulus features characteristic of scenes but not other non-preferred categories. Supporting this view, Nasr and colleagues (2014) recently observed that stimuli that were shown to strongly activate the PPA in previous studies tended to contain more rectilinear edges than non-preferred stimuli. Moreover, they demonstrated that PPA response is modulated by rectilinearlity for a range of non-scene images. Motivated by these results, we tested whether rectilinearity suffices to completely explain PPA selectivity to scenes. We scanned participants with fMRI while they viewed grayscale photographs of natural scenes and faces matched on rectilinearity, presented in a block design. To equate scene and face rectilinearity, 940 scene and face images were ranked according to their relative rectilinearity, and stimuli (52 unique images per category) were then drawn from this

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set so that average rectilinearity was matched across categories. Faces and scene categories were also matched on a number of other low-level image properties, including mean high spatial frequency content, luminance, and contrast. Despite matched rectilinearity, we found that the PPA – as well as the other scene-selective regions, the retrosplenial complex (RSC) and occipital place area (OPA) – still exhibited a significantly higher response to scenes than faces. Thus, the preference for low-level rectilinear edges does not suffice to completely explain selectivity for scenes in the PPA.

33.4078 **The representation of texture information in the parahippocampal place area** Jeongho Park[1] (jpark203@jhu.edu), Soojin Park[1]; [1]Cognitive Science Department, Johns Hopkins University

Recent studies suggest that the parahippocampal place area (PPA) responds to a broad spectrum of objects and scenes: big objects (Konkle & Oliva, 2011; Troiani et al., 2012), line drawings (Walther et al., 2011), and texture patches (Komblith et al., 2013; Cant & Goodale, 2011; Cant & Xu, 2012). Here, we test two hypotheses about texture representation in the PPA within the scene context. One hypothesis is that the PPA represents the texture ensemble (e.g., the kind of texture) as is, irrespective of the scene context. Another hypothesis is that the PPA represents the texture because it provides an important cue about the placeness of a scene. In the latter case, the PPA would be sensitive to not only the texture ensemble but also the location of texture within a scene (e.g., ceiling or wall) that can change the placeness perception. In Experiment 1 (n=11), participants saw images of synthetic rooms varied by 2 different textures x 2 texture location x 2 spatial layout. Using multi-voxel pattern analysis (MVPA) and a regression with two hypothetical models, we found that the representation-similarity of the PPA activation patterns was explained by the change in texture ensemble but not by the change in placeness (p=0.015). In Experiment 2 (n=6) we asked the same question using the repetition suppression method. In contrast to MVPA results, two scenes with the same texture ensemble but different placeness did not show repetition suppression, suggesting PPA's sensitivity to the change in placeness perception. These results add to growing evidence in the field showing contrasting results from MVPA and repetition suppression methods (Drucker & Aguirre, 2009; Epstein & Morgan, 2011). We'll also discuss the results of other scene-selective areas (e.g., RSC and OPA) and the possibility of the PPA representing the texture in a scene in a hierarchical manner.

33.4079 **The Occipital Place Area is causally involved in representing environmental boundaries during navigation** Joshua Julian[1] (jjulian@sas.upenn.edu), Jack Ryan[1], Roy Hamilton[2], Russell Epstein[1]; [1]Department of Psychology, University of Pennsylvania, [2]Department of Neurology, University of Pennsylvania

Previous work indicates that learning of spatial locations relative to environmental boundaries and the learning of spatial locations relative to discrete landmarks are dissociable processes supported by different neural systems (Wang & Spelke, 2002; Doeller & Burgess, 2008). However, the perceptual systems that provide the inputs to these learning mechanisms are not well understood. We hypothesized that the Occipital Place Area (OPA), a scene-selective region located near the transverse occipital sulcus, might play a critical role in boundary-based learning, by extracting boundary information from visual scenes during navigation. To test this idea, we used transcranial magnetic stimulation (TMS) to interrupt processing in the OPA while subjects performed a virtual navigation task that required them to learn locations of test objects relative to boundaries and landmarks. The environment consisted of a circular chamber, which was limited by a boundary wall, contained a rotationally symmetric landmark object, and was surrounded by distal cues for orientation (mountains, rendered at infinity). The relative position of the landmark and boundary changed across testing blocks. Test objects were tethered to either the landmark or the boundary, thus allowing learning of object location relative to each cue to be independently assessed. Prior to each block, transcranial magnetic continuous theta burst stimulation (cTBS) was applied to either the functionally-defined right OPA or a Vertex control site. Consistent with our prediction, we found that cTBS to the OPA impaired learning of object locations relative to boundaries, but not relative to landmarks. These results provide the first evidence that OPA is causally involved in visually-guided navigation. Moreover, they indicate that the OPA is essential for the coding of environmental boundary information.

33.4080 **Cortical predictions interact with post-saccadic input to primary visual cortex** Grace Edwards[1] (g.edwards.2@research.gla.ac.uk), Luca Vizioli[1], Lars Muckli[1]; [1]Institute of Neuroscience & Psychology, University of Glasgow

Sensory input and internal models combine to generate perception of the world. In vision, internal models can influence processing of feedforward sensory input in the primary visual cortex (V1) through cortical feedback. Whether such cortical feedback is retinotopically specific is still a matter of debate. Here we simultaneously recorded BOLD signal and eye-movements to study the spatial precision of cortical feedback in V1 during saccades. Subjects were shown images of natural scenes and instructed to execute a saccade across visual hemi-fields. During the saccade, the scene stimuli remained the same, changed, or disappeared. Retinotopic localizers were used to identify the processing region in V1 following the saccade. We trained support vector machines (SVM) on one-second time-windows at the post-saccade processing region to assess the extent of feedback related to the pre-saccadic scene. Integration of the relocated feedback and the post-saccadic feedforward signals was expected to affect SVM performance. After eye-movement, we observed lower SVM accuracy to scenes that changed across saccades in comparison to scenes that remained the same. These results suggest an interference of the feedback for the expected post-saccadic content with the processing of the newly presented scene. The decrease in SVM accuracy co-occurred with a univariate increase in BOLD activity at the post-saccadic region, indicative of a predictive coding error signal (Alink et al., 2010; Kok et al., 2012). Classification analysis did not reveal feedback to new retinotopic regions when the scene disappeared with the saccade. We suggest that a post-saccadic reference frame is necessary to support the remapped feedback in V1 across saccades. Our results demonstrate that with each saccade cortical feedback projects to the new relevant retinotopic regions to integrate the expected content with new sensory information. An interaction of predictive coding, saccadic remapping, and visual attention is likely to account for feedback relocation.

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33.4081 **The occipital place area represents the local elements of scenes** Frederik Kamps[1] (fkamps@emory.edu), Joshua Julian[2], Jonas Kubilius[3], Nancy Kanwisher[4], Daniel Dilks[1]; [1]Emory University, [2]University of Pennsylvania, [3]KU Leuven, [4]Massachusetts Institute of Technology

Behavioral and computational research has proposed that a scene (e.g., a kitchen) can be represented by two independent, yet complementary descriptors: i) its spatial boundary (i.e., the external shape, size, and scope of the space the scene represents) and ii) its content (i.e., the internal elements encompassing objects, textures, colors, and materials). But how does the brain represent these descriptors? A central hypothesis is that one scene-selective cortical region (parahippocampal place area – PPA) represents both spatial boundary and content information, while a second region (retrosplenial complex – RSC) represents spatial boundary only. Such representation for a third scene-selective region (occipital place area – OPA) has never been tested. To test spatial boundary representation, we compared responses to images of intact rooms with images of these same rooms when their walls, floors, and ceilings had been fractured and rearranged, such that they no longer defined a coherent space. We found OPA, unlike PPA and RSC, responded similarly to both the intact and fractured rooms, suggesting OPA does not represent spatial boundary per se, but rather the local elements (i.e., walls, floors, ceilings) composing the space, independent of their spatial arrangement. To test content representation, we compared responses to images of furniture with non-furniture objects. We found OPA, like PPA, responded more to furniture than non-furniture objects. Interestingly, however, while both OPA and PPA represent content information, they do so differently; in another test, we found only OPA was sensitive to the number of pieces of furniture, suggesting OPA represents the local elements of scene content, while PPA represents the global aspects of scene content, independent of the number of objects present. Taken together, our results suggest OPA analyzes local scene elements – both in spatial boundary and content representation – while PPA and RSC represent global scene properties.

33.4082 **Texture and Spatial Layout Converge in Human Scene-Selective Cortex** Matthew Lowe[1,2] (matthew.lowe@mail.utoronto.ca), Susanne Ferber[2,3], Jonathan Cant[1]; [1]Department of Psychology, University of Toronto Scarborough, [2]Department of Psychology, University of Toronto, [3]Rotman Research Institute, Baycrest

Scenes are composed of multiple visual features, yet previous research investigating scene representation has often focused on the unique contributions of single features, such as spatial layout and texture. However, these features rarely exist in isolation. As texture can provide depth and contour information necessary for spatial perception, a dynamic and convergent relationship may exist between texture and spatial layout. Yet it

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has been unclear how this relationship would manifest in scene-selective cortex. Since texture is typically more diagnostic of place identity in natural compared with non-natural scenes, and spatial layout is typically less ambiguous in non-natural compared with natural scenes, we tested the hypothesis that PPA would show equal sensitivity to manipulations of texture and spatial layout in natural scenes, but would show greater sensitivity to layout in non-natural scenes. Using fMRI, we examined brain activity in areas of scene-selective cortex while participants performed a matching task when attending to either the layout or texture of four different scene categories which varied by spatial boundary (open vs. closed) and content (natural vs. non-natural). As predicted, univariate analysis in PPA revealed equal sensitivity to texture and layout in natural scenes, but less sensitivity to texture in non-natural scenes. Importantly, multivariate analyses revealed decoding accuracy significantly above chance in PPA for both spatial boundary (only in non-natural scenes, which is consistent with our univariate results) and content, replicating previous studies and validating the use of our stimulus set. Our findings demonstrate that scene representation in PPA is not based solely on spatial structure, and may be driven by interactions between diagnostic visual features such as texture and spatial layout. Therefore, we propose extending the study of scene perception to not only investigate which individual features are represented in scene-selective cortex, but how these features converge to define place identity.

33.4083 **Retinotopically occluded subsections of early visual cortex contain contextual information about individual scenes, category and depth.** Andrew Morgan[1] (a.morgan.1@research.gla.ac.uk), Lucy Petro[1], Luca Vizioli[1], Lars Muckli[1]; [1]Centre for Cognitive Neuroimaging, Institute of Neuroscience & Psychology, University of Glasgow

Introduction Activity in early visual cortex contains information about context, even in the absence of meaningful feedforward input (Smith & Muckli, 2010; Vetter, et al. 2014). To explain these contextual effects, previous work suggests that other brain areas predict sensory input, and that predictions are transmitted to early visual areas via dynamic and diffuse feedback. Here, we aimed to enhance our knowledge regarding the level of detail in feedback representations, which may depict scene-specific features (Naselaris, et al. 2014), or conversely, may be categorical, which has been observed when context was provided by auditory stimulation (Vetter, et al. 2014). To adjudicate these possibilities, we examined whether activity patterns in occluded portions of early visual cortex are sufficient for discriminating individual scenes, or if the absence of feedforward input reveals categorical scene groupings. Methods We blocked feedforward input to subsections of retinotopic visual cortex (Smith and Muckli, 2010) while participants viewed 24 real-world scenes. Scenes spanned multiple categories and spatial depths, two higher-level characteristics previously studied in early visual cortex (Walther, et al. 2009; Kravitz, et al. 2011). This allowed us to examine possible groupings in feedback representations. We investigated the information content of response patterns in occluded subsections of V1 and V2 using functional magnetic resonance imaging and multi-voxel pattern analyses. Results & Conclusions Category, depth, and individual scenes can all be decoded from occluded portions of early visual cortex. Scene decoding errors were uniformly distributed amongst scenes rather than being concentrated within category- or depth-based groupings. These results indicate that non-feedforward processing in early visual cortex is specific to individual scenes and retains high-level structure when context is generated in the visual domain, as would be expected by filling-in of visual information by feedback.

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33.4084 **Measuring the precision of feedback fields in V1 using 3T and 7T fMRI** Lucy Petro[1] (lucyp@psy.gla.ac.uk), Fraser Smith [2], Jan Zimmermann[3], Federico De Martino[4], Lars Muckli [1]; [1]Centre for Cognitive Neuroimaging, Institute of Neuroscience and Psychology, University of Glasgow, Glasgow, United Kingdom, [2]School of Psychology, University of East Anglia, United Kingdom, [3]Center for Neural Science, New York University New York, New York, United States, [4]Maastricht Brain Imaging Center, Maastricht University, Maastricht, The Netherlands

The receptive fields of V1 neurons are driven by sensory input. V1 neurons are also modulated by cortical feedback, and this can be conceptualised as neuronal "feedback fields". Feedback fields can be investigated in human V1 by performing multivoxel pattern analyses on voxels that respond to an occluded portion of a visual scene. We investigated the spatial precision of feedback to V1 using 3T and 7T functional magnetic resonance imaging. Images were presented to 27 (3T) and 4 (7T) subjects with the lower right quadrant occluded (Smith & Muckli 2010) and at three different spatially-shifted versions (selected from 2, 3, 4, 6, 7, 8 degrees). Multivoxel patterns were extracted from the non-stimulated cortex (i.e. receiving feedback) and entered into a classifier analysis. We tested the precision of feedback by training the classifier on images presented at 0 degrees and testing on the same two scenes but shifted by e.g. 2 degrees. The 3T data revealed that the non-stimulated portion of V1 was able to discriminate the surrounding visual context even when shifted by 4 degrees. The 7T data corroborated that we are measuring the precision of feedback, as cross-classification was only possible in layers of V1 that receive feedback, i.e. supragrangular layers. To conclude, cross-classification across spatially-shifted images was significant only in outer layers of cortex, where feedback enters V1. Furthermore, classifier performance decreased to chance level as the spatial shift increased above 4 degrees. This result is suggestive of contextual feedback to V1 from a mid-level visual area such as V4, which has receptive fields large enough to capture similar image features despite their shifting location in the visual field.

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33.4085 **The neural basis of intuitive physical reasoning** Jason Fischer[1] (jason_f@mit.edu), Nancy Kanwisher[1]; [1]Department of Brain and Cognitive Sciences and McGovern Institute for Brain Research, Massachusetts Institute of Technology

Visual scene understanding entails not just determining which people and objects are present in which locations, but also grasping the causal structure of a scene. We "see" that a table supports an object, that a stack of dishes is unstable and may fall, that a squash ball is on a trajectory to ricochet off the wall and head in our direction. Physical reasoning is ubiquitous in daily life. Yet despite the rich literature on the development of physical intuitions during childhood, and evidence that adults can predict in detail how physical events will unfold, little is known about the neural mechanisms that allow us to perceive physical events in a scene and predict what will happen next. Here we sought to identify the brain regions recruited by seeing and reasoning about physical events, and to test how reliably such regions are engaged across a variety of stimuli and tasks that vary in physical content. In a series of fMRI experiments, we uncovered a network of brain regions in parietal and premotor cortices that is engaged both by observing physical events and predicting their future outcomes. Responses in this network are modulated by task (performing a physical prediction as opposed to a non-physical visual judgment on identical stimuli), but are also reliably elicited by passively viewing physical events unfold such as objects rolling, falling, or colliding. Control experiments demonstrated that the pattern of responses in this network cannot be explained by task difficulty, non-physical spatial processing, or the recruitment of domain-general prediction mechanisms. Collectively, our experiments reveal a set of brain regions that may support our ability to perceive and understand physical events from visual input, and lay the groundwork for discovering the neural processes by which we predict how objects in the real world will behave.

33.4086 **Differential representation of length and angle information across scene-selective cortex** Andrew Persichetti[1] (apersic@emory.edu), Moira Dillon[2], Elizabeth Spelke[2], Daniel Dilks[1]; [1]Psychology Department, Emory University, [2]Psychology Department, Harvard University

Neuroimaging studies in human adults have identified three cortical regions involved in scene processing: the parahippocampal place area (PPA), the retrosplenial complex (RSC), and the occipital place area (OPA). While the precise function each of these regions plays in scene processing is unclear, results from several studies suggest that scene processing may be divided into two distinct neural pathways: one for "active" navigation, including RSC and OPA; and the other for recognizing scene categories (e.g., "bedroom," "playground," "desert"), including PPA. Indeed, two recent experiments demonstrated that while RSC and OPA encode both direction (left/right) and egocentric distance (near/far) information – information crucial for navigation – the PPA does not, challenging its role in navigation. Furthermore, behavioral research has shown that human children and non-human animals rely more on direction and distance information during navigation tasks, but use length and angle information during object recognition tasks. Although length and angle information may not directly support navigation, they nevertheless define a scene's overall shape and configuration of the extended surface boundaries and may thus be used for recognizing scene categories. We hypothesize then that PPA, if part of the scene categorization stream, will encode length and angle information in scenes. To test our prediction, we used fMRI adaptation in human adults to measure the sensitivity to changes in length and angle information in scenes in each of the three scene-selective regions. We found sensitivity to both length and angle in PPA and OPA, but not in RSC, supporting the hypothesis that PPA is involved in the recognition of scene category, but not in navigation.

33.4087 **Neural decoding of architectural styles from scene-specific brain regions** Heeyoung Choo[1] (heeyoung.choo@utoronto.ca), Bardia Nikrahei[2], Jack Nasar[2], Dirk Walther[1]; [1]Department of Psychology, University of Toronto, [2]Department of City and Regional Planning, The Ohio State University

The human visual cortex can elicit neural activity patterns that are distinctive for basic-level scene categories (e.g., highways) as well as for superordinate level scene categories (e.g., man-made). Can the human brain also elicit category-specific neural activity patterns for scenes at a subordinate level? Using functional magnetic resonance imaging (fMRI) we recorded brain activity of participants viewing scene categories at a basic level - mountains, pastures, highways, and playgrounds, and scene categories at a subordinate level - buildings in byzantine, renaissance, modern, and deconstructive architectural styles, and buildings designed by four well-known architects of which categorization is likely to be guided more by participants' knowledge than coherent perceptual structure in buildings. Using multi-voxel pattern analysis, we could decode viewed buildings of different architectural styles significantly better than chance from the parahippocampal place area (PPA), retrosplenial cortex (RSC), occipital place area (OPA), lateral occipital complex (LOC). Decoding of buildings by different architects was also successful in the PPA and OPA. Consistent with previous findings, we could successfully decode viewed scene categories. Comparison of error pattern between a simple V1 model and decoding from fMRI data showed that categorical information about architectural styles in the PPA cannot be explained solely by high low-level visual similarity. On the other hand, our simple V1 model was able to discriminate between buildings by different architects to some extent. Our results suggest that the PPA can maintain categorical representation at multiple levels, including subordinate categories, such as architectural styles of buildings, relying on complex structural characteristics of scenes rather than low-level visual similarity. Top-down influences such as domain knowledge or geographical familiarity may thus capitalize on these fine-grained categorical activation patterns in the PPA.

Perceptual Organization: Shapes and objects 1

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

33.4088 **Mechanisms of Spatiotemporal Boundary Formation** Gennady Erlikhman[1] (gennaer@gmail.com), Philip Kellman[1]; [1]Department of Psychology, University of California, Los Angeles

Spatiotemporal boundary formation (SBF) is the perception of illusory boundaries, global form, and global motion from sequential transformations of sparse elements (Shipley & Kellman, 1993, 1994, 1997). SBF may involve two stages: 1) Local oriented edge fragments are recovered from small sets of transformations, and 2) These fragments connect across gaps via well-known contour interpolation processes. Progress in understanding the mechanisms of SBF has been hampered by the lack of a suitable paradigm that isolates the first stage. We created a novel display consisting of a saw-tooth pattern of dots that disappeared and reappeared sequentially. At long ISIs, perception was of a single dot moving along the saw-tooth. With shorter ISIs, however, the percept switched to that of a moving illusory bar that occluded the elements. Two experiments used converging subjective and objective methods to determine the conditions for perceiving the bar. In Experiment 1, subjects rated illusory bar clarity for various inter-element distances and ISIs. In Experiment 2, subjects chose the width of the bar seen from a set of different widths. True width was determined by calculating the width that would produce the timing of disappearances and reappearances. Subjective contour ratings in Exp. 1 predicted objective performance in Exp. 2. Under conditions that gave low clarity ratings, subjects were unable to accurately determine bar width (slope of linear fit =0.065, R2=0.518). Under conditions that supported perceived contours (ISIs ≤ 80 ms and for inter-element distances up to 1 deg) bar width was judged relatively accurately and scaled linearly with true width (slope=0.75, R2=0.997). We provide the first empirical support for local recovery of oriented edge fragments in SBF. We conjecture that this stage in SBF may engage classical motion-energy filters, which, when edge orientation is not given by oriented contrast, function in unsuspected ways as spatiotemporal edge detectors.

33.4089 **Psychophysical evaluation of planar shape representations for object recognition** Ingo Fründ[1] (mail@ingofruend.net), James Elder[1]; [1]Center for Vision Research, York University, Toronto, ON, Canada

Intermediate areas of the object pathway appear to represent shape in terms of features of moderate complexity, however the precise nature of this distributed code remains unclear. Here we use a novel method to evaluate the efficiency with which three candidate representations (Fourier Descriptors, Shapelets and Formlets) capture the planar shape information required for humans to reliably recognize objects. The Fourier Descriptor representation is the Fourier transform of the points defining the object boundary, represented as complex numbers; a good approximation to a shape is attained by truncating this Fourier sequence. Shapelets are a wavelet version of Fourier Descriptors, where each component is localized in both frequency and position along the curve, and these are computed by matching pursuit. Formlets represent shape as a series of smooth localized deformations applied to an embryonic shape (an ellipse in our case), also computed using matching pursuit. We employed a database of 77 animal shapes from 11 categories. In objective terms (Euclidean error), these shapes are most efficiently coded by Shapelets, followed by Fourier Descriptors, and finally Formlets. To evaluate subjective efficiency, shapes were rendered using each of these three representations; the observer's task was to identify the category of each shape from four alternatives. For each representation, the number of shape components ranged from 1 to 10; a representation that reaches subjective threshold with fewer components may be closer to the code employed by the human visual system. For all 6 observers, Shapelets were found to have lowest threshold (mean of 1.8±0.4 components), followed by Fourier Descriptors (4.0±0.4 components), and finally Formlets (5.5±0.6 components). Interestingly, however, both Shapelets and Formlets reach subjective thresholds at a higher mean objective error than Fourier Descriptors, suggesting that the human visual system relies upon localized basis functions for shape representation.
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33.4090 **The role of color in mirror-symmetry perception** Elena Gheorghiu[1] (elena.gheorghiu@stir.ac.uk), Frederick Kingdom[2], Aaron Remkes[1], Hyung-Chul Li[3], Stéphane Rainville[4]; [1]University of Stirling, Department of Psychology, Stirling, FK9 4LA, Scotland, United Kingdom, [2]McGill Vision Research, Department of Ophthalmology, McGill University, Montreal, Canada, [3]Kwangwoon University, Department of Industrial Psychology, Seoul, Korea, [4]VizirLabs Consulting, Chelsea, Qc, Canada

Aim: The role of color in mirror-symmetry perception is controversial: while some reports indicate that mirror-symmetry is color selective, others suggest that symmetry is merely sensitive to color correlations. Here we test between the two ideas as well as examine the role of attention in color-based symmetry perception. Method: Stimuli consisted of a fixed number of colored Gaussian blobs arranged either mirror-symmetrically or randomly. Stimuli contained either two (red, green), three (red, green, blue) or four (red, green, blue, yellow) colors, with respectively 50%, 33% and 25% blobs arranged symmetrically in the symmetric condition, the remaining blobs being randomly positioned and drawn equally from the remaining colors. Stimulus conditions were: (1) 'segregated' – symmetric blobs were just one color that was the same throughout the session; (2) 'random-segregated' – symmetric blobs were just one color, but the color was randomly selected on each trial; (3) 'non-segregated' – symmetric blobs were of all colors and in equal proportions; (4) 'anti-symmetric' – symmetric blobs were of opposite color across the symmetry axis. Perceptual conditions were: (1) the observer knew beforehand the color of the symmetric blobs in the segregated condition and was required to attend to that color; (2) the observer did not know the symmetry color and no attention was required. Results: We found: (a) no significant superiority in performance between the random-segregated and non-segregated conditions, giving no support to the idea that mirror-symmetry is color selective; (b) highest performance in the attention-to-segregated condition, suggesting that symmetry perception can benefit from color-based attention, and (c) near-chance levels for the anti-symmetric condition, suggesting that symmetry perception is sensitive to color correlations. Conclusion: Mirror-symmetry detection mechanisms, while sensitive to color correlations and subject to the benefits of attention-to-color, are not color selective.

33.4091 **Apparent Motion of Negative Parts** E.J. Green[1,2,4] (ej.green.philos@gmail.com), Manish Singh[1,3,4], Jacob Feldman[1,3,4]; [1]Rutgers University, [2]Department of Philosophy, [3]Department of Psychology, [4]Center for Cognitive Science

In this study we investigated the conditions under which the visual system treats negative parts as objects. A negative part is a background region mostly surrounded by a region of negative curvature along a figure's contour. Previous work has shown that negative parts can take on a "quasi-figural" status, inducing globally inconsistent judgments of border ownership (Kim & Feldman, 2009). The degree to which a negative part is treated as figural depends on its geometry, including its depth and the narrowness of its opening. We studied apparent motion of negative parts, focusing on whether variation in a region's figural status could modulate the degree to which it could participate in apparent motion with closed figures. We employed a variant of the Ternus display, containing a sequence of motion frames in which the correspondence between frames can be solved in two distinct ways: "group motion," in which a group of elements in the display appear to translate, and "element motion," in which one object translates while the others do not. Displays were constructed so that group motion percept involved motion between a closed figure and a negative part, while element motion did not, so the proportion of group motion percepts reveals the degree to which the negative part had taken on quasi-object status and thus could be placed in motion correspondence with an ordinary closed object. Critically, we manipulated the geometric factors determining the strength of the negative part. We found that the rate of group motion responses varied with negative part strength, i.e., that stronger negative parts are more likely than weaker ones to be treated as distinct objects. This finding sheds light on the mechanisms by which image regions come to be treated as distinct objects on an equal footing with closed figures.

33.4092 Understanding and Modeling Spatiotemporal Boundary Formation

Philip Kellman[1] (kellman@cognet.ucla.edu), Gennady Erlikhman[1]; [1]Department of Psychology, University of California, Los Angeles

Background: In spatiotemporal boundary formation (SBF), illusory contours, shape, and global motion are seen from sequential transformations of sparse texture elements (Shipley & Kellman, 1994). Formally, local edge orientation can be recovered from small numbers of pairs of element transformations; these "motion signals" are not seen as local motions but are integrated to determine edge orientation. An ideal observer model that uses pairs of transformations outperforms human observers. Evidence suggests information integration in SBF is limited to a 165 ms temporal windows and asymptotes at about 36 element changes. In addition, noise in encoding of distances, angular relations, and intervals between transformations may also affect performance. We measured these noise sources experimentally, incorporated them into the model, and tested the model. Design: Displays consisted of black dots on a white background. An invisible bar moved across the display. Whenever the bar contacted a dot, it disappeared, reappearing when the bar passed. Subjects judged the bar as tilted clockwise or counter-clockwise. Discrimination thresholds were measured in three SBF experiments as a function of element density, number, and frame duration. Three non-SBF, 2IFC experiments tested discrimination of distances, angular relations, and temporal intervals of element transformation pairs. Results: SBF performance improved with increasing density and number, and worsened with increasing frame duration. Noise from psychometric functions fit to human data for precision in discriminating distances, angles and intervals was added to a trial-by-trial ideal observer limited to 36 dots and integration intervals ≤ 165 ms. The model fit human data remarkably well across all three experiments with no free parameters. Conclusions: SBF is based on recovery of local orientation from mechanisms that sample, subject to encoding imprecision of relevant display properties, pairs of element changes under specific spatial and temporal constraints.

33.4093 Dynamic recalibration of perceived space across the visual hemifields

Anna Kosovicheva[1] (anko@berkeley.edu), Benjamin Wolfe[1], Patrick Cavanagh[2], Andrei Gorea[2], David Whitney[1]; [1]Department of Psychology, University of California, Berkeley, [2]Laboratoire Psychologie de la Perception, Université Paris Descartes

Visual input from the left and right visual fields is initially processed separately in the two cortical hemispheres, yet the visual system integrates these representations into a single continuous percept of space. In order to represent alignment and symmetry across the visual field, the visual system may continually recalibrate visual information across the hemifields. If so, any differences, such as misalignments across the two hemifields, should be adaptable. To test this, observers adapted to a set of large randomly rotating and moving colored lines in a circular Gaussian contrast aperture on a dark background, while performing a target detection task at fixation. The stimulus was split across the vertical meridian such that the lines in the left hemifield were shifted 1.8º higher than the lines in the right hemifield, or vice versa. An occluder strip (3.5º wide) eliminated visibility of the discontinuity in the lines at the vertical meridian, and observers were tested in a dark room with neutral density filter goggles to eliminate visual references. After 8 minutes of initial adaptation, observers performed a Vernier discrimination task in which they judged the relative positions of two brief (83 ms) horizontal lines straddling the vertical meridian. Vernier judgments reflected a negative aftereffect; an average shift of 0.08º in the direction of adaptation was required to null the perceived misalignment (p = 0.006). We replicated this result with adaptation to natural movies with the left and right halves of the image vertically misaligned. Results showed that a Vernier offset of 0.07º in the direction of adaptation was necessary to cancel the perceived misalignment (p = 0.02). Our results indicate that the visual system computes and dynamically recalibrates the relative alignment of elements across the visual fields—a mechanism that would help achieve and maintain continuous and stable perception of space.

33.4094 Position of light sources affects the perceived shape from shading under the hollow face illusion

Tatsuya Yoshizawa[1] (tyoshi@neptune.kanazawa-it.ac.jp), Chiemi Nakashima[1]; [1]Human Information System Laboratory, Kanazawa Institute of Technology, Ishikawa, Japan

The hollow-face illusion, the compelling impression of a convex face for a mask, has been believed as the only perception of three-dimensional shape of a face from shading under the single-light source rule, although there are other possible physical interpretations to the mask. This gives rise to questions what extent this rule can be applied and how powerful this rule can constrain the perceived shape. To answer these questions, we investigated shape perceived of a circle (test) located around the hollow face stimulus (inducer) as functions of a distance between the test and the inducer and of a position of the test to the inducer. Results of all of eight observers (undergraduates) showed the hollow-face illusion were produced when the inducer was presented alone. We found there were two types of the results. One group of the observers followed the single-light source rule, and another group responded perception so that the observers interpreted that each of the object in the stimulus field was casted by different light sources. Despite of these different trends of the results, for all observers there was no effect of the inducer to the test in terms of relative location to the inducer and distance from the inducer. These results indicate that across the wide-range of the spatial configuration of the stimulus the single-light source rule is not of robust for a mechanism of the perceptual shape from shading.

33.4095 Shape distortion illusion of flashed circles can be induced by dichoptic stimulation

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Flash presentation of a circle alternating with its inward gradation pattern induces an illusory shape distortion: the circle appears as a polygon (e.g. hexagon) in a short period (Sakurai, 2014 VSS, ECVP). We investigated whether this shape distortion illusion occurs before or after binocular combination in the visual pathway by measuring the induction time (latency) of the illusion in dichoptic and monoptic stimulation conditions. Stereoscopic stimuli consisted of a circle of 3.5 deg in diameter and its inward gradation pattern on a white background, alternating at 2 Hz and located at 4.5 deg on the left or right side of a central fixation cross surrounded by a 15 deg square frame for fusion lock. In the dichoptic condition, the circle was presented to one eye and the gradation pattern was presented to the other eye. In the monoptic condition, both the circle and the gradation pattern were presented to the same eye. In the control condition, the circle was solely presented to one eye flashing at 2 Hz. Observers had their head fixed on a chin-and-forehead rest and viewed the display through a mirror stereoscope. They were asked to press a response key as soon as they noticed the shape distortion in each trial. Results showed that the latencies of this illusion in both dichoptic and monoptic conditions were shorter than that in the control condition. No significant difference in latency was found between the dichoptic and monoptic conditions. These results suggest that the shape distortion illusion occurs after binocular combination and that some cortical process responsive to curvatures is involved in this illusion.

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33.4096 Ellipses look like polygons with fast repeated presentation

Cheng Qiu[1] (qiuxx077@umn.edu), Shikha Saggi[1], Cheryl Olman[1], Daniel Kersten[1]; [1]Psychology, University of Minnesota

We observed that fast-paced peripheral presentations of ellipses (including circles) with slightly varying size and position result in their apparent change in shape. When observers (N=12) were asked to sketch the per-

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ceived shapes, they all portrayed perception of a closed form consisting of a discrete set of vertices connected by straight edges. To explore the time-course of this effect, observers were asked to press a response key when they saw the distortion first begin to appear. The trial ended when a response was received or after a minute of presentation (subjects were instructed not to respond if no distortion was observed). We found that: (1) The time to see the distortion decreases with increasing eccentricity; (2) A larger percentage change in width and/or height between frames decreases the response time (especially at small eccentricities), but an excessively large change increases the response time and reduces the perceived effect; (3) A small translational jittering of the ellipse center does not affect the response time; however, a larger location shift largely eliminates the shape distortion; (4) Over a flashing frequency range between 2 and 20 Hz, the response time decreases up to about 8 Hz. We also found that the effect persists when a temporal gap (i.e. a 100ms blank frame) is inserted between stimulus frames. This effect may be due to an interaction between two processes: fast phase adaptation to local curvature (locally adapted to convex curves make subsequent ones less curved or even straight) together with global shape integration. When observers viewed non-closed curves (e.g. partial ellipses) the perceived distortion was attenuated, suggesting the importance of global continuity contributing to the effect.

33.4097 **Ventral and dorsal stream contributions to a size-contrast illusion: A TMS-induced phosphene study.** Ramisha Knight[1] (rknight54@hotmail.com), Chiara Mazzi[1], Diane Beck[2,3], Silvia Savazzi[1]; [1]University of Verona, National Institute of Neuroscience, Italy, [2]Department of Psychology, University of Illinois at Urbana-Champaign, [3]Beckman Institute, University of Illinois at Urbana-Champaign

Size-contrast illusions are processed in the ventral stream of the occipito-temporal cortex and the dorsal stream of the parietal cortex. Greater interactions between these two regions are associated with stronger illusions. The present study tests if visual percepts (phosphenes) induced by TMS of the occipital and parietal cortices are also susceptible to size-contrast illusions. Using the Ponzo illusion, wherein a two-dimensional image exhibits an illusory third dimension of depth, we predicted that the size of phosphenes and their reaction times would be modulated by perceived distance, similar to results found with normal external stimuli. A novel image illustrating a business park with buildings depicted as being 'near' or 'far' from the observer was used to elicit depth cues. In Experiment 1, single-pulse TMS was administered to the left primary visual cortex and left intraparietal sulcus to induce phosphenes. Participants (N=10) were to respond as fast as possible by pressing a button when they experienced a phosphene, and to report its size and location on the monitor. Previous work has shown that participants are faster to respond to an object whose perceived size is larger. We verified in a second experiment, with the same participants, that a size illusion was present for physical stimuli (i.e. no TMS phosphenes) on the same background using an adjustment task. In Experiment 1, we found the illusion affected perceived size of and RTs to occipital-induced phosphenes but not parietal-induced phosphenes. These results indicate that the ventral stream may also be involved with processing size-contrast illusions arising from TMS of the occipital cortex, but not for percepts induced in the parietal cortex.

33.4098 **Visual Distortions Induced by Simple and Complex Shapes** Galina Goren[1] (galinagoren@gmail.com), James Elder[1]; [1]Centre for Vision Research, York University

We have recently reported that natural contours induce perceptual distortions in neighbouring regions of visual space (Goren & Elder VSS2013). However, the magnitude of these distortions has yet to be quantified, and the precise conditions necessary to generate them remain unclear. Here we employ a new quantitative method to measure the size of these perceptual distortions, and systematically vary the complexity of the inducing contours to determine whether contour shape modulates their genesis. Methods. The stimulus consisted of a collinear triplet of dots orthogonal to a nearby contour. Observers used a mouse to move the central dot along the virtual line connecting the flankers until it was perceived to bisect them. 11 positions of the dot probe were evaluated, ranging from one side of the contour to the other. Contours included horizontal and vertical lines and line segments, circles and arcs of circles, as well as natural animal shapes. Results. The induced distortion of perceptual space was found to be highly similar for both simple and complex contours. Generally, space was perceived as compressed in the immediate vicinity of the contour and expanded at intermediate distances, and the magnitude of these distortions generally peaked at roughly 7 arcmin, or 0.8% of the half-width of our 2.8 deg dot probe. Space was generally undistorted at points distant from the contour. These findings suggest that the observed distortions may be determined by local properties of contours rather than global shape.

33.4099 **Filling-in of Kanizsa-style illusory figures is under top-down control** A.J Ayeni[1] (ajayayeni@gmail.com), William Harrison[1], Peter Bex[1]; [1]Department of Psychology, Northeastern University

Illusory Kanizsa figures demonstrate the visual system's ability to interpolate shape and structure from fragmented information. For example, on a gray background, white "pacman" inducers arranged at the corners of an imaginary triangle produce an apparent occluding surface that is darker than the background, whereas black pacmen produce an apparently lighter occluding surface. Although such "filling-in" has been accounted for by the bottom-up properties of early visual cortex, we sought to investigate the extent to which top-down attention can influence the computations underlying visual interpolation. We thus developed a perceptually bi-stable hexagram figure composed of two inverted and spatially overlapping Kanizsa triangles on a gray background (20 cd/m2). The pacmen defining one triangle were white (40 cd/m2), and the others were black (0 cd/m2). An observer's task was to report whether only one of the two illusory figures was lighter or darker than a luminance-defined matching triangle presented on a background of white noise, with match luminance adjusted according to an adaptive staircase. To draw observers' attention to one of the two illusory figures, they were instructed to judge only the illusory triangle that matched the orientation of the luminance-defined triangle, which was chosen randomly trial-by-trial. We therefore directed observers to attend to an illusory triangle defined by white (or black) inducers endogenously, but not by referring to the color of the inducers. For 15 observers, perceptual reports strongly depended on the pacman color of the attended illusory triangle, despite both sets of pacmen being present for all trials. Because the illusory triangles spatially overlapped, these opposite changes in the perceived lightness of the surface could only be due to our attention manipulation. We thus show that, when at least two percepts are equally plausible, visual attention ultimately guides the perceptual experience of filling-in.

33.4100 **3-D computer graphics to obtain psychometric function for hollow-mask illusion** Attila Farkas[1] (ajf215@ruccs.rutgers.edu), Thomas Papathomas[2], Steven Silverstein[3], Hristiyan Kourtev[4], Yannis Papayanopoulos[5]; [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, Rutgers University Behavioral HealthCare and Robert Wood Johnson Medical School Department of Psychiatry, Rutgers Biomedical and Health Sciences , [4]Center for Cognitive Science, Rutgers University , [5]College of Engineering, Georgia Institute of Technology

Introduction: The hollow-face illusion is a depth-inversion illusion: the concave mask is misperceived as convex. Earlier studies employed mostly static stereo pairs of two-dimensional (2-D) images (e.g., Liu et al. 2000) and 3-D physical models (e.g., Yellott & Kaiwi, 1979). There are two extreme renderings: (1) hollow masks with random-dot texture are perceived as hollow (Georgeson, 1979); (2) hollow masks painted as realistic faces appear convex (Papathomas & Bono, 2004). We sought to combine these renderings and modulate the strength of the illusion. Methods: Random-dot (noise) texture and a computer generated texture of human features were digitally scaled and applied onto the 3-D geometry of a hollow mask. These textures were mapped onto the mask as two different layers using weight $F(0 \leq F \leq 1)$ for the featural texture and $R=1-F$ for the noise texture. The strength of the illusion increases monotonically as F varies from 0 to 1. The mask was presented in stereo using red-green glasses. Results: Experiment 1: To validate the stimuli, we used several variants of hollow masks (against a blank background, or "anchored" on a frontoparallel plane) and replicated the inversion effect; namely the illusion was significantly weaker when the mask was turned upside-down, as compared to the upright mask, as documented in previous studies (Hill and Bruce 1993, 1994; Papathomas & Bono, 2004). Experiment 2: We tested a hollow mask with F values ranging from 0.0 to 1.0). Our results indicate that the illusion strength increases monotonically, indeed, as F increases, starting with no illusion at F=0.0 and creating the strongest illusion at F=1.0. Conclusions: We have a method for obtaining a psychometric function for the hollow-mask illusion that can be adapted for staircase procedures because of its monotonicity. The method is well suited for perceptual studies with pathological populations, such as in schizophrenia research.

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Visual Memory: Objects and features

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

33.4101 Investigating the relation between representations of feature- and object-level in visual working memory

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Introduction: Basing on the hierarchical working memory theory, the present study investigated the relation between representations of feature- and object-level. Participants needed to complete a color and a face recognition task in the same trial. Memory load of color task was manipulated. According to previous studies, increasing the colors load would reduce the fidelity of facial features competing for resources. We assumed that, if there was independence between these two levels, degradation of feature fidelity should have little influence on object-level representation (increasing the color load won't affect the face performance). In contrast, the opposite result should be observed. Method: 24 students participated. The experiment comprised two sessions. Each session comprised three blocks (64 trials each) that set size of colors in color task was two, three, and four respectively. In the face-first session, each trial began with two visually-presented digits for rehearsing to prevent semantic encoding. Then, the study items of face task (an upright/inverted face, 50% each) and color task (color patches) were presented subsequently. The probes of face task (a face, 50% matched) and color task (a color patch, 50% matched) was then presented subsequently. Participants needed to match the probe with study item for each task and respond by key press. The trial end with two visually-presented digits and participants needed to match them with those had rehearsed. The task sequence was switched in the color-first session. Orders of sessions and blocks were randomized. VWM performance was measured by the sensitivity (d'). Main Results: Three-way analyses of variance with within-subjects factors of task order, color load, and face orientation were conducted on d' of face task. Only the main effect of task order (color-first better) and face orientation (upright better) were significant. Conclusion: There is some level of independence between feature- and object-level representations in VWM.

33.4102 Relational information decays faster than object features in visual working memory.

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Visual working memory (VWM) actively maintains visual information for a short period. While some researchers suggested that VWM representation consisted of slots storing bound objects (e.g., Luck et al., 2001), other researchers found that degradation of relational information decreased VWM capacity (e.g., Wilken et al., 2004). Recently, Brady et al. (2013) found that different features of objects decayed at different rates in long-term visual memory. However, the same hypothesis has not been tested in VWM. We investigated whether relational information among items decayed faster than object features in VWM. To test this hypothesis, we used a change detection task. We varied the retention intervals (short: 150 ms, long: 750 ms) and used different locations between test and memory arrays. The memory array was presented in the parafovea and the test array was presented around the fixation to prevent participants from utilizing sensory memory. There were three types of changes in the test array. In the color change condition, the color of one item was changed. Because colors of individual objects and relationship between colors were preserved, participants could use both object features and relational information. In the location change condition, relative location of one item was changed. Note that absolute locations of all items in test array were changed from those of the memory array because of the different locations between the test and memory arrays. Thus, only relational information was available in the location change condition. Finally, in the both change condition, both relative location and color of one item were changed. Change detection performance was similar at the short retention interval across the conditions. However, at the long retention interval, change detection performance of the location change condition decreased significantly more than the other conditions. These results suggest that relational information decays faster than object features in VWM.

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33.4103 Parallel maintenance of type and token representations in visual working memory

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Binding of non-spatial features in visual working memory (VWM), and the role of location in binding, remain unknown. Empirical evidence for and against feature binding in VWM has been based on null results. Object file theory postulates that spatiotemporal location is critical in maintenance of feature binding in VWM, but no evidence has been provided for the binding of feature conjunction to location. The current study combined the redundancy gain paradigm and the object reviewing paradigm to investigate the relationship between color-shape binding and location. A set of features was presented in a two-object memory display, followed by a single object probe. Participants judged if the probe contained any features of the memory display, regardless of location. The probe contained two, one, or zero features in the memory display (redundant trials, single-feature trials, or new trials, respectively). Within the redundant trials, the features were either grouped or separated. To investigate the role of location, single-feature and redundant-grouped trials were further classified into location-shared and location-unshared trials The race model analysis examined whether RT advantage of redundant over single-feature trials is due to probability summation, and revealed object-based feature co-activation regardless of location sharing between probe and memory objects, suggesting location-unbound binding of color and shape. Location-sharing benefits were obtained for both redundant and single-feature conditions, indicating maintenance of object files independent of non-spatial feature binding. Amplitude modulations in N350 ERP component reflecting the feature co-activation had the peak in a frontal region, whereas those reflecting the location-sharing benefit had the peak in a posterior region, suggesting different neural mechanisms for the maintenance of color-shape binding and object files. In a location-irrelevant task, color-shape binding is maintained without binding to location, inconsistent with object file theory. These novel findings suggest a parallel maintenance of type and token VWM representations.

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33.4104 Feature binding in Working Memory Requires Object-based Attention

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Feature binding is a core concept in many research fields, including the study of working memory (WM). Over the past decade, it has been debated whether keeping the feature binding in visual WM consumes more visual attention than the constituent single features. Previous studies have only explored the contribution of domain-general attention or spatial-based attention in the binding process, no study so far has explored the role of object-based attention in retaining binding in visual WM. We hypothesized that object-based attention underlay the mechanism of rehearsing feature binding in visual WM. Therefore, during the maintenance phase of a visual WM task, we inserted a secondary mental rotation, transparent motion, or object-based feature report task to consume the object-based attention available for binding. In line with prediction of the object-based attention hypothesis, we consistently revealed a significant impairment for binding than for constituent single features. However, this selective binding impairment was not observed by inserting a spatial-based visual search task. Finally, we found binding recovery if giving participants sufficient time after the secondary object-based task; but not after the secondary spatial-based task. Taken together, these results suggest that the maintaining feature binding in WM needs object-based attention. (Acknowledgement: This research is supported by the National Natural Science Foundation of China (No. 31170975, 31271089).Corresponding author: zaifengg@gmail.com)

33.4105 Real-world objects are recalled better than photographs of objects

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Research studies of human memory have largely relied on two-dimensional images as substitutes for real-world exemplars. Real objects, however, differ from images in a number of important respects: they exist in three-dimensional space, have a definite size, distance, and location from the observer, and offer the potential for grasping and interaction. Moreover, neuroimaging evidence suggests that real objects may be encoded and/or represented differently to their pictorial counterparts. In a series of recent experiments we reported that memory performance was enhanced for real objects versus matched pictures and line-drawings of the same items. The memory advantage for real objects was replicated across two experiments in the context of a between-subjects design. Here, we examine whether the mnemonic advantage for real objects over pictures can be observed within

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individual observers. Thirty-three undergraduate students were asked to freely recall, and then to recognize forty-two common household objects. Critically, half of the objects were presented as real-world exemplars and the remainder as high-resolution color photographs. We varied the objects that were assigned to each viewing condition from observer to observer and the order of trials in each condition was varied randomly throughout the study phase. Stimulus viewing time was controlled using PLATO LCD spectacles and the stimuli in each viewing condition were closely matched in terms of visual size, lighting conditions, and viewing distance. In the free recall task, memory performance was significantly better for objects that were viewed as real exemplars than photographs. There were no significant differences in recognition performance between the two viewing conditions. These data confirm that real-world are more memorable to individual observers than pictorial representations of objects. Our data shed further light on the important but largely overlooked question as to whether images are appropriate proxies for real objects in psychology and neuroscience.

33.4106 Maintenance of saccade goals boosts working-memory

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Although saccade processing, visuospatial attention and visual working-memory (WM) are interdependent aspects of visual cognition, the interactions between all three have rarely been directly investigated. By combining a change detection task with a delayed saccade task, we were able to examine their separate influences on visual WM. Participants fixated centrally while memorizing two peripherally presented radial frequency patterns. Shortly afterwards, the position of one of the patterns was cued. In two blocked conditions participants had to encode this cue to later make a saccade either toward that position ("saccade toward'' condition) or away to a different location ("saccade away" condition). After a variable delay, two saccade response items appeared, one at the previously cued location and another at a random new location. In the "saccade toward" condition, subjects were required to saccade to the previously cued location, while in the "saccade away" condition they had to look to the new item. Subjects then returned to fixation and WM performance was probed with a change detection task for one of the memorized radial frequency patterns. We found a selective improvement in WM for objects at locations cued to be looked at, compared to uncued locations. In the "saccade away" condition we obtained no differences, neither between cued and uncued locations, nor between looked at and not looked at locations. Additionally, in 25% of both conditions trials, subjects were only cued (without saccade response items) and remained at fixation. Here we found that planning and maintaining saccade goals was sufficient to boost WM performance - even without the actual execution of a saccade. Our results suggest that the maintenance of the saccade goal and the associated attentional deployment (but not saccade execution or visual cueing by the saccade target) improves the fidelity of WM representations maintained at the goal location.

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33.4107 How feature information affects the retrieval of object location

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In a series of experiments, we investigated how retrieving object features affects the precision of memory for their location. Participants viewed 6 objects randomly located on a display for 2.5 seconds. Each object was made up of a combination of one of 6 colors, 6 shapes, and 6 patterns for a total of 216 possible combinations. After a delay of approximately 4 seconds, participants were shown one feature (color, shape, or pattern) and asked to indicate the location on the screen of the object that contained that feature. After responding, participants were asked to indicate another feature the object contained. Participants were significantly more accurate to indicate the location of the object when they were given a color property, than a shape, or pattern. In addition, location accuracy was positively correlated with feature accuracy. In a second set of experiments, 3 of the objects had the same color, shape, and pattern (duplicate objects), and 3 had unique combinations (unique objects). Memory for spatial location and features was significantly more accurate for duplicate than unique objects. The overall spatial accuracy of both the 3 unique and 3 duplicate objects was also significantly higher than 6 unique objects. This indicates that participants may be able to chunk together similar objects to reduce total memory load. These results have important theoretical implications for how feature and spatial information are bound and used to reference each other.

33.4108 Visual working memory of irrelevant features in multi-feature objects

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The object-based view of working memory (Luck and Vogel, 1997) postulates that features of the same multi-feature object are remembered together. This would imply that irrelevant features are automatically encoded. Here, we tested this hypothesis directly. Stimuli were colored, oriented ellipses. Either color or orientation was designated to be the relevant feature throughout the experiment. Subjects viewed four stimuli and, after a delay, another four, where one item had changed in its relevant feature. Independently, one item (the same or a different one) had also changed in its irrelevant feature. In the first 30 trials, subjects were asked to locate the change in the relevant feature, but on the 31st trial, they were asked to locate the change in the irrelevant feature. Since the 31st trial suddenly makes the irrelevant feature relevant, there is no point in continuing the experiment thereafter. Thus, we get only one "irrelevant" trial per subject. To solve this problem, we crowd-sourced data from subjects on Amazon Mechanical Turk. Online subjects were able to recall the relevant feature, although not as well as lab subjects. Performance on "irrelevant" trials pooled across subjects was at chance, suggesting that the irrelevant memory was not retrieved. However, subjects might have discarded this memory right after seeing the second display. To address this, we used a delayed-estimation paradigm (Wilken and Ma, 2004), which does not have a second display. Online subjects viewed a single colored, oriented ellipse, and reported their estimate of its relevant feature on a continuum. Again, the 31st (last) trial was an "irrelevant" trial. Subjects' performance on "irrelevant" trials was well above chance, but not as high as on "relevant" trials. This supports a weak form of the object-based view of visual working memory, namely one in which memory quality is weighed by relevance.

33.4109 Grouping in visual working memory is determined by the task context

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Visual working memory (WM) can only hold a very limited amount of information, and one way to overcome this capacity limitation is to group several items to one chunk. While perceptual grouping may be regarded as preattentive, grouping in WM should be flexible enough to allow WM representation to adapt to a changing environment. We examined the influence of context on grouping of color-color conjunctions in WM. We used a change detection paradigm with moving colored squares as stimuli, and monitored the contralateral delay activity (CDA), an electrophysiological marker whose amplitude rises as more items are stored in WM. We compared a "common fate" condition (two color-color conjunctions that moved together) to two and four separate colors. If the common fate conjunctions are grouped, the CDA amplitude should be similar to two separate colors. Conversely, if the conjunctions are represented separately, the CDA amplitude should be similar to four separate colors. Critically, while these exact three conditions appeared in all experiments, we manipulated the presence of an additional condition that served as a context cue. When the additional condition included four separately-moving colors that met and then moved together, the CDA amplitude of the common fate conjunctions was identical to two separate colors, indicating perfect grouping. Without the "joining" condition, the common fate conjunctions were initially grouped but then individuated during their memory maintenance, producing a CDA amplitude higher than two colors. When the joining condition was replaced by a separating condition (two color-color conjunctions that separated to four colors), the CDA amplitude of the common fate condition gradually rose until it reached that of four separate colors, indicating increasing individuation. Our results suggest that grouping in WM is highly sensitive to environmental cues, with items being grouped when the context implies "togetherness" and individuated when it implies independence.

33.4110 Inhibition has negative affective consequences for task-irrelevant stimuli that are similar to the active contents of visual working memory

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Ignoring a visual stimulus causes it to subsequently receive more negative affective ratings than novel items or prior targets of attention. This has been taken as evidence that attentional inhibition alters the coding of stimulus-associated value to ensure that previously distracting stimuli can be

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effectively avoided in future encounters. Previous results have suggested that this 'inhibitory devaluation' effect may operate through affective associations with specific perceptual features that allow distractors to be differentiated from targets. Prior inhibition can thereby impact the affective value both of specific items that have appeared as distractors and of novel items that share a previously ignored feature. But what happens when a distractor shares the same perceptual features as a target being held in visual working memory? Recent electrophysiological evidence suggests that while the similarity may initially cause selective attention to be biased toward such task-irrelevant items, active inhibition may then be triggered to prevent them from interfering with the ongoing task. If inhibition causes affective devaluation, then such findings predict greater devaluation of task-irrelevant stimuli that share the same perceptual features as a target being held in visual working memory than those that do not. To test this, we utilized delayed-match-to-sample trials that required participants to maintain a uniquely-coloured stimulus in working memory while task-irrelevant probe arrays were presented. The probe arrays contained abstract shapes whose colour either matched or did not match that of the stimulus being held in memory. Subsequent affective-evaluation trials revealed that prior memory-matching distractors received more negative ratings than non-matching distractors or a set of previously-unseen shapes. These results converge with prior electrophysiological evidence to suggest that distractors matching the contents of visual working memory are subjected to greater levels of attentional inhibition than other task-irrelevant stimuli, and that the consequences of this inhibition include alterations in affective value.

Acknowledgement: NSERC

33.4111 **Working memory representations produce inhibition of similar (but not identical) stimuli in visual attention**

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Working memory (WM) maintenance can produce patterns of neural activity similar to visually-attended sensory stimuli, suggesting that WM and visual attention may share neural representations. If this is the case, an item in WM should impact behavior just like a visually-attended one. Here, we examine whether the center-surround selective tuning mechanism that is purported to focus attention in the visual system also applies to stimuli that are attended internally (i.e., in WM). When attention is directed at a particular stimulus, processing for that location or feature is enhanced, while nearby stimuli are inhibited. We test whether maintaining a color stimulus in WM produces inhibition, during a visual attention task, of nearby stimuli in color space. Participants viewed a colored WM sample whose shade was selected randomly from a circular color space (and then performed a change detection task on a subset of "catch trials"). During the WM delay, they completed a visual search wherein the targets and distractors (which were opposite each other on the color wheel) varied continuously in similarity to the WM sample. Targets could thus be an exact match to the WM item, or different in 10° steps. Visual search was fastest when the target was an exact WM match, and slowest when a distractor was an exact WM match, but similarity between the target and WM sample did not produce a linear effect on search speed. Instead, search was slowed when targets were similar in color to the WM sample (i.e., 10-30° away), then speeded again as targets became more dissimilar to the WM sample, and would presumably fall outside a suppressive surround. This suggests that focusing internal attention on a color in WM produced surround-inhibition that impaired visual processing for similar colors. WM and visual attention, thus, seem to activate the same representations.

33.4112 **Visual working memory for multiple moving objects in occlusion**

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Visual working memory (VWM) capacity is typically assessed using tasks in which participants must remember two-dimensional arrays of items that blink in and out of existence. These studies have found VWM limits of around 3-4 items. In the physical world, however, VWM may be required to maintain representations of multiple three-dimensional objects as they move in and out of occlusion. This may put different demands on VWM, requiring more attentional resources than stationary 2D items. In the current experiment, we explored participants' VWM for objects that moved into occlusion. Twenty-four participants viewed 3-D rendered displays in which sets of differently oriented bars moved sequentially behind separate rectangular occluders. Two of the occluders then dissolved, revealing the objects behind them. On half of the trials, one of the objects changed orientation. Participants reported whether they detected a change. We manipulated both set size (2-6 objects) and which object in the hiding sequence was probed (first-hidden, second-hidden, etc.) Change detection performance was best at set size 2 (88% correct), but declined significantly thereafter (set size 3: 68%; set size 4: 68% set size 5: 59%; set size 6: 60%, $p< 0.001$). Mean k across set sizes was 1.38 objects, fewer than typical limits observed for stationary 2D items. For all set sizes, change detection performance was best for the last-hidden object in the set (mean=79% correct). Performance then dropped significantly for the second-to-last hidden object, but only at set sizes greater than 3 (all $ps< 0.01$), suggesting that, as the number of hidden objects substantially exceeded participants' limits, VWM resources were preferentially allocated to the last object participants saw hidden. Our results suggest that tracking and representing multiple occluded objects may make sizable demands on attention and VWM, limiting the number of representations that may be concurrently maintained.

33.4113 **The Geometric Invariance in Representing Multiple Objects in Visual Working Memory**

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Visual working memory is highly sensitive to global configurations in addition to features of each individual object. When objects are moving, their configuration varies correspondingly. Here we explore the geometric rules governing the maintenance of such a dynamic configuration in visual working memory. Our investigation is guided by the Erlangen program, which is a hierarchy of geometric stability, including affine, projective and topological invariants. The configuration here was defined as the virtual polygon with the four dots being its vertices. In all cases, the boundary of the virtual polygon overlapped with the convex hull of the four dots. The shape of the virtual polygon was gradually transformed to a new one by the motion of each dot in the memory display. In a change detection task, this memory displays were categorized by which geometry invariance was violated by the objects' motions. The results show that (a) there was no decrement of memory performance until the projective invariance was violated; (b) more dramatic changes (such as a topological change) cannot further enlarge the decrement; (c) objects causing the violation of projective invariance were better encoded in memory. These results collectively demonstrate that projective invariance is the only geometric property determining the maintenance of a dynamic configuration in visual working memory.

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33.4114 **Retroactive Attention can Trigger all-or-none Conscious Access to Past Sensory Stimulus**

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Cueing attention after the disappearance of visual stimuli biases which items will be remembered best (Sperling, 1960; Sligte et al., 2008). The classical interpretation is that post-cueing influences memory consolidation, but not subjective visual experience. We recently challenged this view by showing that post-cued attention can improve objective and subjective report of a single item at threshold-contrast (Sergent et al., 2013). This suggests that conscious perception itself could be influenced retroactively. Here we tested whether post-cued attention can increase one's chances of seeing a stimulus, or whether it merely allows a more precise recall of its features. Attention was cued to the right or left side of a visual display after a single, threshold-contrast Gabor patch had been presented on the same or opposite side. Subjects then reported the precise orientation of the target by matching the orientation of a probe Gabor. A mixture-model analysis of this continuous measure of angular error allowed estimating both the percentage of guesses and the precision of encoding for non-guesses (Zhang & Luck, 2008). Post-cueing at the correct location had no influence on the precision of the reported angle, but significantly decreased the number of guesses. This suggests that post-cued attention in this instance induces discrete shifts in conscious access to the target percept, rather than preventing a decline in the resolution of remembered features. Using a similar approach in an iconic memory setting with several high-contrast items, we further showed that the performance advantage conferred by post-cueing is attributable not only to the maintained precision of perceptual information (as classically assumed), but also to an increased probability of accessing this information. These results suggest that attention can retrospectively trigger conscious access to sensory traces that were not consciously accessed in the first place.

Sunday Afternoon Talks

Spatial Vision: Crowding

Sunday, May 17, 2:30 - 4:15 pm
Talk Session, Talk Room 1
Moderator: Peter Bex

34.11, *2:30 pm* Compression of space as a default for localizing degraded targets in the context of highly visible stimuli

Sabine Born[1] (sabine.born.fr@gmail.com), Eckart Zimmermann[2], Patrick Cavanagh[1]; [1]Centre Attention & Vision, Laboratoire Psychologie de la Perception, Université Paris Descartes, Sorbonne Paris Cité, CNRS UMR 8242, Paris, France, [2]Cognitive Neuroscience, Institute of Neuroscience and Medicine (INM-3), Research Centre Jülich, Jülich, Germany

The visual input reaching our perceptual system is frequently disrupted: Objects may be temporarily occluded, the lighting might change abruptly, and drastic changes in the retinal image occur every time we move our eyes. Some phenomena, such as change blindness (Rensink, O'Regan, & Clark, 1997), demonstrate the challenges of such visual disruptions for perception. In addition, previous research has reported dramatic localization errors around the time of visual disruptions: Stimuli briefly flashed just before a saccade are perceived closer to the saccade target, a phenomenon known as perisaccadic compression of space (Ross, Morrone, & Burr, 1997). More recently, we have demonstrated that brief probes are attracted towards a visual reference when followed by a mask, even in the absence of saccades (Zimmermann, Born, Fink, & Cavanagh, in press). Here, we ask whether, akin to change blindness phenomena, a transient visual disruption is a critical factor in compression. Alternatively, the decrease in visibility of the probe caused by the saccade or mask may determine compression. We used our mask-induced compression paradigm and varied the regions of the screen covered by the transient mask, including an area centered on the probe, areas where no stimulus was presented, and we added a condition without masking. In all conditions, we adjusted probe contrast to make the probe equally hard to see. Compression effects were found in all conditions, even without the mask. To obtain compression without a mask, the probe had to be presented at much lower contrasts than with the mask, though. Thus, compression of space can also be found with low contrast stimuli, without a transient visual disruption. We suggest that compression reflects how the visual system deals with degraded target onsets in the context of highly visible stimuli that share some aspects with the target.

34.12, *2:45 pm* Attentional resolution is not the exclusive limit on visual awareness

William Harrison[1] (willjharri@gmail.com), Mark Johnson[1], Peter Bex[1]; [1]Department of Psychology, Northeastern University

An object in peripheral vision is difficult to identify when it is surrounded by visual clutter, a phenomenon referred to as "crowding". Among the many accounts that have been proposed to explain crowding, we sought to investigate two competing explanations: 1) visual features of nearby objects are averaged together in relatively early levels of the visual system, versus 2) a higher-level attentional filter lacks resolution to allow accurate selection of information that is otherwise veridically encoded. We employed a new method of adjustment paradigm that allowed us to tease apart the contributions of averaging and selection failures. For 500 ms centered at 10° in peripheral vision, a target Landolt C was displayed surrounded by a larger Landolt C flank of varying diameter, with the gaps independently and randomly oriented between 0 and 360°. An observer's task was to rotate a "response" Landolt C, presented at fixation, to match the target. In line with the crowding literature, the standard deviation of the circular distribution fit to response errors decreased linearly with increasing target-flanker separations (Ester, Klee & Awh, 2014), reaching unflanked performance when the flanking ring diameter was approximately 0.35 times the target eccentricity. Subsequent analyses revealed that, when the difference between the orientations of the target and flanker gaps was large, response errors were well explained by observers' difficulty in selecting between target and flanker, in line with attentional accounts of crowding. In a second experiment, observers' task was to rotate a pair of response Landolt Cs to match the target and flank. Even when attentional selection accurately identified separate target and flanker orientations, responses were biased by the average of the two orientations. Our data thus suggest that attentional resolution is not the primary limit on visual awareness, but instead that visual features are averaged prior to attentional selection.

34.13, *3:00 pm* Crowding, Patterns, and Recurrent Processing

Michael Herzog[1] (michael.herzog@epfl.ch), Mauro Manassi[1], Frouke Hermens[2], Greg Francis[1,3]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, [2]University of Aberdeen, Scotland, 3Department of Psychological Sciences, Purdue University

In crowding, target perception deteriorates in the presence of clutter. Crowding is usually explained by pooling models where higher level neurons pool features from both a target and "informationless" flanking elements. Here, we show that such models fail to explain a large body of findings on pattern recognition, thereby undermining the philosophy of this approach. For example, observers judged the offset of a vernier presented in peripheral vision. When the vernier was flanked by eight aligned verniers on each side, strong crowding occurred, as expected. Next, we presented the vernier and the flankers as in the previous condition and, in addition, an aligned vernier at the same location as the target vernier. Crowding did not increase as one might have expected from adding an "informationless" element. Quite to the contrary, crowding strongly decreased. We argue that crowding can be explained by pattern processing and grouping. The aligned vernier complements the two arrays of flanking verniers, by creating a regular pattern of equally spaced, identical elements. Since the aligned vernier groups with the flankers, the target vernier does not group with the flankers anymore, and crowding is weak. When the aligned vernier was longer than both the vernier and flankers, no reduction of crowding occurred because, as we argue, the length difference prohibits the aligned vernier from completing the pattern of the flankers. It is the "good" pattern that matters. When we presented only one flanker to the left and right of the vernier, crowding was as strong as with eight flankers. However, crowding remained strong when we added the aligned vernier. We show by computer simulations how pattern recognition and crowding can be explained by recurrent processing.

Acknowledgement: SNF

34.14, *3:15 pm* Crowding Is Not Holistic for Faces: Low-Level Similarity Matters

Alexandra Kalpadakis-Smith[1] (alexandra.smith.13@ucl.ac.uk), Valérie Goffaux[2], John Greenwood[1]; [1]Experimental Psychology, University College London, [2]Research Institute for Psychological Science, Université Catholique de Louvain

Crowding is the disruptive effect of clutter on object recognition. Despite affecting a range of visual features, from colour to motion, most models characterise it as a singular mechanism. Studies using faces have challenged this idea by proposing a separate 'holistic' crowding stage (Louie, Bressler & Whitney, 2007). We first replicate the holistic effect using an identity-matching task: crowding is strong for an upright target face (processed 'holistically') when surrounded by upright flanker faces and weak when surrounded by inverted flankers. We find no such modulation of crowding by flanker orientation for an inverted target face (processed 'featurally'). Although this effect has been attributed to tuning for 'holistic similarity', we propose that the disproportionate difficulty with inverted faces may obscure lower-level orientation selectivity. In order to match task difficulty for upright and inverted faces, we used an eye-judgment task requiring the detection of horizontal eye-shifts that is immune to inversion effects (Goffaux & Rossion, 2007). Here, we find that crowding is modulated by flanker orientation for both upright and inverted target faces, regardless of their 'holistic similarity': crowding is strong when target-flanker orientations match and weak when they differ. The orientation selectivity for inverted faces can nonetheless be 'switched off' again with the re-introduction of an inversion effect using a more difficult vertical eye-shift task. Finally, we demonstrate the cause of this modulation of crowding using Thatcherised faces. When the position of flanker facial features is shifted to resemble an inverted face (but without feature rotations), crowding is strongly reduced. In contrast, rotations of the flanker features (leaving upright feature positions intact) have no effect. Our findings demonstrate that the crowding of faces is determined by low-level differences in facial feature positions and not by 'holistic similarity', supporting a singular account of crowding.

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34.15, *3:30 pm* **Uncorking the bottleneck of crowding** Mauro Manassi[1] (mauro.manassi@epfl.ch), Aaron Clarke[1], Michael Herzog[1]; [1]Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland

In crowding, target perception deteriorates when flanking elements are added. Crowding is usually thought to be an inevitable bottleneck of object recognition where (1) more flankers increase crowding strength, (2) only nearby elements interfere with the target (Bouma's window), and (3) target-flanker interactions occur mainly within feature specific 'channels'. Here, we show that none of these assumptions hold true. We determined offset discrimination thresholds for verniers at 9° of eccentricity. When the vernier was embedded in a square, thresholds increased compared to the unflanked threshold - a classic crowding effect. When the central square was embedded in an array of seven alternating squares and stars, crowding remained at a high level. Surprisingly, when this array was added both above and below the central array, crowding strongly decreased. When shuffling all the squares and stars in a random manner, crowding was again strong. These results show that (1) more flankers can decrease crowding strength, (2) uncrowding can be due to elements outside Bouma's window and (3) shape rather than low-level interactions determine vernier offset discrimination. These results cannot be explained by the repetitive structure of the array. We show by Fourier analysis, that adding repeating elements does not improve the discriminability for a vernier offset classifier in the Fourier domain, but in fact, it makes the vernier offset less discriminable. We propose that visual acuity for each element in the visual scene depends on all elements in the entire visual field and, on top of that, on the overall spatial configuration. Crowding is not an inevitable bottleneck because adding elements can 'uncork' the bottle and recover target information.

Acknowledgement: Swiss National Science Foundation

34.16, *3:45 pm* **Reduced Contextual Effects on Contrast Perception in Schizophrenia and Bipolar Affective Disorder** Michael-Paul Schallmo[1] (schal110@umn.edu), Cheryl Olman[4], Scott Sponheim[2,3,4]; [1]Graduate Program in Neuroscience, University of Minnesota, [2]Veterans Affairs Medical Center, Minneapolis, Minnesota, [3]Department of Psychiatry, University of Minnesota, [4]Department of Psychology, University of Minnesota

The perceived contrast of a visual stimulus is often reduced by the presence of nearby stimuli. This effect known as surround suppression may help to distinguish stimuli from similar backgrounds. Previous work has shown that people with schizophrenia demonstrate weaker surround suppression. Studying this deficit may help to identify impaired neural processing mechanisms in schizophrenia, as the neurobiology of the visual system is relatively well understood. By examining the surround suppression effect among subjects with schizophrenia (SZ; n = 23) or bipolar affective disorder (BP; n = 19), unaffected biological relatives of SZ (n = 25) or BP patients (n = 17), and healthy controls (n = 38) we sought to determine whether diminished surround suppression was specific to SZ, and if subjects with a genetic risk for either disorder would show a similar deficit. Measuring the modulation by different surround conditions (parallel with and without a gap, drifting in the same or opposite directions, and orthogonal) allowed us to investigate how this suppression effect depends on the similarity of center and surrounding stimuli. We found weaker surround suppression among patients with SZ, regardless of surround configuration. BP subjects showed an intermediate deficit, with stronger suppression than in SZ but weaker than healthy control subjects. Relatives of patients with either disorder showed normal performance. This is the first observation that reduced surround suppression is associated with both SZ and BP, but not with a genetic risk for these disorders. Further, our results indicate a deficit in broadly-tuned (rather than sharply orientation- or direction-selective) suppression mechanisms. This deficit is consistent with impaired surround suppression at an early stage of visual processing (e.g., LGN or V1).

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34.17, *4:00 pm* **Metamers of the ventral stream revisited** Thomas Wallis[1,2,3] (thomas.wallis@uni-tuebingen.de), Matthias Bethge[2,3,5,6], Felix Wichmann[1,3,4,6]; [1]Neural Information Processing Group, Faculty of Science, University of Tübingen, Germany, [2]Werner Reichardt Centre for Integrative Neuroscience and Institute for Theoretical Physics, University of Tübingen, Germany, [3]Bernstein Center for Computational Neuroscience Tübingen, Germany, [4]Max Planck Institute for Intelligent Systems, Empirical Inference Department, Tübingen, Germany, [5]Max Planck Institute for Biological Cybernetics, Tübingen, Germany, [6]Contributed equally to this work.

Peripheral vision has been characterised as a lossy representation: information present in the periphery is discarded to a greater degree than in the fovea. What information is lost and what is retained? Freeman and Simoncelli (2011) recently revived the concept of metamers (physically different stimuli that look the same) as a way to test this question. Metamerism is a useful criterion, but several details must be refined. First, their paper assessed metamerism using a task with a significant working memory component (ABX). We use a purely spatial discrimination task to probe perceptual encoding. Second, a strong test of any hypothesised representation is to what extent it is metameric for a real scene. Several subsequent studies have misunderstood this to be the result of the paper. Freeman and Simoncelli instead only compared synthetic stimuli to each other. Pairs of stimuli were synthesised from natural images such that they were physically different but equal under the model representation. The experiment then assessed the scaling factor (spatial pooling region as a function of retinal eccentricity) required to make these two synthesised images indiscriminable from one another, finding that these scaling factors approximated V2 receptive field sizes. We find that a smaller scale factor than V2 neurons is required to make the synthesised images metameric for natural scenes (which are also equal under the model). We further show that this varies over images and is modified by including the spatial context of the target patches. While this particular model therefore fails to capture some perceptually relevant information, we believe that testing specific models against the criteria that they should discard as much information as possible while remaining metameric is a useful way to understand perceptual representations psychophysically.

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Motion Perception: Biological motion and motion in depth

Sunday, May 17, 2:30 - 4:15 pm
Talk Session, Talk Room 2
Moderator: Alexander Huk

34.21, *2:30 pm* **Independent processing of disparity-based and velocity-based 3D motion in human visual cortex** Sung Jun Joo[1,2,3] (sjjoo@utexas.edu), Lawrence Cormack[1,2,3], Alexander Huk[1,2,3,4]; [1]Center for Perceptual Systems, [2]Institute for Neuroscience, [3]Department of Psychology, [4]Department of Neuroscience, The University of Texas at Austin

Recent human fMRI and monkey electrophysiology has shown that MT neurons are tuned to 3D direction. Furthermore, both psychophysics and single-unit recordings in MT have demonstrated that 3D motion signals arise from two distinct binocular cues: changing disparity (CD), and inter-ocular velocity differences (IOVD). We assessed how these two binocular cues for 3D motion interact in the visual hierarchy using an fMRI adaptation paradigm. We tested (1) whether CD- and IOVD-isolating stimuli could generate 3D direction-selective adaptation using cue-congruent test stimuli, and (2) whether cross-cue adaptation occurred. In a fully-crossed design, the adapter was either an IOVD or CD stimulus, and the test probe was either an IOVD or CD stimulus (or a "Full" cue stimulus containing both CD and IOVD). On a given scan, observers were adapted to either towards or away 3D motion of one adapting cue (e.g., IOVD towards) and tested with all possible combinations of test stimulus (CD, IOVD, and Full) and motion direction (towards/away). We found robust adaptation effects for cue-congruent conditions: after adaptation to IOVD and testing with IOVD, or after adaptation to CD and testing with CD, the fMRI response in MT+ was lower when the test direction was the same as the adapting direction compared to when the test direction was the opposite. However, we found no adaptation in MT+ in cross-cue conditions: IOVD adaptation did not affect CD test responses in a direction-selective manner, and vice versa. In V1 there was no adaptation effect across all conditions, consistent with previous findings suggesting that 3D motion signals are computed after V1. The lack of cross-cue interactions in MT+ suggests that, even though both CD and IOVD stimuli drive MT neurons, they represent distinct channels of 3D motion information.

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34.22, *2:45 pm* **Neural correlates of action aftereffects triggered by adaptation to biological motion** Steven Thurman[1] (sthurman@ucla.edu), Jeroen van Boxtel[2], Martin Monti[1], Hongjing Lu[1,3]; [1]Department of Psychology, University of California, Los Angeles, [2]School of Psychological Sciences, Monash University, [3]Department of Statistics, University of California, Los Angeles

A hallmark of human vision is the capacity to recognize diverse actions from point-light displays of biological motion (BM). The adaptive nature of BM perception is documented in behavioral studies where prolonged viewing of a stimulus can bias judgments of subsequent stimuli towards the opposite of its attributes. However, the neural mechanisms underlying action adaptation aftereffects remain unknown. We used functional magnetic resonance imaging (fMRI) to measure neural adaptation after prolonged viewing of a BM stimulus (n=12). Using an event-related design with topping-up adaptation, we measured neural aftereffects from brain responses to morphed actions after adapting to walking or running actions within two bilateral regions of interest: 1) human medial temporal area (hMT+), a lower-level motion-sensitive region of cortex, and 2) superior temporal sulcus (pSTS), a higher-level action-selective area. Neural adaptation in hMT+ was observed only when the adapting and testing stimuli were in the same location. In contrast, neural adaptation in the action-sensitive area pSTS was found to be location-invariant. Importantly, we found a significant correlation across subjects between the strength of neural aftereffects in the right pSTS and perceptual aftereffects measured behaviorally. We also measured fMR-adaptation to repeated actions (e.g. repetition suppression) and found significant effects in the right pSTS, although the strength of fMR-adaptation did not correlate with perceptual aftereffects, suggesting that distinct mechanisms are involved in action aftereffects and repetition suppression. Interestingly, the magnitudes of behavioral and neural aftereffects were significantly correlated with individual differences in autistic traits (Baron-Cohen et al., 2001). Participants with more autistic traits exhibited less modulation of brain responses in right pSTS and correspondingly weaker perceptual aftereffects. These results suggest a direct link between perceptual adaptation and neural adaptation in right pSTS, and suggest this as a core brain region for understanding social and perceptual deficits in Autism Spectrum Condition.

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34.23, *3:00 pm* **Interaction between adaptation and perceptual multi-stability in body motion recognition** Martin Giese[1] (martin.giese@uni-tuebingen.de), Leonid Fedoriv[1], Rufin Vogels[2]; [1]Sect. Comp. Sensomotorics, Dept. of Cogn. Neurol., HIH / CIN, University Clinic Tuebingen, Germany, [2]Dept. of Physiology, University of Leuven, Belgium

Biological motion recognition can show perceptual multi-stability with spontaneous transitions between the perceived walking directions (Vanrie, 2004). It is also subject to adaptation, as demonstrated by high-level after-effects and fMRI repetition suppression in relevant areas. Existing neural models for action recognition do not account for these phenomena. We present a neural mass model that accounts for these effects, and which permits to study the dynamic interplay between multi-stability and adaptation. METHODS: The model is based on a 2D dynamic neural network (field) that is composed from 'snapshot neurons' that encoding different views of body postures, which arise during the recognized action. These neurons are laterally coupled, resulting in competition between different views, and in sequence selectivity with respect to the temporal order of the presented stimulus frames. The model neurons are noisy, and include two different adaptation processes: a) a firing rate (FR) fatigue process, which increases their thresholds after firing, and b) an input fatigue (IF) process, which reduces the efficiency of input synapses after frequent stimulation. Parameters of the model were fitted to data from action- and shape-selective neurons in the STS and area IT of macaques. RESULTS / DISCUSSION: The neural field model reproduces the multi-stability of biological motion perception and spontaneous perceptual switching. The model also reproduces in detail neurophysiological data on adaptation effects in area IT, and specifically confirms that input fatigue is critical to reproduce the relevant data (deBaene, 2011). Using the same adaptation mechanism in a model for the recognition of body motion, results in adaptation effects that depend on the relative dominance of IF vs. FR fatigue. For dominance of FR fatigue the model reproduces electrophysiological observations showing very weak adaptation in action-selective neurons (Caggiano, 2012, Kilner, 2013).

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34.24, *3:15 pm* **Invariant representations for action recognition in the visual system** Andrea Tacchetti[1,2] (atacchet@mit.edu), Leyla Isik[1,2], Tomaso Poggio[1]; [1]Center for Brains, Minds and Machines, Massachusetts Institute of Technology, [2]These authors contributed equally to this work

The human brain can rapidly parse a constant stream of visual input. The majority of visual neuroscience studies, however, focus on responses to static, still-frame images. Here we use magnetoencephalography (MEG) decoding and a computational model to study invariant action recognition in videos. We created a well-controlled, naturalistic dataset to study action recognition across different views and actors. We find that, like objects, actions can also be read out from MEG data in under 200 ms (after the subject has viewed only 5 frames of video). Action can also be decoded across actor and viewpoint, showing that this early representation is invariant. Finally, we developed an extension of the HMAX model, inspired by Hubel and Wiesel's findings of simple and complex cells in primary visual cortex as well as a recent computational theory of the feedforward invariant systems, which is traditionally used to perform size- and position-invariant object recognition in images, to recognize actions. We show that instantiations of this model class can also perform recognition in natural videos that are robust to non-affine transformations. Specifically, view-invariant action recognition and action invariant actor identification in the model can be achieved by pooling across views or actions, in the same manner and model layer as affine transformations (size and position) in traditional HMAX. Together these results provide a temporal map of the first few hundred milliseconds of human action recognition as well as a mechanistic explanation of the computations underlying invariant visual recognition.

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34.25, *3:30 pm* **Motor simulation does not underlie action perception: evidence from upper limb dysmelia** Gilles Vannuscorps[1,2] (gilles.vannuscorps@unitn.it), Alfonso Caramazza[1,2]; [1]Department of Psychology, Harvard University, Cambridge, MA, USA, [2]Center for Mind/Brain Sciences, Università degli Studi di Trento, Rovereto, Italy

Every day, we interact with people synchronously, immediately understand what they are doing, and easily infer information about their mental state and the likely outcome of their action from their kinematics. According to motor theories of perception, such efficient perceptual processing of others' actions is achieved within the motor system by a process of "motor simulation", i.e., an unconscious covert imitation of the observed movements. On this hypothesis, individuals incapable of simulating observed movements in their motor system should have difficulties perceiving and interpreting observed actions. Contrary to this prediction, we found across eight sensitive experiments that five individuals born without upper limbs (i.e., upper limb dysmelia) perceived, anticipated, predicted, comprehended and memorized upper limb actions (i.e., that they cannot simulate) as accurately and as rapidly as age- and education- matched typically developed participants. We also found that, like the typically developed participants, the dysmelic participants systematically perceived the position of moving upper limbs slightly ahead of their real position but only when the anticipated position would be biomechanically possible. Such anticipatory bias and its modulation by implicit knowledge of the body biomechanical constraints were previously considered as indexes of motor contribution to perception. Our findings undermine this assumption and, together, show instead that efficient action perception does not rely on a motor simulation process.

34.26, *3:45 pm* **Robust Size Illusion Produced by Expanding and Contracting Flow Fields** Xue Dong[1] (dongx@psych.ac.cn), Min Bao[1]; [1]Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, Beijing, P.R. China

When observing a moving object, its position appears shifted in the direction of motion. This illusion, called the motion induced position shift, has been studied since the 1990s. But here we introduce an illusion that shows the opposite effect. Randomly positioned dots moved radially within an imaginary annular window centered on a mid-gray background. The dots' motion periodically changed the direction, leading to an alternating percept of expanding and contracting motion. Strikingly, the apparent size of the inner annular boundary shrank during the dots' expanding phase and dilated during the contracting phase. Size matching measurements revealed about a 10% difference in diameter between the perceived sizes for expanding and contracting motion. We also tested whether the illusion depends upon a global percept of 3D motion, rather than simply the

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presence of energy at the local kinetic edge. We divided the annulus in half and rendered the dots within each half annulus to move in opposite directions. The local account predicts that this should cause the two halves of the circle defining the annulus' inner edge to appear different sizes. However, subjects reported no difference in size between the two halves, and instead reported illusory lateral motion of the circle. Adding a texture inside the circular region weakened but did not eliminate the illusion, suggesting that the uniform gray region was not crucial. To test whether the illusion mainly arose from a monocular processing stage, we measured it when the dots were presented either monocularly or dichoptically, and found stronger illusion for the dichoptic condition. Combining these findings, our observed illusion is likely induced by a global percept of motion in depth controlled by higher level mechanisms. Expanding dots are consistent with self-motion that approaches the circle in depth. Given its constant retinal size, this may make the circle appear smaller.

34.27, *4:00 pm* **Psychometric curves describe action discrimination in humans** Guy Orban[1] (guy.orban@med.kuleuven.be), Artem Platonov[1]; [1]Deptmt Neuroscience, University of Parma

Action observation is a visual function of a great importance from both the ethological and social point of view. Recently, a number of studies provided new insights into its functional organization as a three-level cortical network encompassing in human and non-human primates occipito-temporal, parietal and premotor regions. However, there is still no general framework which would allow to establish a relationship between neuronal activity in these areas and its behavioral correlates. Demonstrating that general psychophysical laws are also applicable to the visual processing of observed actions could provide us with such a framework. We reasoned that changing the amount of dynamic noise in action movies would produce behavioral responses in human subjects qualitatively similar to the classical psychometric curves. To test this hypothesis, we presented human subjects (n=4) with the movies (2 sec) in which they had to discriminate between the two different hand-actions (rolling and rotation) in a two-alternative forced-choice task. The movies were randomly presented in 5 different fronto-parallel positions and at 2 depths. On every frame in each movie, a certain percentage of random dot-pixel pairs separated by a distance randomly chosen from within a fixed interval were scrambled. By manipulating the percentage of scrambled dot pairs, we created 6 noise levels from 60% (i.e. 60% of dots on each frame were scrambled) to 100%. Our data indicate that the amount of noise in action movies attenuated the ability of our subjects to discriminate between the two actions tested, such that the observers' performance could be described by the classical logistic regression. This psychometric curve suggests that action discrimination follows general rules described in classical visual psychophysics. One implication is that by changing the input strength in action movies can be used to manipulate the activity in single cells and neural populations.

Acknowledgement: ERC Parietalaction

Attention: Tracking and motivation

Sunday, May 17, 5:15 - 7:15 pm
Talk Session, Talk Room 1
Moderator: Michael Esterman

35.11, *5:15 pm* **Neural mechanisms of incentive salience in naturalistic human vision** Clayton Hickey[1,2] (clayton.hickey@unitn.it), Marius Peelen[1]; [1]Center for Mind / Brain Sciences, University of Trento, Italy, [2]VU University Amsterdam, The Netherlands

What role does reward play in real-world human vision? Reward coding in the midbrain is thought to cause the rapid prioritization of reward-associated visual stimuli. However, existing evidence for this incentive salience hypothesis in vision is equivocal, particularly in naturalistic circumstances, and little is known about underlying neural systems. We used human fMRI to test the idea that reward will prime perceptual encoding of naturalistic visual stimuli and to identify the neural mechanisms underlying this function. Twenty participants detected examples of cued object categories - trees, cars, or people - in briefly presented images of cityscapes and landscapes. For each participant, one category of stimuli was special: when this object was the cued target, correct detection of a category example resulted in a cash payout. Using multivoxel pattern analysis we found that visual cortex carried more information about such reward-associated targets than reward-neutral targets. In contrast, when participants were cued to search for one of the reward-neutral categories, but the scene contained an example of the reward-associated category as distractor, encoding of information about the reward-associated stimulus was strongly suppressed. The strength of this suppression could be predicted by the magnitude of distractor-evoked activity in the dopaminergic midbrain and a connected cortical network, as well as by participant scores on a personality inventory indexing trait reward sensitivity. Examples of a reward-associated object category thus become visually salient, creating the need for attentional suppression when they are task irrelevant. The dopaminergic midbrain appears to mediate this effect, suggesting an interaction between the neural systems responsible for reward processing and visual perception in the human brain.

Acknowledgement: Netherlands Organization for Scientific Research (NWO) Autonomous Province of Trento, Italy

35.12, *5:30 pm* **Money on my mind: reward induces differential neurocognitive strategies during a sustained attention task** Michael Esterman[1,2] (esterman@bu.edu), Kathryn Russo[1], Guanyu Liu[1], Francesca Fortenbaugh[1], Joseph DeGutis[1,3]; [1]Boston Attention and Learning Lab, VA Boston Healthcare System, [2]Department of Psychiatry, Boston University School of Medicine, [3]Department of Medicine, Harvard Medical School

Reward and motivation have powerful effects on cognition and brain activity, but less is known about how they impact sustained attention and the neural mechanisms supporting accurate performance over time. Using a sensitive measure of sustained attention, the gradual onset continuous performance task (gradCPT), we recently showed that multiple types of motivators substantially improved accuracy and reduced variability in performance. To investigate how both transient and sustained activity in task-positive attention networks support these behavioral effects, participants completed multiple fMRI runs of the gradCPT, where minute-long blocks alternated between a rewarded (motivated) and unrewarded (unmotivated) condition. During motivated blocks, task-positive regions in attention networks exhibited sustained increases in activity relative to unmotivated blocks, and further, these increases predicted future performance from moment-to-moment. This suggests that reward elicits proactive, sustained cognitive control. During unmotivated blocks, activation in these task-positive attention regions was restricted to transient responses to errors and periods of more erratic and error-prone performance ("out of the zone"). This suggests that without reward, subjects use a more miserly strategy, in which task-positive control is only summoned reactively, when most needed. Together, this demonstrates that greater activation in task-positive attention networks can be both an indicator of optimal and suboptimal performance. In contrast, we found that basal ganglia activity best tracked optimal performance across both intrinsic, within-block fluctuations (in and out of the zone) and reward-driven between-block fluctuations (motivated vs. unmotivated). These results support a nuanced view of how task-positive attention networks and subcortical regions are engaged strategically during both intrinsic and reward-driven fluctuations in sustained attention.

Acknowledgement: Career Development Award (1IK2CX000706-01A2) from the U.S. Department of Veterans Affairs Clinical Sciences Research and Development Program to M.E.

35.13, *5:45 pm* **Voluntary attention is selective in time: perceptual tradeoffs** Rachel Denison[1] (rachel.denison@nyu.edu), David Heeger[1], Marisa Carrasco[1]; [1]Department of Psychology and Center for Neural Science, New York University

Purpose: Temporal attention is the prioritization of visual information at specific points in time. We used a new experimental approach to test the hypothesis that voluntary temporal attention selects among successively appearing stimuli. This approach allowed us to evaluate whether attention enhances discriminability by redistributing limited attentional resources in time. Methods: On each trial, two Gabor stimuli (S1 and S2) were presented successively at the same peripheral location, with an SOA of 250 ms. Each stimulus was tilted slightly clockwise or counterclockwise, with independent tilts for S1 and S2. The amount of tilt was determined individually for each participant using a staircase procedure. An auditory pre-cue instructed participants in advance of each trial to attend to S1 or S2 (with 75% validity) or to both stimuli (via a neutral, uninformative pre-cue). A response cue instructed participants to report the orientation of either S1 or S2. A match between the pre-cue and response cue yielded a valid cue, a mismatch, an invalid cue. Results: Because two stimuli were presented on every trial and only the temporal allocation of attention varied, we could measure how temporal attention affected perception of both S1 and S2. Performance accuracy was higher for valid than for invalid cues for both S1 and S2 (n=10). We also observed main effects of both benefits for valid cues and costs for invalid cues, compared to neutral cues. Such perceptual tradeoffs between two stimuli due to attention are a hallmark of selectivity. Conclusion: Attending to one stimulus improves discrimination performance for that stimulus relative to other stimuli presented either slightly earlier or later in time,

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even when the stimuli are not masked and there is no uncertainty about stimulus timing. We conclude that voluntary attention is selective in time.

Acknowledgement: NIH RO1 EY019693 to DJH and MC

35.14, *6:00 pm* **Mental tracking of dynamic features** Julian De Freitas[1] (julian.defreitas@psy.ox.ac.uk), Nicholas Myers[1,2], Anna Nobre[1,2]; [1]Department of Experimental Psychology, University of Oxford, [2]Oxford Centre for Human Brain Activity, Department of Psychiatry, University of Oxford

A temporarily occluded object is perceived as persisting through occlusion, emerging as the same unitary object. In the real world, an object's features are also often changing as they become occluded. However, it is unknown how the brain continues to keep track of such dynamic, invisible features, binding them to the correct objects. In a first case study of this question, we found that such featural information (dynamic orientation change) was mentally extrapolated forwards in time (E1). This effect scaled with the speed of the object (E2), occurred for both moving and stationary objects (E3), occurred only during free eye movements (E4), and is an effect of mental transformation (E5). These results demonstrate how the brain tracks a dynamic feature through 'gaps' of visual input.

Acknowledgement: Welcome Trust Grant

35.15, *6:15 pm* **Modelling the dynamics of visual attention under uncertainty** David Hoppe[1] (hoppe@psychologie.tu-darmstadt.de), Constantin Rothkopf[1,2]; [1]Technical University Darmstadt, Department of Psychology, Darmstadt, Germany , [2]Frankfurt Institute for Advanced Studies, Goethe University, Frankfurt, Germany

While several recent studies have established the optimality of spatial targeting of gaze in humans, it is still unknown whether this optimality extends to the timing of gaze in time-varying environments. Moreover, it is unclear to what extent visual attention is guided by learning processes, which facilitate adaption to changes in the world. We present empirical evidence for significant changes in attentive visual behavior due to an observer's experience and learning. Crucially, we present a hierarchical Bayesian model, that not only fits our behavioral data but also explains dynamic changes of gaze patterns in terms of learning. We devised a controlled experiment to investigate how humans divide their attentional resources over time among multiple targets in order to achieve task-specific goals. Eye movement data was collected from the participants. During each trial, three stimuli were presented on a computer screen arranged in a triangle. Each stimulus consisted of a small dot moving randomly inside a circular boundary. Participants were asked to detect when a dot exceeded its boundary. Subjects showed significant differences in allocation strategies over time that led to behavioral changes. The hierarchical Bayesian model captures the course of these changes. For example, in accordance with our computational model participants switched between the targets at a higher rate if the underlying dynamics were unknown (early trials). However, as more information about the statistics underlying the movement of the stimuli was collected (later trials) the switching rates decreased. Our model provides an explanation for these changes by linking them to different stages of learning the dynamics of the experiment. The ideal learner proposed in this work extends the ideal observer underlying many computational approaches to understanding visual attention by taking hierarchical learning effects into account.

35.16, *6:30 pm* **Human visual response gain increases with arousal** Dongho Kim[1,2] (kimdh@bu.edu), Savannah Lokey[1], Jianfei Guo[1], Franco Pestilli[3], Sam Ling[1,2,4]; [1]Dept. of Psychological & Brain Sciences, Boston University, [2]Center for Computational Neuroscience and Neural Technology, Boston University, [3]Dept. of Psychological & Brain Sciences, Indiana University, [4]Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, The Netherlands

How do states of arousal affect perception? Large gains have been made in characterizing how top-down processes, such as attention, influence vision. However, measurements of the effects of arousal on human perception are relatively limited and the underlying mechanisms remain surprisingly far less understood. Here, we examine the modulatory role of arousal on one of the cornerstones of vision: the contrast response function. To do so, we measured contrast psychometric functions in two groups of subjects. One group – high-arousal – was asked to refrain from eating and drinking for 5 hours prior to the experiment. The other group – low-arousal – was allowed normal access to eating and drinking and was given water prior to the experiment. During the experiment, both groups received drops of water at 80% probability coincident with stimulus presentation, throughout the experiment. Participants performed a fine orientation discrimination task on a grating shown at fixation, which varied in contrast from trial-to-trial. Water during the experiment aroused participants differently depending on deprivation history: when deprived, water drops led to high levels of arousal, when satiated, water drops led to lower levels of arousal. Results reveal that participants in the high-arousal group yielded psychometric functions that saturated (Rmax) significantly higher than the low-arousal group, consistent with an increase in the response gain of the underlying contrast response. However, we found no difference in the semi-saturation constant (C50) between the two groups. These findings are in line with reports from animal models showing a multiplicative effect of alertness on the contrast response function in LGN neurons (Cano et al., 2006). and suggests that arousal alters early visual perception by mitigating suppressive neural activity, thereby boosting neural responsivity and perceptual sensitivity.

35.17, *6:45 pm* **The Identity-Location Binding Problem** Piers Howe[1] (pdhowe@unimelb.edu.au), Adam Ferguson[1]; [1]School of Psychological Sciences, University of Melbourne, VIC 3010

The effortlessness of vision belies the challenges faced by the visual system. Different attributes of an object, such as its colour, shape, size and location, are often processed independently, sometimes in different cortical areas. The results of these separate analyses have to be combined before an object can be seen as a single coherent entity and not just a collection of unrelated attributes. Without visual binding you can be aware of the individual object attributes but binding is required for you to be able to perceive whether or not a given object has a particular combination of these attributes. Visual bindings are typically initiated and updated in a serial fashion, one object at a time. In contrast to this, here we show that one type of binding, location-identity binding, can be updated in parallel. The location-identity binding problem is the problem of knowing which objects are where in the visual scene. Using complementary techniques, the simultaneous-sequential paradigm and systems factorial technology, we examine the computational processing that underlies the updating of these bindings. Although these techniques make different assumptions and rely on different behavioral measures, both came to the same conclusion. Our findings are surprising, strongly constrain several theories of visual perception and help resolve an apparent conflict in the field.

35.18, *7:00 pm* **Who wins the race for consciousness? Ask the phase of ongoing ~7Hz oscillations.** Marina Inyutina[1,2] (marinainy@gmail.com), Hsin-Mei Sun[3], Chien-Te Wu[3], Rufin VanRullen[1,2]; [1]Université de Toulouse, CerCo, Université Paul Sabatier, Toulouse, France, [2]CNRS, UMR 5549, Faculté de Médecine de Purpan, Toulouse, France, [3]School of Occupational Therapy, College of Medicine, National Taiwan University

Most visual stimuli enter perceptual consciousness when they enter the visual field. However, in some cases, such as during Motion-Induced Blindness (MIB), a stimulus spontaneously disappears and re-enters consciousness without any external cause. We have previously shown that the latter type of conscious access is faster by ~100ms than the former, even after sensory latencies are accounted for (Wu et al., Current Biology, 2009). This leads to a surprising temporal reversal in which a sudden transient, such as a color change in a MIB-suppressed target, can cause the target to return to consciousness, yet will often be perceived to occur later: the target reappears with its old color and then changes to the new one. In the race for consciousness, old unconscious information leads against new information. Where does this lead come from, and what factors affect it? We hypothesized that brain oscillations, which have been suggested to play a role in establishing, maintaining and suppressing conscious representations, could affect the magnitude of the lead. To assess this, we recorded EEG while observers (N=16) viewed an MIB display. At a fixed delay after the reported perceptual disappearance of the green target, we abruptly changed its color to purple, resulting in the near-instantaneous return of the target to consciousness. After each trial, observers reported the target color at the time of reappearance. As found previously, an illusory reversal (old-color first) happened on a significant proportion of trials (45%). Crucially, the phase of ongoing 6-7Hz EEG oscillations significantly affected this proportion: at some phases the old information was more likely to win, while the new information was favored at the opposite phase. Over centro-parietal electrodes, where this effect was maximal, the modulation strength reached 14.5%. We conclude that the race for consciousness is decided on a rhythmic basis, with ~150ms-long cycles.

Acknowledgement: M Inyutina and R VanRullen are supported by an Agence Nationale de la Recherche grant (ANR-12-ISV4-0001-01) and ERC Consolidator Grant P-CYCLES (614244), HM Sun and CT Wu are supported by the National Science Council of Taiwan grant (NSC 102-2923-H-002-002-MY3).

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Scene Perception: Mechanisms and models

Sunday, May 17, 5:15 - 7:15 pm
Talk Session, Talk Room 2
Moderator: Melissa Vo

35.21, *5:15 pm* **The contributions of central and peripheral vision to scene gist recognition with a 180° visual field** Lester Loschky[1] (loschky@ksu.edu), Muriel Boucart[2], Sebastien Szaffarczyk[2], Clement Beugnet[2], Alicia Johnson[1], Jia Li Tang[1]; [1]Psychological Sciences, Kansas State University, [2]CHRU Lille, Hôpital Roger Salengro, service EFV, Lab. Neurosciences fonctionnelles & pathologies

In current theories of scene perception, the construct of scene gist plays a critical role in guiding attention, facilitating object recognition, and influencing memory. Yet an important and frequently overlooked issue in research and theory on scene gist is the relative contributions of central versus peripheral vision in its acquisition. The current study investigated this issue, while testing how well the conclusions of Larson and Loschky (2009) generalize to more realistic viewing conditions. Larson and Loschky used 27° x 27° images (i.e., maximum retinal eccentricity = 13.5°--near peripheral vision), whereas the current study used a 180° (H) x 40° (V) screen (i.e., maximum eccentricity = 90°--the extreme periphery). We similarly used the Window/Scotoma paradigm, comparing perception of full scenes centered at fixation versus scenes viewed through a "Window" (circular region centered at fixation, with no imagery outside the circle), or a "Scotoma" (the inverse--a blank circular region centered at fixation, with normal imagery outside the circle). Window radii varied from 1-24°, Scotoma radii varied from 10-70°, with both compared to the full image. We flashed images for 33 ms and ensured central fixation using an eyetracker. Stimuli were 512 full color panoramic photographs in 8 basic level scene categories. The results confirmed the main findings of Larson and Loschky (2009) but more dramatically. First, peripheral vision was more important for scene gist than central vision. Removing all information ≤ 30° eccentricity was equal to viewing the entire image, but showing only information within the central 5° eccentricity was significantly worse. Second, although central vision was less important, it was far more efficient than peripheral vision in terms of scene gist extracted per image pixel viewed. Window and Scotoma regression slopes for non-asymptotic proportion accuracy as a function of proportion of image shown were 9.55 versus 1.05, respectively.

35.22, *5:30 pm* **Two distinct scene processing networks connecting vision and memory** Christopher Baldassano[1] (chrisb33@cs.stanford.edu), Andre Esteva[1], Diane Beck[2], Li Fei-Fei[1]; [1]Department of Computer Science, Stanford University, [2]Psychology Department and Beckman Institute, University of Illinois Urbana-Champaign

Research on visual scene understanding has identified a number of regions involved in processing natural scenes, but has lacked a unifying framework for understanding how these different regions are organized and interact. We propose a new organizational principle, in which scene processing relies on two distinct networks at the edge of visual cortex. The first network consists of the Transverse Occipital Sulcus (TOS, or the Occipital Place Area) and the posterior portion of the Parahippocampal Place Area (PPA). These regions have a well-defined retinotopic organization and do not show strong memory or context effects, suggesting that this network primarily processes visual features from the current view of a scene. The second network consists of the caudal Inferior Parietal Lobule (cIPL), Retrosplenial Cortex (RSC), and the anterior portion of the PPA. These regions are involved in a wide range of both visual and non-visual tasks involving episodic memory, navigation, imagination, and default mode processing, and connect information about a current scene view with a much broader temporal and spatial context. We provide evidence for this division from a diverse set of sources. Using a data-driven approach to parcellate resting-state fMRI data, we identify coherent functional regions corresponding to scene-processing areas. We then show that a network clustering analysis separates these scene-related regions into two adjacent networks, which exhibit sharp changes in connectivity properties across their narrow border. Additionally, we argue that the cIPL has been previously overlooked as a critical region for full scene understanding, based on a meta-analysis of previous functional studies as well as diffusion tractography results showing that cIPL is well-positioned to connect visual cortex with many other cortical systems. This new framework for understanding the neural substrates of scene processing bridges results from many lines of research, and makes specific predictions about functional properties of these regions.

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35.23, *5:45 pm* **Functions Provide a Fundamental Categorization Principle for Scenes** Michelle Greene[1] (mrgreene@stanford.edu), Christopher Baldassano[1], Andre Esteva[2], Diane Beck[3], Li Fei-Fei[1]; [1]Stanford University, Department of Computer Science, [2]Stanford University, Department of Electrical Engineering, [3]University of Illinois Urbana-Champaign, Department of Psychology

How do we know that a kitchen is a kitchen by looking? Here we start with the intuition that although scenes consist of visual features and objects, scene categories should reflect how we use category information. In our daily lives, rather than asking ourselves whether we are in (for example) a "beach" scene, we tend to use scene category information for actions such as navigation and search. Because we act within scenes, we test the hypothesis that scene categories arise from scene functions. We collected a large-scale scene category similarity matrix (5 million trials) by asking observers to simply decide whether two images were from the same or different categories. To serve as a noise ceiling (maximum possible correlation) for comparison among computational models, we used boostrapping to compute the correlation among observers (r=0.75). Using the actions from the American Time Use Survey, we normed these scenes by what actions could be done in each scene (1.4 million trials). We found a strong relationship between category distance and functional distance (r=0.50, or 66% of the maximum possible correlation from noise ceiling). Furthermore, the function-based model outperformed alternative models of object-based similarity (r=0.33), visual features from a convolutional neural network (r=0.39), lexical distance between category names (r=0.27), and models of simple visual features such as color histograms (r=0.09), gabor wavelets (r=0.07), and gist descriptor (r=0.11). Using hierarchical linear regression, we found that functions captured 85.5% of overall explained variance, with nearly half of the explained variance captured only by functions, implying that the predictive power of alternative models was due to their shared variance with the function-based model. These results challenge the dominant school of thought that visual features and objects are sufficient for categorization, and provide immediately testable hypotheses about the functional organization of the human visual system.

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35.24, *6:00 pm* **A model of surface depth and orientation predicts BOLD responses in human scene-selective cortex** Mark Lescroart[1] (mark.lescroart@berkeley.edu), Jack Gallant[1]; [1]Helen Wills Neuroscience Institute, University of California, Berkeley

A network of areas in the human brain—including the Parahippocampal Place Area (PPA), the Occipital Place Area (OPA), and the Retrosplenial Cortex (RSC)—represent visual scenes. However, it is still unclear whether these areas represent high-level features (such as local scene structure or scene category), or low-level features (such as high spatial frequencies and rectilinear corners). To better characterize the representation of visual features in PPA, OPA, and RSC, we define several feature spaces hypothesized to be represented in scene-selective areas, and use them to predict brain activity. The feature spaces we define reflect scene structure (3D orientation of large surfaces), scene expanse (distance from visible surfaces to the virtual camera), and local spatial frequency (Gabor wavelet transformations) of each rendered scene. We fit each feature space to BOLD fMRI data recorded while human subjects viewed movies of a virtual world rendered using 3D graphics software. The graphics software allows us to quantify scene structure and expanse with continuous parameters instead of categorical labels such as "open" or "closed". We fit models for all feature spaces using L2-regularized regression, and evaluate each model based on how much response variance it predicts in a withheld data set. The scene structure model explains more response variance in our data than the scene expanse and local spatial frequency models. A hybrid model that combines surface orientation and distance from the virtual camera explains still more variance. These results are consistent whether subjects attend to the size of each scene or to the number of objects in each scene. Together, these results suggest that PPA, OPA, and RSC represent conjunctions of the depth and orientation of walls, ceilings, and other large objects in scenes.

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35.25, *6:15 pm* When scenes and words collide: Irrelevant background scenes modulate neural responses during lexical decisions. Melissa Vo[1] (mlvo@psych.uni-frankfurt.de), Tim Cornelissen[1], Sabine Oehlschlaeger[1]; [1]Scene Grammar Lab, Department Psychology, Goethe University Frankfurt

Usually, linguistic operations and visual-perceptual operations are studied separately in domain-specific experimental paradigms. However, there has been evidence that language and image processing interact behaviorally in a purely linguistic task (Võ & Wolfe, VSS 2014). Here we test whether brain responses during lexical decisions are modulated by an irrelevant, visual background scene, via analysis of EEG signals. Participants were presented with a background scene and a location cue before a string of letters appeared at the pre-cued scene location. The sole task was to decide whether the letter string formed a word or non-word. Words could either be congruent with the scene ('SOAP' on sink), semantically incongruent ('EGG' on sink), syntactically incongruent ('SOAP' on towel rack – i.e., semantically congruent but it in a wrong relative location), or double-incongruent ('EGG' on towel rack). We found that words that were semantically incongruent with respect to the background scene triggered a negative deflection compared to the consistent words about 400ms after word onset. In the language domain, this N400 response is known to signal difficulties in the semantic integration of a word with its sentence context. Interestingly, this incongruity effect between scene and words was more pronounced on left- rather than right-hemispheric electrodes, possibly due to the involvement of linguistic processes. Semantically congruent words presented in improbable scene locations, on the other hand, did not significantly affect brain responses. Thus, the syntactic placement of a word on an irrelevant background scene did not modulate neural responses to the extent that semantically incongruent words did. We conclude that a brief visual scene preview — even if task-irrelevant — automatically interacts with linguistic operations on at least the semantic processing level. Therefore, language and visual scene processing may share common parsing mechanisms that are efficiently integrated to function as a unitary whole.

Acknowledgement: Deutsche Forschungsgemeinschaft (DFG) Grant VO 1683/2-1 to M. L.-H. Vo

35.26, *6:30 pm* Laminar communication in V1 at ultra-high field fMRI Luca Vizioli[1] (Luca.Vizioli@glasgow.ac.uk), Lars Muckli[1]; [1]Centre for Cognitive Neuroimaging, Institute of Neuroscience and Psychology, University of Glasgow.

Ultra-high field fMRI provides the unique opportunity to record brain activation at sub-millimeter resolution. It is thus possible to reconstruct different cortical depth layers within primary and early visual cortices. Here we investigated how neural activity transfers across different cortical depth layers in V1. Specifically we ask whether thalamo-cortical, and cortico-cortical triggered responses lead to different inter-laminar communication patterns. To address this issue we used previously recorded data (Muckli et al., 2014), that were acquired to investigate laminar sensitivity to cortico-cortical contextual information. Using a visual occlusion paradigm these data showed that in the absence of thalamic input to V1, outermost layers hold meaningful contextual information about the immediate visual environment.The current data set encloses the BOLD signal of 4 participants while they were viewing images of natural scenes. To isolate non-thalamic-related activity, retinal input to a selected portion of V1 was blocked by occluding the bottom right quadrant of the images. Our analysis focused on a subpopulation of V1 voxels obtained by retinotopically mapping the cortical representation of the occluded area. We used two simple linear encoding models to assess the preferential tuning of individual voxels to contextual information. This approach provided additional evidence that outermost layers exhibit the largest concentration of voxels sensitive to contextual information. We also iteratively trained support vector machines (SVM) on each layer and tested on the remaining 5, independently for feed-back (i.e. neural activity triggered by occluded images) and feed-forward (i.e. neural activity triggered by non-occluded images) signals. We found feed-forward cross-layer SVM accuracy was highest in the mid layers; and feed-back cross-layer SVM accuracy was highest in the outermost layers. In line with animal models, these results suggest that mid-layer communication is prominent during feed-forward processing, while outer layers interact mostly during feed-back.

Acknowledgement: European Research Council (ERC)

35.27, *6:45 pm* P-imaging: a technique for comparing visually evoked population responses across visual areas and subjects Karl Zipser[1] (karlzipser@berkeley.edu), Kendrick Kay[2]; [1]Helen Wills Neuroscience Institute, U.C. Berkeley, CA 94709, [2]Department of Psychology, Washington University, St. Louis, MO 63130

A distinct advantage of fMRI is the ability to study activation in multiple visual areas simultaneously. However, the sheer number of units (voxels) from which measurements are obtained raises the question of how to devise analyses that preserve the native resolution of the data (i.e. single voxels) while still maintaining tractability. Furthermore, comparing response properties across visual areas is challenging due to the convoluted anatomical structure of cortex. These problems are exacerbated when attempting to compare and contrast brain responses from different individuals. To address these problems, we propose a technique called 'P-imaging' in which functional activity measurements are projected onto stimulus space. This projection is carried out based on an estimated receptive field for each unit. P-imaging allows visualization of activation across all units present in a given visual area, comparison of activation across visual areas within a subject, as well as comparison of results from different subjects. These capabilities facilitate interpretation of response activations, especially for complex visual stimuli. Moreover, P-imaging can be used to quickly and effectively compare measurements of activity for a set of voxels against predictions of activity for the same voxels based on a computational model. We apply P-imaging to a previously acquired fMRI dataset in which a large set of natural scenes were presented to three subjects. We find striking similarity of the population responses of V1 and V2 to individual scenes within and across subjects. We also show that a simple model of texture-energy integration accounts for much of the data in these early visual areas. However, we discover some discrepancies: human faces tend to evoke stronger responses than predicted by the model, and extended contours and extended periodic patterns evoke weaker responses than predicted by the model. These observations support revisions to standard models of early visual cortex.

35.28, *7:00 pm* Human and monkey detection performance in natural images compared with V1 population responses Yoon Bai[1] (yoonbai@utexas.edu), Yuzhi Chen[1], Wilson Geisler[1], Eyal Seidemann[1]; [1]Center for Perceptual Systems, University of Texas at Austin

Detection is a fundamental task that is critical to visual behavior. Our aim here was to measure and model behavioral and neurophysiological performance for detection of targets under naturalistic conditions. We first measured behavioral detection performance in three humans and two macaque monkeys. Localized oriented stimuli were presented for 250 ms and contrast psychometric functions were measured on uniform backgrounds and for several contrasts of the natural image backgrounds. We found that (i) threshold contrast power is a linear function of background contrast power for both humans and macaques, and (ii) the relative threshold functions (the ratio of thresholds under natural and uniform background as a function of background contrast) for humans and macaques are in good agreement, although (iii) the macaques are less sensitive overall. Subsequently, we used voltage-sensitive dye imaging (VSDI) to measure the neural population activity in V1 for the same stimuli, while the monkeys held fixation. The spatial scale of VSDI measurements was sufficient to resolve orientation columns over the whole region activated by the target. The average VSDI response to high-contrast targets on a uniform background was used to define a "matched template". Then, for each condition we applied the template to the responses on target + background trials and background alone trials and computed the signal-to-noise ratio (d'), which specifies the neurometric functions. We found that (i) the threshold contrast power for the VSDI responses is also linear with background contrast power and (ii) the relative thresholds for the VSDI responses are in fairly good agreement with the human and macaque behavioral thresholds. Conclusions: the macaque is a good model of human detection behavior in natural images, and population responses at the columnar scale in V1 predict behavioral detection performance in natural images.

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Sunday Afternoon Posters

Perceptual Organization: Models and neural mechanisms

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

36.3001 Brain Activity in Response to Visual Symmetry

Marco Bertamini[1] (m.bertamini@liv.ac.uk), Alexis Makin[1], Letizia Palumbo[1], Giulia Rampone[1], Damien Wright[1]; [1]Department of Psychological Sciences, University of Liverpool, Liverpool, U.K.

Research on the neural basis of symmetry perception is making rapid progress. ERP studies reliably show a sustained posterior negativity (SPN), with lower amplitude for symmetrical than random patterns at occipital electrodes, beginning around 250 ms after stimulus onset. Functional MRI shows activity in extrastriate visual areas and in the lateral occipital complex (LOC). We summarise and integrate the evidence by answering six questions. (1) Is there an automatic and sustained response to symmetry in visual areas? Yes, and because this is broadly unaffected by the task it suggests automatic processing of symmetry. (2) Which brain areas are involved in symmetry perception? There is an extended symmetry-sensitive network in extrastriate visual areas and the LOC. (3) Is bilateral reflection special? Reflection is the optimal stimulus for a general regularity-sensitive network that responds also to rotation and translation. (4) Is the response to symmetry independent of view angle? When people classify patterns as symmetrical or random, the response to symmetry is view-invariant. When people attend to other dimensions, the network responds to residual regularity in the image. (5) Does the neural response to symmetry scale with degree of regularity? Yes, the proportion of symmetrically positioned elements predicts the size of SPN and fMRI responses (see attached Figure). Finally, (6) Are connections between the hemispheres especially important for symmetry perception? No. SPN amplitude increases with the number of axes, and is comparable for horizontal and vertical symmetry. Overall, these studies of the brain mechanisms involved in symmetry perception show a consistent link between brain activity and measures of sensitivity from psychophysical studies.

Acknowledgement: Grant from the Economic and Social Research Council (ESRC, Ref. ES/K000187/1)

36.3002 Decoding the neural representation of size using multivariate pattern analyses and high density electroencephalography

Christopher Blair[1] (netiger@hotmail.com), Ryan Mruczek[1], Gideon Caplovitz[1]; [1]University of Nevada, Reno

In recent years a number of exciting fMRI studies have highlighted the role of primary visual cortex in the representation of the perceived size of objects. Several studies have now demonstrated that an object's perceived size, independent of its retinal size, is correlated with functional and anatomical aspects of V1. These results have been surprising, given previous assumptions about the retinotopic nature of V1 processing. What remains fundamentally unknown is whether these representations of the perceived size of objects are originating in V1 and propagating in a feed-forward manner to the rest of the visual system, or if representations of an object's perceived size may first originate in higher level visual areas before feeding back to V1. Unfortunately, fMRI lacks the temporal resolution to directly address this question. Here we explore the viability of High Density EEG as a potential tool for resolving this question. EEG offers the necessary temporal resolution, and when combined with Dipole Source Localization, has the potential to identify neural correlates of perceived size throughout visual cortex . We demonstrate an important first step in determining whether EEG can reveal neural correlates of perceived size: the classification of retinal size with ms temporal resolution. Using a 256 channel High Density EEG system, event related potentials were evoked by either small or large circles presented within Ebbinghaus-type arrays. Multivariate pattern analyses performed on the electrode data could successfully distinguish between small and large target circles. This suggests that HD-EEG may indeed be a plausible approach for addressing questions related to the representation of perceived size.

Acknowledgement: 1R15EY022775, 1P20GM103650

36.3003 Neural responses to naturalistic movies in the common marmoset using electrocorticography and fMRI

ChiaChun Hung[1,2] (aldenhung@gmail.com), Julian Day-Cooney[1], Brian Russ[1], Cecil Yen[2], Lucia Notardonato[2], Afonso Silva[2], David Leopold[1,3]; [1]Section on Cognitive Neurophysiology and Imaging, Laboratory of Neuropsychology, National Institute of Mental Health, [2]Cerebral Microcirculation Section, Laboratory of Functional and Molecular Imaging, National Institute of Neurological Disorders and Stroke, [3]Neurophysiology Imaging Facility, National Institute of Mental Health, National Institute of Neurological Disorders and Stroke, National Eye Institute

The common marmoset (Callithrix jacchus) is a New World monkey that has shown promise as a model for visual neuroscience. Recently we identified several face-selective patches along the occipitotemporal cortex whose configuration resembles those of macaque. Here we investigated neural responses inside and outside face patches during free viewing of naturalistic stimuli. Three awake marmosets actively viewed dynamic videos of socially interacting monkeys as their eye position was monitored. In two animals, electrocorticography (ECoG) was used to measure neural activity over an uninterrupted swath of the visual cortex spanning V1 to TE. In the other monkey, whole brain fMRI was carried out during the viewing of the same movies. The ECoG and fMRI data were recorded over multiple repetitions of 15-minute movies. In the main analysis, we created low-level (e.g. luminance, contrast, motion) and high-level (e.g. faces, bodies, scenes) feature models extracted from the evolving content in each of the movies. We then generated functional maps, based on the similarity between neural/hemodynamic time courses and feature models. This analysis revealed robust principles of cortical processing based on both ECoG and fMRI results. First, a subset of areas in the early ventral visual pathway were driven strongly by the changing contrast of the videos, with the proportion of variance explained by this factor falling off in a posterior to anterior gradient. Second, motion signals drove large regions of the visual cortex, particularly in regions dorsal to the contrast-driven regions in and around the shallow superior temporal sulcus. Third, several face patches could be extracted in the fMRI data based on the face feature time course. We will present these and related findings as part of a larger exploration of the brain activation under naturalistic viewing conditions.

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36.3004 fMRI decoding reveals neural representations of grouping in ventral visual cortex

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In everyday visual object perception, simple shapes are often combined to form complex ones according to Gestalt grouping principles. However, how grouping between shapes is implemented at the neural level and where in the human brain different types of grouping are encoded are not fully understood. In this study, using fMRI multi-voxel pattern analysis (MVPA), we examined the neural representation of grouping by spatial connectedness and temporal synchrony in the ventral visual cortex of the human brain. Specifically, in pre-defined regions of interest, we obtained fMRI response patterns for two shapes shown either (1) spatially connected and presented simultaneously, (2) spatially disconnected and presented simultaneously, or (3) spatially disconnected and presented asynchronously. We also obtained fMRI response patterns for each shape shown alone. We then linearly combined the patterns for the individual shapes and tested the similarity between our synthesized two-shape patterns and the actual two-shape patterns using a linear classifier. Gestalt principles have argued that grouping results in the whole to be different from the sum of the parts. This would predict that the difference between the actual and the synthesized two-shape patterns would be greater for the grouped than the ungrouped shapes. With this approach, we observed grouping by spatial connectedness and temporal synchrony in multiple retinotopic areas as well as the lateral occipital region. These results demonstrate the feasibility of using fMRI MVPA to study the neural representation of Gestalt grouping.

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36.3005 Scene Categorization: The Good, The Bad and The Early

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Humans are extraordinarily quick at processing natural scenes. Furthermore, good exemplars of natural scene categories are not only categorized more easily but are also more readily detected than bad exemplars. However, it remains unclear when and how this good exemplar advantage arises. To address this question, we measured event-related potentials (ERPs) while participants viewed (and made a delayed judgment about) good and bad exemplars of six scene categories: beaches, city streets, forests, highways, mountains and offices. Good and bad exemplars first evoked differential ERPs 250 to 350ms after onset, with bad exemplars producing greater frontal negativity than good exemplars. This effect is consistent with the N3 complex, previously associated with global structure in an image. The results thus indicate that structural processing is easier for good than for bad exemplars. Good exemplars then elicited a larger late positive complex (LPC) response, likely reflecting more confident judgments for these items. Furthermore, the separation between natural vs. man-made ERP waveforms was both earlier and larger in amplitude for good exemplars as compared to bad exemplars. Overall, the results indicate that the good exemplar advantage may not only extend to eased cognitive processing, but also to perceptual processing, having its roots in higher order visual processing and possible feedback to lower level processing areas

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36.3006 Towards a complete forward prediction from visual stimulus to BOLD.

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Functional magnetic resonance imaging (fMRI) has become a standard tool in vision science, and some properties of visual cortex are fairly well understood and modelled, such as retinotopic organisation, contrast response functions and the spatiotemporal Hemodynamic Response Function (stHRF). Here we combine these individual models into a new framework, integrating existing models. The key components are (i) retinal processing; (ii) accurate retino cortical projection (Schira et al 2010); (iii) neural responses; and a (iv) spatiotemporal hemodynamic modeling (Aquino et al. 2012 PLoS CB), combined to a modular toolbox. We argue that the result is greater than the sum of its parts, allowing the complete simulation of fMRI experiments, from visual input (video) to BOLD responses in space and time on an average cortical surface (FS_average) within a few minutes. This supports a number of novel applications. Firstly, exploring interactions between the models and generating exact predictions for a more realistic testing of each of the integrated models. Secondly, a more precise planning of fMRI experiments by generating concrete hypothesis in the space that is actually measured, such as estimating the effect of spatial and temporal interactions between multiple stimulus components. Thirdly, it provides a novel teaching tool, with approximately 5-10 minutes from stimulus video to simulated BOLD responses on a normal desktop computer.

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36.3007 Use of a prior to improving the retinotopic maps of individual subjects

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Recent advances in retinotopic modeling have led to the development of retinotopic template maps that depend only on the sulcal topology of the individual subject yet predict individual retinotopy with high accuracy (Benson et al., 2014, PLoS Comput. Biol. 10:e1003538). These templates are constructed via registration of the aggregate retinotopic map of many subjects to a retinotopic model and thus provide a strong prior for the retinotopic organization of an individual subject. We ask whether empirical retinotopic data measured in individual subjects combined with the template prior have greater prediction accuracy than template maps alone, empirical maps alone, and smoothed empirical maps. We examine the quality of retinotopic predictions in 28 subjects whose V1-V3 retinotopic maps were measured out to 10° (21 subjects), 20° (6 subjects), and 48° of eccentricity (1 subject) using fMRI. Refined templates were produced by registering the empirical map to a retinotopic model using the registration of the aggregate-based template map as the starting position for the registration. When the refined map derived from a low quality partial scan of a subject is compared to the empirical map derived from the remaining scan, we found that the refined templates (median absolute errors: 0.67° eccentricity, 20.34° polar angle) were more accurate than aggregate-based template maps (1.34° eccentricity, 20.55° polar angle). Additionally, the ability to predict the retinotopic organization outside of the extent of the stimulus is slightly improved in the refined templates (0.44° eccentricity, 18.03° polar angle) versus the aggregate templates (1.44° eccentricity, 21.10° polar angle). Finally, the refined maps have better representation of the vertical meridia than either empirical or smoothed empirical maps and eliminate the edge biases from smoothing. Combining a template model with measured data provides a better representation of an individual's retinotopic map than either data or template alone.

36.3008 Visual awareness is constrained by the functional organization of the higher-level visual system

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The limits of visual awareness are often attributed to a finite supply of visual attention (Chun & Wolfe, 2001) and processing constraints of the prefronto-parietal network (Dehaene & Changeux, 2011). Here, we investigate the extent to which the limits of visual awareness are related to representational constraints within the higher-level visual system. To measure the limits of visual awareness, we used two different behavioral paradigms that render stimuli invisible. In Experiment 1, we used visual masking to measure how well items from different categories mask one other (e.g., buildings masking cars). In Experiment 2, we used continuous flash suppression to measure how long it takes an item from one category (e.g., a face) to break through suppression by items from another category (e.g., bodies). We then used fMRI to measure the similarity of the neural responses elicited by those categories across the visual hierarchy and used representational similarity analysis (Kriegeskorte & Kievit, 2013) to compare the behavioral and neural results. In both experiments, we found that pairs of categories that strongly mask and suppress each other in behavior also elicit more similar neural response patterns. Brain/behavior correlations were strong within ventral occipital cortex (Exp. 1: r=0.84*; Exp. 2: r=0.64*) and lateral occipital cortex (Exp. 1: r=0.70*; Exp. 2: r=0.73*), weaker within occipitoparietal cortex (Exp. 1: r=0.52*; Exp. 2: r=0.44), and not significant within V1-V3 (Exp. 1: r=0.05; Exp. 2: r=-0.39). Together, these results show that the organization of higher-level visual cortex predicts the degree to which different stimuli will compete for visual awareness. We suggest that this organization imposes a limit on the capacity of visual awareness. Under this view, the extent to which items activate overlapping, capacity-limited neural channels constrains the amount of information that can be accessed by visual awareness.

36.3009 A retinotopic basis for the division of category selectivity into lateral and ventral regions

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High-level human visual cortex contains a repeated organization of category-selectivity on the lateral and ventral surfaces of occipitotemporal cortex. In general at least one region showing strong selectivity for each category is present on each surface. The reasons for this apparent redundancy and the mechanisms by which it is created are not well understood. Here, we argue this structure results from an extension of earlier retinotopic organization, and reflects not redundancy but distinct high-level visual representations of different locations in the visual field. Multiple independent tests were employed to measure retinotopic biases within scene-selective cortex. First, pRF mapping revealed that TOS and PPA exhibit a striking contralateral bias coupled with a pronounced upper field bias in PPA and lower field bias in TOS. Second, in an event-related experiment participants performed a demanding fixation task whilst images of scenes were presented randomly into one of the four quadrants of the visual field. Consistent with the pRF estimates, scene representations in PPA were strongest for the contralateral upper quadrant, whereas in TOS representations were strongest for the contralateral lower quadrant. Third, our behavioral experiment was based on our previous observation of a prominent open/closed distinction in the responses of PPA (Kravitz et al., 2011). Consistent with an upper field bias in PPA, we observed better behavioral performance in the upper than lower visual field when making open/closed but not manmade/natural judgments. Finally, we investigated the functional connectivity of PPA and TOS at rest. These data demonstrate that lateral and ventral scene-selective regions TOS and PPA contain functionally and behaviorally relevant biases for the contralateral lower and upper visual fields. These biases are not only consistent with anatomical projections in monkey, but are also evident in human object-selective areas, suggesting that retinotopic organization may determine the structure of category-selectivity in high-level visual cortex.

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36.3010 **Retinotopic organization of the primary visual cortex before and after pharmacological treatment for a large prolactinoma with compression of the optic chiasm** Alexandra Coros[1] (lexcoros@gmail.com), Philippe Chouinard[1,2], Stan Van Uum[3], Donald Lee[4], Alexander Fraser[5], Alain Proulx[5], Melvyn Foodale[1,6], Neil Duggal[7]; [1]The Brain and Mind Institute, The University of Western Ontario, [2]School of Psychological Science, La Trobe University, Bendigo, Victoria, Australia, [3]The University of Western Ontario, Department of Medicine , [4]The University of Western Ontario, Department of Medical Imaging, [5]The University of Western Ontario, Department of Ophthalmology, [6]The University of Western Ontario, Department of Psychology, [7]The University of Western Ontario, Clinical Neurological Sciences

Patients suffering from pituitary macroadenomas – pituitary tumors larger than 10mm – often have visual deficits, typically bilateral hemianopsia, because of chiasmal compression. Treatment of macroadenomas is usually successful, and thus such patients provide a unique opportunity for studying neuroplasticity in the human visual system and its consequences for vision. This case study focuses on patient BS, a 48-year-old man, who had a large prolactinoma, a common pituitary tumor, and, as a consequence, a severe visual field loss. We used functional magnetic resonance imaging (fMRI) to map the retinotopic organization of primary visual cortex (V1) of patient BS before and after successful treatment of his prolactinoma with cabergoline over the course of 13 months. In addition, we used the same fMRI protocol to examine the organization of V1 in a healthy age- and gender-matched control participant with normal vision. Humphrey's perimetry was used to assess the integrity of the visual fields, before and after the completion of treatment for patient BS, and over two successive scans in the healthy control. The Humphrey field exam revealed significant visual improvement after treatment and this recovery was accompanied by substantial changes in V1 activation. Before the start of treatment, the amount of cortical tissue in V1 which was activated by the retinotopic stimuli was only 21% that of the healthy control participant. After treatment, the amount of activation normalized to approximately 90% of that of the control participant. The organization of retinotopic representations in V1 also normalized after treatment. These results illustrate that the visual system is capable of repair following conservative medical treatment, opening the door for assessing the effects of compression on different components of the optic nerve and tract.

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36.3011 **Temporal framing in apparent motion perception cycles with a 12Hz (alpha) rhythm** Stephanie Morand[1] (stephanie.morand@glasgow.ac.uk), Joachim Gross[1], Gregor Thut[1]; [1]Institute of Neuroscience and Psychology, University of Glasgow, UK

Visual perception is periodic and structured in recurrent temporal frames. However, it is unclear whether these cycles simply reflect fluctuations of visual excitability, and/or organize perception into discrete moments of information integration in which two events falling within one frame are more likely to be perceived as causally linked. In 1981, Varela et al. probed temporal framing of perception by presenting two sequential flashes at a constant delay and found these flashes to be perceived as simultaneous or sequential depending on the phase of ongoing alpha (7-13Hz) oscillations. These results are still awaiting replication (VanRullen et al, 2014). We here tested periodicity of visual information integration in two behavioural experiments probing (i) simultaneity and (ii) apparent motion perception in double flash stimuli. We flashed two visual events either sequentially or simultaneously. In experiment 1, two dots were displayed in the left and right visual fields, while participants reported whether the events were perceived as sequential or simultaneous. In experiment 2, the two events consisted of random dot patterns that could be perceived as coherent motion, incoherent motion or glass patterns. These stimulus pairs were presented time-locked to a preceding sound (0-300ms delays), shown to reset the phase of visual brain oscillations (Romei et al., 2012). Spectro-temporal dynamics of behavioural time courses (hits) revealed periodicity in perception. Dots perceived as sequential (Group 1, n=19) and apparent motion perception (Group 2, n=19) showed identical, cyclic patterns in the 12Hz (alpha) frequency band (with a significant phase consistency across participants). In contrast, a cyclic pattern in the 4Hz (theta) band was observed in the control conditions (simultaneously presented stimuli), suggesting that the alpha cycles in visual perception go beyond reflecting fluctuations in visual excitability. These data suggest that perceptual frames in the alpha-band play a key role in spatio-temporal visual information integration.

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36.3012 **Competing for Dominance: Using Artificial Scotoma to Explore Figure-Ground Perception** Shruti Narang[1] (nshruti@uga.edu), Richard Plummer[1], James Brown[1]; [1]Department of Psychology, University of Georgia

Research suggests that biased competitive interactions of the Magnocellular (M)/dorsal and Parvocellular (P)/ventral pathways within and between figure and ground regions play an integral role in figure-ground perception/processing (e.g., Wong & Weisstein, 1986; Narang, 2014). Figure and ground regions are relatively more associated with, or biased towards P/ventral and M/dorsal respectively. In an artificial scotoma paradigm, the scotoma or target region (TR) initially seen as figure, becomes perceived ground when it fades. Whatever competition is across the figure/ground boundary signaling the TR as figure becomes replaced or overwhelmed by signals "from" the background. We examined if relatively biasing either M or P processing would alter the time course of figure-ground competition in an artificial scotoma paradigm. By manipulating temporal and chromatic characteristics of the background relative to the TR, we examined how M vs. P biased stimuli influenced the time-to-fade (TTF) in seconds. Conditions biasing TR processing towards P vs. M were expected to result in longer vs. shorter TTF respectively, while conditions biasing background processing towards M vs. P were expected to result in shorter vs. longer TTF respectively. A static, 2° square shaped TR was presented against a 26.7° x 17.2° random-dot background that was either static or flickering (20 fps). TR/background color combinations tested were: Gray/Gray; Gray/Green, Gray/Red, Red/Green, Red/Gray with trained observers indicating when the TR faded completely. Consistent with our hypotheses, significantly longer TTFs were found for (1) static vs. flickering backgrounds, (2) M-suppressing red backgrounds vs. gray or green backgrounds, and, (3) a red TR vs. a gray or green TR. Our results indicate an artificial scotoma paradigm may be a useful technique for studying the underlying mechanisms of figure/ground segregation. These experiments provide important new information about the competitive nature of the roles of the M&P pathways during figure-ground perception.

36.3013 **Electrophysiological responses to symmetry presented in the visual hemifields** Damien Wright[1] (Damien.Wright@liverpool.ac.uk), Alexis Makin[1], Marco Bertamini[1]; [1]University of Liverpool

When perceiving symmetry, an ERP component known as the Sustained Posterior Negativity (SPN) is produced. From around 250ms, amplitudes in posterior electrodes are more negative for symmetrical than random patterns (Makin et al., 2012). This component is thought to be spread over both hemispheres. A role for the corpus callosum has also been highlighted when symmetrical patterns are presented at fixation (Herbert & Humphrey, 1996). We tested this callosal hypothesis by measuring SPN response to peripheral stimuli. Twenty-four participants were presented with a reflection and a random dot pattern. Patterns were both either light or dark red in different trials, and participants made a colour discrimination. Patterns were presented to a single hemisphere by simultaneously positioning one to the left of the fixation cross and the other to the right. We contrasted trials where symmetry was on the left and random on the right, and trials where symmetry was on the right and random on the left. There are two ways to describe the results: Amplitude was lower in the hemisphere contralateral to the symmetrical pattern, than in the opposite hemisphere, contralateral to the random pattern. Put another way – we found an SPN within each hemisphere, where the SPN is defined as lower amplitude for reflection than random. This pattern of results shows that each hemisphere has its own symmetry processing mechanism, which is sensitive to symmetry in the contralateral visual field. This is in sharp contrast to the callosal hypothesis, which suggests a special role for cross-hemispheric connections in symmetry perception. References Herbert, A. M. H. & Humphrey, G. K. (1996). Bilateral symmetry detection: Testing a 'callosal' hypothesis. Perception, 25, 463-480. Makin, A. D. J., Wilton, M. M., Pec-

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36.3014 Relationships Between Indices of Retinal Thinning as Revealed by Spectral Domain Optical Coherence Tomography, and Visual and Cognitive Impairments in Schizophrenia

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Schizophrenia is a neuropsychiatric disorder in which visual processing abnormalities are common. An unanswered question in this field is the extent to which some of these functional impairments (e.g., contrast sensitivity) may be due to altered retinal structure and function. This question has gained in importance with two recent studies showing retinal nerve fiber layer (RNFL) thinning in schizophrenia, as revealed by spectral domain optical coherence tomography (SD-OCT). OCT is a noncontact imaging technology that can image retinal structure (including thickness) in vivo with a resolution of 10 microns or less using optical backscattering of light. It has been used to document RNFL thinning in neuropsychiatric disorders such as multiple sclerosis and Parkinson's disease. A second unanswered question in the schizophrenia literature is whether retinal abnormalities can serve as markers of global brain function. Because the retina and optic nerve are outgrowths of brain tissue, they are considered part of the central nervous system, and some past OCT studies in other neuropsychiatric disorders (e.g., multiple sclerosis, Parkinson's disease) indicate that retinal tissue loss parallels cortical degeneration and cognitive decline. This has not yet been investigated in schizophrenia, however, although progressive gray and white matter loss, and cognitive decline, have been repeatedly documented, especially early in the illness. To make progress on the above questions, we are generating SD-OCT data on RNFL and macular thickness, and determining relationships with visual acuity, contrast sensitivity, perceptual organization, and global cognitive capacity (expected sample sizes of 20 patients and controls each before VSS 2015). To date, 6 of 7 schizophrenia patients have demonstrated significant RNFL and/or macular thinning compared to control norms. Moreover, extent of thinning is significantly related to illness chronicity, controlling for age, and to poorer visual acuity. Relationships between OCT findings and visual and cognitive task performance will be reported.

Perception and Action: Pointing, tracking and catching

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

36.3015 Temporal evolution of theta and beta band activities during motor preparation reveals the reach endpoint formation process in a free pointing task

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Deciding 'where to go' is important for our volitional motor control, especially when the environment is uncertain. In a previous study we found that in a 'free' pointing task (pointing to a long horizontal line), the saccade onset was delayed by around 120 ms when subjects pointed to the line compared to when they pointed to a salient single dot, while the hand movement onset stayed the same in both conditions (Berret et al., 2014). It suggests that the knowledge about the target endpoint built up gradually along with the arm motor planning, and that the delaying of reach-related saccades is to gain more information to form the final target endpoint. In the present study we wanted to investigate the cortical activity during the target endpoint formation process in this 'free' pointing. We recorded EEG from 24 participants during both pointing to a line and to a dot, and found both the increase of fronto-parietal theta power (3-5 Hz) and the decrease of beta power (16–32 Hz) in supplemental motor area and posterior parietal area during motor preparation covaried with the saccade reaction time. These results confirm the suggested roles of theta band and beta band activities in motor preparation (Rawle et al., 2012; Tzagarakis et al., 2010). Furthermore, we found the difference in theta power between the two conditions occured earlier than the difference in beta power. The location, the timing, and the correlation with the target uncertainty suggest that theta and beta activities are likely involved in the target endpoint formation when we have to decide 'where to go' in a pointing task.

36.3016 People quickly adjust their movement if a more attractive option arises

Eli Brenner[1] (e.brenner@fbw.vu.nl), Jeroen Smeets[1]; [1]MOVE Research Institute, Faculty of Human Movement Sciences, VU University Amsterdam

It is well established that people can quickly adjust goal-directed movements to small changes in the target object's or obstacles' positions. When the target object changes orientation people can quickly adjust their decision about how they can best grasp it. Here we examine whether they also quickly redirect their movement to a completely different object if it is advantageous to do so, and if so, whether their decisions are consistent with the true advantages (i.e. do they make optimal choices). Subjects stood in front of a large screen. There was always at least one target on the screen. Their task was to tap on as many targets as possible within 2 minutes. After every tap, a new target appeared. Sometimes, a second target that was larger and nearer, and therefore easier to hit, appeared some time after the original target had appeared. We determined the time it took each subject to hit each kind of target, as well as whether they switched to the target that was easier to hit when there were two targets. We did so for various delays before the second target appeared. We found that subjects generally switched to the easier target whenever they could hit more targets by doing so. They considered the position of their hand at the moment the easy target appeared, as well as the overall advantage of the target being nearer and larger. We found no evidence of any additional cost of determining whether it was advantageous to switch to a different target. Thus, for this kind of simple movements, visual information is used very efficiently to direct our choices as well as to guide the movements themselves.

36.3017 Small head movements that accompany goal-directed arm movements provide various useful cues about the target's distance

Cristina de la Malla[1] (c.delamalla@gmail.com), Stijn Buiteman[1], Wilmer Otters[1], Jeroen Smeets[1], Eli Brenner[1]; [1]MOVE Research Institute, Faculty of Human Movement Sciences, VU University Amsterdam, The Netherlands

How a static object's position and orientation relative to oneself change when one moves one's head can be used to judge the object's distance. There are three distance cues that change when moving one's head: the direction of gaze that is required to fixate the object, the orientation of the object with respect to such a direction of gaze, and the object's position relative to distant objects in the retinal image. They do so to an extent that depends on the object's distance and on the magnitude of the head movement. When making goal-directed arm movements we inevitably move our head to some extent. To find out which, if any, of the above-mentioned cues influence distance judgments under such circumstances, we conducted a study in which participants had to move their index finger to virtual objects in the dark. The objects' sizes and positions varied across trials, with pairs of trials in which the same object was presented at the same location, except that one or more of the three above-mentioned cues was artificially manipulated to indicate that the object was either nearer or further away. We found that all three cues influence the movement endpoints, but the magnitude of the influence shows that the cues only contribute a few percent to the judged distance.

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36.3018 Visual motor control in patients with Parkinson's disease

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Although previous studies have suggested deteriorated visual motor control in patients with Parkinson disease (PD) is likely due to deficits in both the motor and perceptual systems, no study has directly measured such deficits and how antiparkinsonian medication improves visual motor control in PD patients. Here we took a control-theoretic approach to address

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these issues. We tested 20 PD patients ON and OFF mediation and 20 healthy controls with a typical manual control task. Specifically, in each 90-s trial, participants were instructed to use a joystick to control the movement of a red target to keep it centered on a CRT display (37°Hx21°V) as its horizontal position was perturbed by the sum of seven harmonically-unrelated sinusoids (0.1-2.19Hz). The time series of target position and joystick displacement were Fourier analyzed and averaged across six trials. The performance data were fit by an extensively validated Crossover Model (McRuer et al., 1965) to evaluate the deficits in PD patients' perceptual processing and motor control. We found that although antiparkinsonian medication improved visual motor control in PD patients, they still showed significantly decreased control precision (measured by RMS error) and response amplitude (gain) as well as increased response delay (phase) compared with the controls. Our model based analysis showed PD patients' deteriorated visual motor control was due to (1) impaired perceptual sensitivity to input visual information for online motor control, (2) impaired perceptual ability to anticipate the input error to generate control ahead of the error signal, and (3) decreases stability of the neuromuscular system. Surprisingly, antiparkinsonian medication improved the former two but did not help the latter, suggesting that the effect of the medication on visual motor control is primarily through improving perceptual processing. The findings have practical implications for developing assessment tools to evaluate the efficacy of different therapies for PD.

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36.3019 **An Action-specific perception effect that withstands feedback** Zach King[1] (kingzac@rams.colostate.edu), Nate Tenhudnfeld[1], Jessica Witt[1]; [1]Psychology, Natural Sciences, Colorado State University

The action specific perception approach claims that ability to act on a given task changes perception of task relevant stimuli. Critics of this claim argue that a response bias occurs, not perceptual changes. The current experiments minimized response bias by giving trial by trial feedback on speed judgments. Participants were trained on two anchor speeds, a fast ball and a slow ball, then played a computer-based game of tennis. The ball moved across the screen at various speeds between the two anchor speeds. Ability to act was manipulated by having either a large paddle or a small paddle with which to block the ball. After each attempt to block the ball, participants performed a speed judgment task. Participants typically perceive the ball to move faster when using a small paddle than when they use a big paddle. We examined if this effect of paddle size on perceived speed would diminish or even be eliminated in the presence of feedback on speed judgments. In Experiment 1, participants completed pre-feedback, feedback, and post-feedback blocks with interleaved paddles size. Paddle size had a significant effect on speed judgments for all three blocks and did not diminish when feedback was given. Perhaps there was not enough feedback to alter responses, so in Experiment 2, participants received feedback during the entire experiment. Again, feedback did not diminish the effect of paddle size on speed judgments. These results support the claim that change in action ability affects perception, not response bias.

Acknowledgement: National Science Foundation

36.3020 **Distinct influences of size-contrast illusion on action preparation and execution** Christine Gamble[1] (christine_gamble@brown.edu), Joo-Hyun Song[1,2]; [1]Department of Cognitive, Linguistic and Psychological Sciences, Brown University, Providence RI, [2]Brown Institute for Brain Science, Brown University, Providence RI

Introduction: Many previous studies examining visually-guided actions within size contrast illusions have shown dissociation between vision for perception and vision for action. However, such investigations have focused almost exclusively on movement execution, ignoring other aspects of movement such as preparation. Additionally, the majority of these studies have examined grasping movements, with little research conducted on other types of hand movements like pointing, or other effectors such as the eyes. Methods: To determine the influence of illusion on movement preparation and movement execution in different forms of visually-guided action, we manipulated both physical and perceptual target size using a variation of the Ponzo illusion. Participants performed a two-alternative forced choice task in which they pointed and made saccadic eye movements to targets. We analyzed two aspects of both pointing and saccades: movement preparation, measured by initiation latency and movement execution, measured by movement time. Results: Across both tasks we found that the preparation leading to pointing and saccades was modulated by the perceived as well as the physical sizes of targets, while execution was influenced solely by physical size. Thus movement preparation fails to show the classic perception-action dissociation—measures of action being immune to illusion despite its influence on perception—while movement execution does show this dissociation. Furthermore, we showed that within participants the extent to which illusion influenced the preparation of saccades and reaching was significantly correlated. Conclusion: Thus, we suggest that a shared mechanism modulates the preparation of visually-guided action across the two effectors of pointing and saccades. We propose that this mechanism is responsible for illusion's influence on movement preparation but not movement execution. Our ongoing studies examining coordinated hand and eye movements further explore the influence of illusion on visually-guided action, and the relationship between the preparation and execution of individual action effectors.

36.3021 **Haptic plus auditory feedback help timing interceptive actions in the absence of late vision.** Joan Lopez-Moliner[1,2] (j.lopez-moliner@ub.edu); [1]Institute for Brain, Cognition and Behaviour (IR3C), [2] Universitat de Barcelona

Many studies in interceptive timing only consider visual information provided by the moving target in order to explain how action is executed and, largely ignore the contribution of the temporal and spatio-temporal reliability of the feedback. We address how these two aspects of the feedback affect action kinematics in intercepting virtual parabolic balls with the hand. In some sessions the feedback on successful timing was temporally reliable (a beep), but less robust in terms of the grip aperture at the time of the beep. In other sessions we gave spatio-temporal reliable feedback by providing haptic information through a tennis ball stuck on the data glove in addition to the beep. Within each session, we showed parabolic paths with four flight durations (0.606, 0.776, 0.945, 1.115 s) in two different viewing conditions (early and full vision). We expect to observe differences between type of feedback when subjects could not rely on online vision (early vision) to time their catch and rather had to plan the movement by anticipating the expected feedback. In full vision subjects started close the hand earlier when haptic feedback was provided but there were no differences between type of feedback in the velocity of the closing hand which was clearly bell-shaped denoting great capacity to anticipate the moment of the contact. However, when subjects only saw the initial 40% of the path, velocity profiles in the temporally-reliable condition were no longer bell-shaped, specially for paths with longer duration (i.e. longer blank period) which reflects less capacity to anticipate the contact. Interestingly, when haptic information was present grip velocity profiles were again bell-shaped as if subjects anticipated better the moment of contact. The spatio-temporal feedback seems to compensate a bit for the absence of late vision when planning interceptive movements.

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36.3022 **Lost in the Lights: The Effects of Glare on Catching Performance** Rob Gray[1] (robgray@asu.edu), Luke Wilkins[2]; [1]Human Systems Engineering, Arizona State University Polytechnic, [2]School of Sport, Exercise & Rehabilitation Sciences, University of Birmingham

It has long been observed that glare produced by bright external light sources can impair sports performance, however, empirical research on this topic is limited. The goals of the present study were to investigate the effects of glare on catching performance and to determine to what extent these effects could be predicted by clinical tests of vision. College baseball players caught balls varying in both speed and direction. Glare was produced by a spotlight above the ball with glare magnitude varied by changing the angle subtended by the ball and the glare source. Three glare angles (12, 15 and 18 deg) were compared to a no glare condition. At 12 deg, the presence of glare produced both delayed reaction times and spatial and temporal errors in catching, while only the errors occurred for larger glare angles. Glare susceptibility assessed using a low contrast visual acuity test significantly correlated with catching performance in only 3 out of 7 conditions in which significant effects of glare on catching were found. The presence of glare can produce problems both in detecting an approaching object and in judging its trajectory and time of arrival. Clinical vision tests will have limited effectiveness for evaluating glare interventions.

Eye Movements: Saccades and perception

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

36.3023 Low Spatial Frequency Suppression During Vertical Saccadic Eye Movements

Abhishek Mandal[1] (Abhishek.Mandal@gcu.ac.uk), Niall Strang[1], Velitchko Manahilov[1]; [1]Department of Vision Sciences, Glasgow Caledonian University

Purpose Contrast sensitivity reduction to low spatial frequency stimuli has previously been found to occur around the time of onset of both horizontal saccadic and vergence eye movements. In this study we aim to examine whether similar reductions in contrast sensitivity occur during vertical saccadic eye movements. Methods Contrast sensitivity during vertical saccadic eye movements were measured in six young optically corrected adults (Mean age (±SD) was 25.5 ± 7.5 years). We used vertical sinusoidal grating of 0.5c/deg as a test stimuli. Two computer generated white fixation crosses (4 deg above and below the horizontal) were used to initiate the vertical saccades. Infrared video eye tracker (EyeLink I) was used to record binocular eye movements. The test stimulus was presented at various time lags across the saccadic response range. Detection thresholds measured during the vertical saccade (single interval yes/no procedure and method of constant stimuli) was compared to static thresholds. Results Average onset latencies and velocities for vertical saccades in all experimental conditions did not differ significantly among subjects (mean latency = 166 ± 2.7ms, mean velocity = 194 ± 63deg/sec). A statistically significant reduction in contrast sensitivity was found in all subjects (mean reduction 0.24 ± 0.05, $p< 0.05$) around the onset (-50 to +100 ms) of the fixation change when compared to static condition values. Conclusion Reduced contrast sensitivity to low spatial frequency information was found around the onset of vertical saccadic eye movements. The magnitude and timing of the reduction is similar to previous values found during horizontal saccadic and vergence eye movements.

36.3024 What is visual remapping to saccade adaptation, a cause or a consequence?

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Introduction: Previous studies argue that saccade adaptation, traditionally induced by intrasaccadic step (ISS), remaps visual perception. Here, we ask whether saccadic vector alteration is cause or consequence of the perceptual remapping. For this reason, we applied ISS on a landmark near an unmoved saccadic target, and then tested subjects' localization performance and their saccadic gains towards the landmark, in two separate experiments. Methods: In Experiment 1, six subjects made delayed saccades (cued by offset of fixation point) to a target with a nearby landmark. Subjects used a mouse cursor to localize the post-saccadic position of the landmark, which in some trials disappeared on saccade onset (Landmark-Off) and in the others stayed on until the appearance of the cursor (Landmark-On). After a baseline period, the landmark underwent ISS. Experiment 2 was the same as Experiment 1, except subjects localized landmarks via saccades (with screen blanking on saccade onset to eliminate any feedback). When the saccadic goal was the target, the landmark stayed on for 400ms after saccade onset. Again, after a baseline period the landmark underwent an ISS. Results: In Experiment 1, the landmark was significantly mislocalized in both Landmark-On and, more importantly, Landmark-Off trials—despite no corresponding change in saccade gain to the target. In Experiment 2, saccades to the target were also unchanged, but saccades to the landmark were adapted, despite the lack of visual feedback for saccades to the landmark. Discussion: We conclude that the visual system includes non-target (landmark) error signals between pre-saccadic and post-saccadic visual information to maintain its spatial accuracy. These findings also suggest that saccade adaptation, induced by ISS, is not just a motor recalibration based on saccadic landing error: Part of the saccadic gain change is derived by a prior change in visual perception.

36.3025 Trans-saccadic attraction between highly dissimilar pre- and post-saccadic stimuli.

Celine Paeye[1] (celine.paeye@gmail.com), Therese Collins[1], Patrick Cavanagh[1]; [1]Laboratoire Psychologie de la Perception, Université Paris Descartes & CNRS UMR 8242, 45 rue des Saints-Pères, 75006 Paris, France

When saccading towards a grating that disappears during the eye movement, observers report a short-lived sensation of this target at the saccade goal (Wolf et al, 1980). Our study further characterizes this short-lived percept, examining how its localization can be influenced by a highly dissimilar post-saccadic stimulus. Participants made saccades towards a small, black square. During the eye movement this target was replaced with a white disk that was eight (experiment 1) or ten (experiment 2) times larger. The center of the disk could be situated up to 6° on the right or left of the pre-saccadic target, where the target location fell well outside the disk. Subjects indicated whether they perceived the square inside or outside the post-saccadic disk. In a control condition both stimuli appeared with the same spatio-temporal characteristics but subjects were required to maintain fixation. Overall, participants perceived the stimuli at overlapping locations more often in the saccade than in the fixation condition. Surprisingly, the square was perceived inside the disk even when it was as much as 6° outside. In the fixation condition, the responses were more veridical. This erroneous perception of the target inside the disk can be considered as an instance of trans-saccadic fusion. This is in contrast with previous experiments that failed to observe this phenomenon (eg. O'Regan & Levy-Schoen, 1983) probably because they used complex stimuli. Moreover, this interaction between pre- and post-saccadic stimuli may be related to the classic saccadic suppression of displacement (SSD, Bridgeman et al, 1975). However, unlike the normal SSD case where the similar pre- and post-saccadic targets are seen as one replacing the other, the two targets here differ dramatically and both can be seen. This suggests that the short-lived sensation of the pre-saccadic target might be involved in SSD.

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36.3026 Object-selective processing of remapped information

Benjamin Wolfe[1] (bwolfe@berkeley.edu), David Whitney[1]; [1]University of California, Berkeley

Saccadic remapping may be an object-selective process (Wolfe and Whitney, VSS2014). Using the face aftereffect (FAE; Webster et al., 2004) in a saccadic paradigm, we showed that remapped information from a face that was never foveated could alter perception of a subsequently foveated face, suggesting that saccadic remapping may acquire object- rather than feature-level information. If remapping is object-selective, we reasoned that there should also be an inversion effect with our stimuli (Yin, 1969), and that our effect should be temporally tuned around the time of the saccade (Duhamel et al., 1992). In one experiment, we tested whether remapped face information exhibits an inversion effect. We presented an inverted emotional face (happy or sad) 15° from fixation and asked subjects to saccade to it; it was removed from the display on saccade onset. Once the saccade terminated, an inverted morphed test face (ranging from happy to sad) was presented foveally and subjects judged whether the test face was happy or sad. Using the method of constant stimuli, we estimated the point of subjective equality as a measure of the FAE. Compared to the same experiment performed with upright pre-saccadic faces, we found a significantly reduced saccade-contingent FAE with inverted faces. We performed a separate experiment to determine the temporal tuning of saccadic remapping relative to saccade onset. Subjects were cued to saccade to a peripheral location, where an emotional face was presented for 50 ms at a random temporal offset after the cue and before the saccade. Subjects then judged a morphed test face at fixation after the saccade. We find that information is only remapped from the pre-saccadic face when it is presented 120 ms or less prior to the saccade. These new results support our account that saccadic remapping is object-selective and occurs immediately prior to the saccade.

36.3027 Landmark-induced positional shifts point to a shared map for auditory and visual targets

David Aagten-Murphy[1] (david.aagten-murphy@gmail.com), Martin Szinte[1], Heiner Deubel[1]; [1]Allgemeine und Experimentelle Psychologie, Ludwig-Maximilians-Universität München, Munich, Germany.

Visual objects that are present both before and after saccadic eye movements have been shown to act as landmarks for the localization of other visual stimuli across saccades. We investigated whether auditory localization would also be affected by visual landmark displacement during an eye-movement. Subjects fixated in the centre of the screen while a visual landmark, consisting of two LED lights above and below the midline, appeared in the periphery. They were then required to saccade to the center of this visual landmark, which either remained stationary or was displaced during the eye-movement. On each trial two brief visual or auditory test stimuli were presented sequentially before and after the execution of the saccade, at various locations. Subjects were instructed to compare the position of the second test stimulus relatively to the position of the first one. This allowed the localization abilities of the test stimuli to be computed for different sized landmark displacements (-3°, -1.5°, 0°, 1.5° or 3°). We found that the landmark displacement induced a proportionate shift in subject's localization of visual test stimuli, which is consistent with previous findings. Critically however, despite the head and ears remaining stationary,

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also the localization of the auditory test stimuli was found to be shifted, proportionate to half the landmark displacement. This indicates that the visual landmarks used to align pre-and post-saccadic visual representations also serve to calibrate auditory events localisation across saccades. Overall, these results suggest that a common, supra-modal spatial map is utilised to maintain a stable representation of objects of both modalities.

Acknowledgement: This research was supported by a DFG grant (DE336/3-1) to DAM and an Alexander von Humboldt Foundation fellowship to MS

36.3028 **Spatially-Specific Repetition Suppression in Transsaccadic Perception** Scott Fairhall[1] (scott.fairhall@unitn.it), Jens Schwarzbach[1], Martijn van Koningsbruggen[2], Angelika Lingnau[1], David Melcher[1]; [1]Center for Mind/Brain Science, University of Trento, Italy, [2]Center for Neuroscience and Cognitive Systems@UniTn, Istituto Italiano di Tecnologia, Rovereto, Italy

Brain representations of visual space are predominantly eye-centered (retinotopic) yet our experience of the world is largely world-centered (spatiotopic). A long-standing question is how the brain creates continuity between these reference frames across successive eye movements (saccades). Here we use fMRI to address whether spatially specific repetition suppression (RS) is evident during transsaccadic perception. Nine participants were presented with two successive Gabor patches (S_1 and S_2) displayed in either the upper or lower visual field, to the left or right of fixation. Spatial congruency was manipulated by having S_1 and S_2 occur in the same or different upper/lower visual field. On half the trials, a saccade was cued between S_1 and S_2, which placed spatiotopic and retinotopic reference frames in opposition. Equivalent frontoparietal RS was observed when S_1-S_2 were spatiotopically congruent, irrespective of whether retinotopic and spatiotopic coordinates were in accord or were placed in opposition by a saccade. RS was maximal in the superior parietal lobe and the frontal eye fields ($p < .005$, corrected). Further examination of saccade trials in classically retinotopic visual regions revealed RS for spatially congruent S_2 as early as extrastriate (but not striate) cortex ($p < .005$). Collectively, these results show that transsaccadic RS is contingent on the spatial congruency of the two stimuli, that spatiotopic representations emerge in extrastriate cortex and that by the level of the frontoparietal network, spatiotopically consistent stimuli can be processed in a similar way irrespective of retinotopic congruency.

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36.3029 **Space-fixed, retina-fixed, and frame-independent mechanisms of trans-saccadic feature integration: repetition suppression and enhancement in an fMRIa paradigm.** B.-R. Baltaretu[1,2,3] (brb@yorku.ca), B. Dunkley[6], S. Monaco[7], Y. Chen[1,2,4], J. Crawford[1,2,3,4,5]; [1]Centre for Vision Research, York University, Toronto, Ontario, Canada, [2]Canadian Action and Perception Network (CAPnet), [3]Department of Biology, and Neuroscience Graduate Diploma Program, York University, Toronto, Ontario, Canada, [4]Department of Kinesiology, York University, Toronto, Ontario, Canada, [5]Departments of Psychology, Biology, and Kinesiology and Health Sciences, and Neuroscience Graduate Diploma Program, York University, Toronto, Ontario, Canada, [6]Department of Diagnostic Imaging, Hospital for Sick Children, Toronto, Ontario, Canada, [7]Center for Mind/Brain Sciences, University of Trento, Trento, Italy

To date, the neural mechanisms of feature information integration across saccades, also known as trans-saccadic integration (TSI), of low-level object features are relatively unknown. Using fMRI adaptation (fMRIa), we found that the right inferior parietal lobule (IPL; specifically, SMG) and extrastriate cortex (putative V4) are sensitive to stimulus orientation in a space-fixed reference frame (Dunkley & Crawford, Society for Neuroscience Abstracts, 2012). To identify the neural mechanisms of underlying TSI in multiple reference frames, we employed fMRIa to probe three spatial conditions: 1) Space-fixed, 2) Retina-fixed and 3) Frame-independent (neither Space-fixed, nor Retina-fixed). Functional data were collected across 12 participants while they observed an obliquely oriented grating (45° or 135°), followed by a grating at the same ('Repeat' condition) or different angle ('Novel' condition). Participants were instructed to decide via 2AFC if the subsequent grating was repeated or novel. Repeat vs. Novel contrasts showed repetition suppression (RS) and enhancement (RE). RS showed condition-specific patterns within a parieto-frontal network. Distinct areas of activation were identified for the three conditions (i.e., SMG for Condition 1; middle and inferior frontal gyri (MFG, IFG) for Condition 2; and FEF and area 7 for Condition 3) as well as common clusters (i.e., posterior middle intraparietal sulcus, M1 and pre-supplementary area). RE was observed in occipito-temporal areas. Specifically, RE in Condition 1 was observed in cuneus, inferior occipital gyrus, medial occipitotemporal gyrus (MOtG), lateral occipitotemporal gyrus (LOtG) and MFG. RE in Condition 2 was observed in lingual gyrus (LG) and MOtG. In Condition 3, RE was found in cuneus, LOtG, middle occipital gyrus and LG. Shared RE areas included cuneus, LG and MOtG. Overall, TSI of orientation activated different cortical patterns (with some parietal overlap) in the three frames. Further, suppression occurred in a 'cognitive-sensorimotor,' parieto-frontal network, whereas enhancement occurred in an 'early visual,' occipital network.

Acknowledgement: NSERC and Canada Research Chair Program, NSERC 'Brain in Action' CREATE Program

36.3030 **On saccade programming as a function of stimulus complexity: Estimating the population-averaging window for simple shapes, textured discs and natural objects** Lotje Linden[1] (lotskaja@gmail.com), Gregory Zelinsky[2], Françoise Vitu[1]; [1]Aix-Marseille University, CNRS, LPC UMR 7290, Marseille, France, [2]Department of Psychology, Stony Brook University, New York, United States

In visual displays containing two stimuli, saccades reveal a global effect (GE): Even though participants aim for one of the stimuli, their eyes land in between the two. The GE presumably results from population averaging in the superior colliculus (SC): As neurons in the retinotopic sensory and motor maps have large and overlapping receptive/movement fields, overlap in the recruited populations causes activity to peak at the intermediate location. Consequently, the GE should diminish when the distance between the two recruited populations exceeds a threshold separation. However, while this threshold should remain invariant across the SC, due to non-homogeneous afferent mapping to the SC, the corresponding inter-stimulus distance (i.e. averaging window) in visual space should increase as stimuli become more eccentric. Casteau and Vitu (ECEM, 2009) confirmed this prediction for simple shapes. To investigate whether the same mechanisms generalize to the programming of saccades towards more natural stimuli, we estimated the averaging window in a saccade-targeting task for distractor-target (TD) pairs of increasing complexity: (1) simple shapes (circles/ triangles, diameter = 0.24°), (2) images of objects normalized for pixel area (median diameter = 1.7°) and, (3) as an intermediate level, discs (diameter = 1.4°) whose texture was matched to the texture of the objects. We systematically varied distance (3-10°) and eccentricity (3 or 5°) of the TD arrangement along various axes (0, 45, 90°). As predicted, we found that for shapes and discs, the critical distance for a GE increased with eccentricity in visual space, but was relatively constant when converted to millimeters of collicular space (Ottes et al., 1986). For objects, the pattern appeared similar, although the variance of landing positions was larger. We will discuss which object properties modulated the averaging window, in the framework of models of saccade programming.

36.3031 **Saccadic eye movements reveal an orientational bias, but not a position bias, in the Poggendorff figure** Michael Morgan[1,2] (m.morgan@city.ac.uk), Barbara Dillenburger[1]; [1]Max-Planck institute for Metabolism, Cologne, Germany, [2]Division of Optometry, City University London, UK

Two competing low-level origins of the Poggendorff illusion have been proposed (1) The angle of the pointer is biased by cross-orientation inhibition (2) the position of the intersection of pointer and inducing lines is mislocated by large-scale neural blurring. We tested the latter by getting 8 observers to make saccades to the acute-angle intersection point in a Poggendorff figure from a remote fixation position. On half the trials the position of the target intersection was shifted during the saccade, either in the direction of the Poggendorff bias or in the opposite direction, to prevent the observers from recalibrating their response. These shifts were not detected in a forced-choice test during the experiment. Some observers showed a bias of the first saccade endpoint into the acute angle, but most did not. All observers showed a large Poggendorff bias when making a saccade from a pointer to an imagined extrapolation point on a landing line. These findings suggests that mislocalization is not the origin of the Poggendorff bias. Previous psychophysics using a matching method have been used to argue that the intersections are mislocated (Morgan, Vision Research ,1999). However, this conjecture was based upon a method of adjustment which may be susceptible to decisional biases. Using a more rigorous 2AFC method with roving pedestal no consistent mislocation bias was found, although it was present in some observers. We conclude that the Poggendorff bias arises from a bias in the direction in which the pointers appear to point, although (paradoxically) not in the perception of their orientation. The Poggendorff bias is computationally interesting, since it raises the question: why does pointing use only information from the pointer termination, where it is least reliable?

Acknowledgement: Wellcome Trust and the Max-Planck Society

Sunday PM

36.3032 **Information gain does not modulate the facilitation of saccades by a perceptual task** Christian Wolf[1] (Christian.Wolf@psychol.uni-giessen.de), Alexander Schütz[1]; [1]Department of Psychology, Justus-Liebig-University Giessen

Visual acuity is best in the fovea and declines in the peripheral retina. Eye movements are used to project interesting objects onto the fovea, to acquire high-acuity information. Consistently, it has been shown that eye movement latencies are reduced if participants have to perform a perceptual task at the saccade target (Montagnini & Chelazzi, 2005). So far it is unknown if this facilitation is a general effect of the task, or if it depends on the gain in information by the eye movements. Here we tested if saccade latencies are sensitive to pre-saccadic peripheral visibility, post-saccadic foveal visibility or the ration of the two, which is the information gain. Observers had to foveate peripherally appearing plaid stimuli consisting of a vertical and a horizontal component and judge the orientation of the vertical component. We varied the contrast ratio of the two components while the overall contrast remained constant. To independently manipulate peripheral and foveal visibility, we changed the plaid during the saccade. Both, peripheral and foveal visibility could either be above or below previously determined individual thresholds. As a control, we measured saccade latencies without any perceptual task with varying contrast ratios. Perceptual performance followed the pattern intended by the manipulation. Without perceptual task, latencies were not influenced by the contrast ratio of the plaid. Consistently with previous reports, latencies were reduced by about 40 ms with perceptual task, even when a fast saccade was maladaptive because peripheral visibility was higher than foveal visibility. While foveal visibility did not affect latencies, there was a tendency towards reduced latencies with poor peripheral visibility. These results indicate that perceptual tasks generally facilitate eye movements, independently of peripheral and foveal visibility. This suggests that eye movement latencies are not equally modulated by informational gain as by motivational gain (Milstein & Dorris, 2007).

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Sunday PM

Object Recognition: Mechanisms

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

Poster Session, Banyan Breezeway

36.3033 **The neural basis of context-driven object perception** Talia Brandman[1] (talli.brandman@gmail.com), Marius Peelen[1]; [1]CIMeC - Center for Mind/Brain Sciences, University of Trento

Considerable evidence points to a division of scene and object processing into two distinct neural pathways, relying on different types of visual cues. However, scene and object perception may also interact, as demonstrated by contextual effects of background on object perception. At present, the neural underpinnings of scene-object interaction remain unknown. Here we asked how visual context shapes the neural representation of objects in real-world scenes. We presented subjects with contextually-defined objects, created by degrading the object such that it is identifiable only within its original scene context. Using fMRI and MEG in two studies, we examined the neural representation of object animacy in contextually-defined objects relative to degraded objects alone and scenes alone. An animacy localizer included animate and inanimate intact objects with no background. A linear classifier was trained to discriminate animate versus inanimate intact objects and then tested on animacy discrimination in contextually-defined objects, degraded objects alone and scenes alone. In the fMRI study, applying this multivariate approach in a searchlight analysis uncovered above-chance decoding of object animacy for contextually-defined objects, which was significantly stronger than for degraded objects alone or scenes alone, in an extrastriate visual area of the right occipital-temporal cortex. In addition, we present the results of a connectivity analysis correlating the response pattern in this region with the fMRI signal across the brain. In the MEG study, using similar cross-decoding, multivariate analysis of sensors revealed above-chance decoding of object animacy for contextually-defined objects, significantly more than for degraded objects alone or scenes alone, peaking at 300 ms from stimulus onset. In sum, our results provide the first evidence for shaping of neural representation of objects by scene context, suggesting that the category of an unidentifiable object is disambiguated by contextual scene cues after 300 ms and is represented in the extrastriate visual cortex.

Acknowledgement: The research was funded by the Autonomous Province of Trento, Call

36.3034 **The fovea is essential for peripheral vision: The effect of foveal distractors on extra-foveal perception** Kimberly Weldon[1,2] (kim.weldon@mq.edu.au), Alexandra Woolgar[1,2], Anina Rich[1,2], Mark Williams[1,2]; [1]Perception in Action Research Centre (PARC) & Department of Cognitive Science, Faculty of Human Sciences, Macquarie University, [2]ARC Centre of Excellence in Cognition and its Disorders, Macquarie University

Neuroimaging evidence indicates that visual information about objects in the periphery is fed back to foveal retinotopic cortex in a new and separate representation. Additionally, delayed disruption of foveal confluence via transcranical magnetic stimulation impairs discrimination of objects in the periphery, suggesting this feedback mechanism is essential for extra-foveal perception. In this study, we developed a behavioural paradigm to further explore the nature of this feedback mechanism and provide a behavioural measure. Participants performed a discrimination task on objects in the periphery while fixating centrally. A visual distractor presented at the fovea 100ms after presentation of the peripheral stimulus disrupted perceptual discrimination more than visual distractors presented at other stimulus onset asynchronies (SOAs). In a control experiment, a visual distractor presented elsewhere in the periphery at the same SOAs did not impair behavioural performance. These results corroborate previous research showing foveal retinotopic cortex is essential for extra-foveal perception. This study also demonstrates a new paradigm for investigating the nature of the foveal feedback phenomenon.

36.3035 **Neural representation of contextually consistent and inconsistent object pairs in human ventral visual cortex** Ruosi Wang[1] (ruosiwang@fas.harvard.edu), Yaoda Xu[1]; [1]Harvard University

Objects in our everyday environment rarely appear in isolation. But rather, they often appear together and interact in a predictable manner. The representation of such contextual grouping is useful in both object recognition and in our subsequent interaction with the objects. Indeed, behavioral studies have demonstrated that objects pairs are processed more efficiently when they appear together in a contextually consistent than inconsistent manner. However, the neural mechanism mediating such enhancement is still under debate. In the current study, using fMRI multi-voxel pattern analysis, we examined neural representations of contextually consistent and inconsistent object pairs in human retinotopically defined early visual areas as well as object processing regions in lateral and ventral visual cortex. In these pre-defined regions of interest, we obtained fMRI response patterns for two objects shown either in a contextually consistent manner (i.e., a cake above a cake stand, and a cooking pot above a burner) or in a contextually inconsistent manner (i.e., a cake above a burner, and a cooking pot above a cake stand). We also obtained fMRI response patterns for each object shown alone. We then linearly combined the patterns for the individual objects and tested the similarity between our synthesized two-object patterns and the actual two-object patterns using a linear classifier. In multiple ventral visual areas, preliminary results showed that the difference between the actual and the synthesized two-object patterns was greater for the contextually consistent than the contextually inconsistent object pairs. This suggests stronger nonlinear interaction between the two objects when they form a contextually consistent pair. These results illustrate one way in which contextual grouping may be represented in the human brain

36.3036 **The modulation of self-bias on the retinotopic C1 in size perception** Jie Sui[1,2] (jie.sui@psy.ox.ac.uk), Yang Sun[2], Glyn Humphreys[1]; [1]Department of Experimental Psychology, Oxford University, [2]Department of Psychology, Tsinghua University, Beijing, China

People tend to respond faster to self-relevant stimuli relative to stimuli associated with other people. There is well-established evidence on the self-bias effect on high level memory and attentional processes, but little evidence for effects on perception. In this study, we test whether the self-bias effect can modulate perception, by focusing on the effect of self-bias on the earliest cortical component C1 which links to activity in the primary visual cortex (V1). Using high-density event-related potential measures, we recorded participants' brain activity when they performed a matching task to personally relevant stimuli. Participants were randomly assigned three sets of geometric shapes (triangle, circle, and square) to three personal labels (self, mother, and stranger). After the associative instruction, they carried out a shape-label matching task. The size of the stimuli was manipulated (large vs. small). The results showed that there were faster responses to the shape associated with the self compared to others, showing the self-bias effect. The effect was modulated by the size of stimuli – participants made faster responses to the large than to the small stimuli in the self association, whereas there were no differences between the large and small stimuli for other associ-

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ations (mother and stranger associations). The size effect in self-bias was linked to the activity in the C1 component. The amplitude of C1 increased for the large relative to small shapes associated with the self, but the size of stimuli did not affect the amplitude between the large and small stimuli in other associations. The results indicated that self-bias can affect perception by modulating the earliest C1 component generated in the primary visual cortex. The data suggest that the self-bias may automatically facilitate the perceptual encoding of visual stimuli early on just following stimuli onset.

Acknowledgement: National Nature Science Foundations of China (31170973)

36.3037 **Is LOC Responsive to Object Familiarity?** Bryan Shilowich[1] (shilowic@usc.edu), Manan Shah[2], Irving Biederman[1,2], Bosco Tjan[1,2], Brenton Keller[2]; [1]Department of Psychology, University of Southern California, [2]Neuroscience Program, University of Southern California

Malach et al. (1995) discovered that the lateral occipital cortex and the posterior fusiform gyrus, cortical areas that they termed the lateral occipital complex (LOC), yielded greater fMRI BOLD responses when viewing intact images of familiar objects than their scrambled versions (resembling texture). Malach et al. discounted a role of familiarity by showing that unfamiliar "abstract" Henry Moore sculptures also activated LOC more than its scrambled versions. Although such a comparison does indicate that intact images produce greater LOC activation than their scrambled versions, it is not clear, without control for lower-level stimulus features, whether there is, in fact, no effect of familiarity. There is strong evidence that LOC represents objects in terms of their parts (Hayworth & Biederman, 2006). We put this issue of object familiarity to test by comparing cortical activation to 72 familiar objects and their novel counterparts, produced by rearranging their simple geon-like parts, thus holding the part ensemble of an image constant while varying familiarity (Panel A of Fig). Each object was composed of three or more geons, with each geon corresponding to a simple part of the object. The intact minus scrambled versions of each object was used to define LOC itself. With subjects performing an orthogonal task, greater activation in LOC was found for the familiar compared to the novel objects (Panel B). There was no effect of object symmetry. Although novel objects produce greater BOLD activity in LOC than their scrambled versions, there was still greater activation for familiar objects than their novel arrangements.

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36.3038 **Isolation of ventral stream EEG sources using Steady State EEG and Independent Components Analysis** Shamsi Sanati Monfared[1] (ss11u@fsu.edu), Sara Milligan[2], Jonathan Folstein[3]; [1]EPLS, Education, Florida State University, [2]Psychology, Florida State University, [3]Psychology, Florida State University

It has long been known that the ventral stream of the visual system contains discrete areas sensitive to object categories, including the Fusiform Face Area (FFA), the Parahippocampal Place Area (PPA) and the Lateral Occipital Complex (LOC). These areas have been well studied using fMRI, but the limited temporal resolution of fMRI has prevented investigation of the temporal dynamics of interactions between them. While event related potentials (ERPs) have high temporal resolution, their limited spatial resolution has hampered the isolation of signals from discrete ventral stream sources, especially non-face areas. Here we explore a possible solution to this problem using a combination of steady state EEG (SSEEG) and Independent Components Analysis (ICA). Our goal is to use ICA to generate a reliable set of spatial filters for ventral stream sources that can be used in ERP paradigms similarly to the way localizer scans are used in fMRI. SSEEG was recorded from 10 subjects while they viewed pictures of objects, faces, scenes, and scrambled objects flashing at a rate of 3.5 hz in a block design. The data for each subject were decomposed using ICA and the scalp distribution and spectral decomposition of each Independent Component (IC) was examined for each stimulus type. After removal of artifactual components, ICs were labeled as face-sensitive, object-sensitive, or scene-sensitive if 1) they showed an increase in power at 3.5 hz and 2) 3.5 hz power was selectively enhanced for a stimulus type. The vast majority of the category-sensitive components had postero-lateral scalp distributions as one would expect from ventral stream sources. All 10 subjects had face-sensitive ICs; object- and scene-sensitive ICs were each seen in 6 subjects. These data suggest that it is possible to isolate ventral stream sources of EEG. Future work will test the reliability and functional validity of category-sensitive ICs.

36.3039 **High Resolution fMRI Reveals Holistic Car Representations in the anterior FFA of Car Experts** David Ross[1,2] (davidross@umass.edu), Benjamin Tamber-Rosenau[1], Thomas Palmeri[1], Jiedong Zhang[3], Yaoda Xu[3], Isabel Gauthier[1]; [1]Vanderbilt University, [2]University of Massachusetts Amherst, [3]Harvard University

Perceptual expertise with an object category correlates with increased neural selectivity to that category in several visual areas, with the most robust effects in the fusiform face area (FFA). While expertise effects in FFA are well established, little is known about the representations that underlie these effects. Prior work in training studies with novel objects found that acquired behavioral holistic processing effects correlated with selectivity in FFA. Here, we probe the neural representations of cars for evidence of holistic information as a function of car expertise. With high-resolution 7T fMRI, in a sample of 26 participants, we measured the activation patterns elicited by whole cars, scrambled cars and car parts (top or bottom halves). We trained a SVM classifier to differentiate whole and scrambled cars in several face and object selective ROIs (FFA1, FFA2, OFA and LO). We then tested the classifier on the average of the part-evoked fMRI patterns. If the neural representations consisted only of part information, the classifier should classify the average as being equally like the whole car as the scrambled car. However, if the neural representations included information about the configural information of the parts, then the average of the parts should look more like the scrambled image than the whole. In line with this second prediction, we found a strong correlation between the tendency for the classifier to classify an averaged part pattern as scrambled and behavioral car expertise ($r = 0.58$, $p< 0.01$) in the anterior FFA (FFA2), bilaterally. FFA1, OFA and LO did not show expertise effects (ps>.40). These results go beyond the correlation of neural signals with behavioral holistic effects, providing direct evidence that the neural representations of objects in FFA of perceptual experts are more holistic than in novices.

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36.3040 **White-matter connectivity of brain regions recruited during the perception of dynamic objects** John Pyles[1,2] (jpyles@cmu.edu), Michael Tarr[1,2]; [1]Department of Psychology, Carnegie Mellon University, [2]Center for the Neural Basis of Cognition, Carnegie Mellon University

Dynamic objects are ubiquitous in our visual environment. In previous work we identified a network of brain regions recruited during the perception of dynamic objects, and provided evidence that many regions within higher-level and retinotopic visual cortex encode invariant information about dynamic objects (Pyles & Tarr, 2013, 2014). However the structural connectivity of this network remains largely unknown. Here we combine fMRI with diffusion-weighted imaging and deterministic fiber-tracking to investigate the white-matter connectivity between these areas. Dynamic object-selective regions were identified with a new fMRI localizer using short animations of moving, articulating novel objects, contrasted with phase scrambled versions of the same animations. Subjects also participated in a diffusion spectrum imaging scan using a 257 direction sequence. During viewing of dynamic objects we observed the recruitment of large regions of occipito-temporal cortex, substantially overlapping with LOC and hMT+ (designated dynamic-LOC) as well as regions of parietal cortex. These functional regions as well as results from retinotopy and a MT/MST localizer were used as regions of interest for deterministic fiber-tracking to map the white matter connections between these areas. Additionally we investigated the connectivity of these regions to the rest of the brain in an unconstrained analysis. Results show short range connections between nearby areas selective for dynamic objects, as well as connectivity to retinotopic cortex. Fiber streamlines originating in the large dynamic-LOC region showed longer range connections to regions of anterior temporal lobe and frontal lobe. Finally, we explicate the relationship of these tracts to the inferior longitudinal fasciculus, and the vertical occipital fasciculus (a tract connecting dorsal and ventral cortex (Yeatman et al., 2014)). A better account of the structural connectivity of this network and its relation to other major tracts in visual cortex will improve our understanding of its functional organization and inform future research.

36.3041 **Electrophysiological Correlates of Visual Object Category Formation in a Prototype-Distortion Task** Stephanie Long[1] (sml008@email.uark.edu), Matthew Gannon[1], Nathan Parks[1]; [1]Department of Psychological Science, University of Arkansas

A fundamental question in the visual neurosciences relates to how high-level visual patterns are extracted from a visual scene and segregated into discrete object categories. Extensive literature has been dedicated to the investigation of the cognitive and neural processes through which object categories are formed, but little is known of how complex visual object categories are extracted from a crowded visual environment and then represented in the cortical visual hierarchy. Here, we used event-related potentials (ERPs) to investigate the neural underpinnings of visual object category extraction in a cluttered visual field. EEG was continuously recorded while observers were given a hybrid of an object category learning and visual search task. In this hybrid task, a peripheral array of four dot patterns was briefly flashed for 200 ms. In 50% of the trials, one position of the peripheral array contained a distortion of a prototype dot pattern. The visual array in the remaining trials consisted entirely of randomly generated dot patterns. Over the course of hundreds of trials, observers learned to detect the dot pattern object category via correct or incorrect feedback given on each trial. We assessed these improvements in dot pattern detection (d') in conjunction with visual ERPs to examine the neural mechanisms of visual object category formation. Preliminary results indicate that observers exhibited significant improvements in dot pattern detection over the course of the experiment and that these improvements were associated with the emergence of a visually evoked component previously linked to category learning and perceptual expertise: the N250. These results elucidate the neural mechanisms underlying the formation of cortical representations for novel visual object categories and the processes through which these object categories are extracted from a complex visual array.

36.3042 **Exploring expert object recognition by the means of fast periodic visual stimulation** Simen Hagen[1] (shagen@uvic.ca), James Tanaka[1]; [1]University of Victoria

Expert category domains are thought to be instantiated within the human ventral visual pathway. For instance, differential responses to expert domains (e.g., faces, birds, cars, novel objects) have been shown in spatially localized areas using functional magnetic resonance imaging. In the current study we used fast periodic visual stimulation (FPVS) to explore the neural sensitivity to expert categories. Electroencephalogram was recorded from bird experts and bird novices, each presented with two trials of 60s sequences containing a base-bird (A, e.g., american robin) sinusoidally contrast-modulated at a presentation rate of 6 images per second (F=6Hz) with size varying every cycle to control for low-level adaptation effects. At every 5th cycle (F/5=1.2Hz), a different oddball-bird (e.g., northern cardinal, anna's hummingbird…) (B, C…) substituted the repeating base-bird (i.e., AAAABAAAACAAAAD…). The results showed that despite changes in low-level information (i.e., image size), the experts showed an adaptation in the right occipito-temporal channels (PO8, P8) in response to the base-bird within the first 18s of the 60s sequence, whereas the novices showed a sustained signal-to-noise ratio (SNR) throughout the entire sequence. For the oddball-birds, both experts and novices showed a significant SNR at the fundamental 1.2 Hz frequency and its harmonics that remained sustained across the entire 60s sequence and that peaked at the right occipito-temporal channels (PO8, P8). In summary, the experts but not the novices showed an adaption to the base-birds, however, within the same sequence, both the experts and novices showed a sustained response to the oddball-birds. These results indicate that the response to the base-bird and oddball-birds are dissociated in experts, but not the novices.

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36.3043 **Detecting unconscious processes: Demonstrating the flaws of a frequently used reasoning** Volker Franz[1] (volker.franz@uni-hamburg.de), Ulrike von Luxburg[2]; [1]Department of Psychology, University of Hamburg, [2]Department of Computer Science, University of Hamburg

Neuroscientists frequently use a certain reasoning to establish the existence of distinct conscious and unconscious processes in the brain. In a typical paradigm, conscious judgements are shown to be at chance-level when categorizing stimuli, while those same stimuli have clear and significant indirect ("unconscious") effects on reaction times or neuronal activity. Based on such a pattern of results it is typically concluded that unconscious processes can classify the stimuli better than conscious processes (this reasoning is sometimes called the dissociation paradigm). We show that this reasoning is flawed for theoretical reasons: Indirect effects do not allow one to infer that they were based on a good underlying classification performance. In fact, indirect effects would be compatible with any above-chance classification performance. That is, the indirect effect is a necessary but not sufficient condition for good underlying classification performance. We illustrate the fallacy with a recent study (ten Brinke, Stimson, & Carney, 2014, Psychological Science, 25(5), 1098-1105) that received an enormous press coverage because it concluded that humans detect deceit better if they use unconscious processes instead of conscious deliberations. The study was published under a new open-data policy that enabled us to reanalyze the data with more appropriate methods. We found that unconscious classification performance was close to chance - just as the conscious performance. This illustrates the flaws of a widely used statistical reasoning, the benefits of open-data practices, and the need for careful reconsideration of other studies on the visual system (e.g., on unconscious priming) using the same rationale.

36.3044 **Ultra-fast decoding of snakes from cortical ventral visual stream** Michele Fabre-Thorpe[1,2] (michele.fabre-thorpe@cerco.ups-tlse.fr), Maxime Cauchoix[3]; [1]Université de Toulouse UPS Centre de Recherche Cerveau et Cognition Toulouse France, [2]CNRS CerCo France, [3]IAST Toulouse School of Economics France

Many studies have reported rapid detection of visual threats such as the presence of a snake which induces very rapid reactions in both human (adults and children) and non-human primates. According to the "snake detection theory" (Isbell 2006), snakes provided intense selective pressure during the evolution of our visual systems. Although a subcortical route might be important for these fast responses since pulvinar neurons can respond to snakes with »60ms latencies (Van Le et al., 2013), we provide evidence that the ventral cortical stream may also be involved. Two macaque monkeys implanted over V4 and infero-temporal cortex with subdural electrodes performed a go/no-go animal categorization task with briefly flashed natural images. Targets included snakes and faces of macaques, chimpanzees and otters, distractors included car wheels, beer mugs, flowers and fruits. Human faces and round body parts were used as neutral stimuli (rewarded for both go and no-go responses). The gray-scale stimuli were equalized for global luminance and RMS contrast. MVPA was applied to intracranial field potentials to obtain a global accuracy measure and to characterize the time-course of decoding. The presence of human faces, macaque faces and snakes could be decoded in the 50-100ms post stimulus time window in both monkeys. However, in both monkeys, the presence of snakes was decoded more accurately (76-77%) than other target categories and could be read-out at 65-70ms post stimulus, about 20-30ms earlier than other categories. Unlike the macaque and human face images, the average snake picture was not recognizable because of snake's pictures high inter-stimulus variability. Nevertheless, using just global image statistics, MVPA decoding accuracy was very high for all faces and even higher for snakes. Rapid feed-forward processing of global statistics through the cortical ventral stream may thus be involved in the rapid detection of dangerous stimuli.

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36.3045 **Neurogenetic variations in enhanced perceptual vividness are linked to differences in task-related brain activity** Mana Ehlers[1] (manaehlers@psych.ubc.ca), Jennifer Whitman[1], Daniel Müller[2], Adam Anderson[3,4], Rebecca Todd[1]; [1]Department of Psychology, University of British Columbia, [2]Department of Psychiatry, University of Toronto and Neurogenetics Section, Centre for Addiction and Mental Health, [3]Department of Psychology, University of Toronto, [4]Department of Human Development, Cornell University

Growing evidence suggests that emotional stimuli are not only better remembered than mundane ones, but that affective salience alters their perception. In a previous study, we demonstrated that emotional events are perceived with the subjective experience of enhanced perceptual vividness, or EEV as assessed with a visual magnitude estimation task (Fig. 1) (Todd et al., 2012). More recently, we were able to show that marked individual differences in EEV can be partly explained by a genetic polymorphism in the ADRA2b gene associated with altered norepinephrine levels. Participants genotyped for the ADRA2b deletion variant had to estimate the magnitude of random noise overlaid on emotionally salient and neutral pictures while fMRI data was collected. EEV is indexed by the extent to which observers rate more emotionally arousing images as containing less overlaid noise, reflecting greater signal-to-noise ratio for the underlying image. Blood oxygenation level-dependent (BOLD) response was analyzed using a novel multivariate approach (Hunter and Takane, 2002). Constrained principle component analysis (CPCA) allows detection of those components or brain networks that account for most of the variance in the data that is directly related to the task. The analysis revealed that ADRA2b deletion carriers show higher activity in general task- and attention-related brain regions such as the visual cortex and parietal regions (Fig. 2). Moreover, EEV modulated activity in a network involving salience-related brain regions such as ACC, the caudate nucleus and early visual areas (Fig. 3) reflecting behavioral findings of greater EEV in ADRA2b deletion carriers. The present study underlines the effectiveness of CPCA to detect task-related brain networks. The findings suggest that common genetic differences linked to norepinephrine influence both brain activity related to overall attention to the magnitude estimation

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task and EEV modulated activity of salience related brain regions linked to subjective experience of emotionally enhanced perceptual vividness.

36.3046 Manipulating Perceptual Decisions Using Input From Others
Koel Das[1] (koel.das@iiserkol.ac.in), Bapun Giri[1], Arpita Chowdhury[1], Sucheta Chakraborty[1]; [1]Indian Institute of Science Education and Research, Kolkata

How prior expectation modulates perceptual decision making(Summerfield and de Lange, Puri and Wojciulik) is a topic of active research. But it is not clear how our decision making is influenced by decisions of others. Here we systematically manipulate cues to explore how input from observers affect perceptual decisions. Seventeen naive observers perceptually categorized briefly (50 ms) presented images of cars (C) and faces (F) embedded in filtered noise while their EEG activity was recorded for 1000 trials. Observers were rapidly (100 ms) presented with prior cues(FF,CC,F-C,CF) in the guise of decisions of previous observers. Cues were randomly generated so that equal number of images have positive cues(e.g.:FF followed by Face image), negative cues, neutral cues and no cues. Observers reported their decision (face/car) using a 10-point confidence rating. A multivariate pattern classifier was used to predict the object (face/car). Classifier performance identifying Face/Car from single trial EEG activity averaged across observers increased significantly (69.1%± 0.02) in presence of positive cues and decreased (66.5%± 0.02) with negative cues. Behavioral performance was consistent with the neural results. The neural decision variables extracted from the classifier correlated with observer's decision confidence showing highest positive correlation(r=0.76) with positive cues and lowest (r=0.605) with negative cues. Classifier performance for positive cues increased significantly reaching the highest accuracy(64.8% ± 0.02) during the time-interval of 240-280 ms. Classifier accuracy monotonically decreased till 400 ms and increased to 63%± 0.02 during a later epoch(500-550 ms.). Our findings suggest that perceptual decisions can be reliably manipulated using non-informative cues. The identified neural mechanisms predicting the object when positive cues are presented seem to be distinct from those with negative cues. The temporally localized nature of the neural activity suggests that input from others influence an observer's decision significantly in the visually evoked epoch and later post-stimulus intervals.

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36.3047 Category-selective patterns of neural response to scrambled images in the ventral visual pathway.
David Coggan[1] (ddc506@york.ac.uk), Wanling Liu[1], Daniel Baker[1], Timothy Andrews[1]; [1]Department of Psychology, University of York, York, UK

Neuroimaging studies have found reliable patterns of response to different object categories in the ventral visual pathway. This has been interpreted as evidence for a categorical representation of objects in this region. However, in addition to their semantic content, categories also differ in terms of their image properties. The aim of this study was to determine if image properties could explain category-selective patterns of neural response in the ventral visual pathway. We hypothesized that, if patterns of response in this region are tuned to low-level image properties, similar patterns of activity should also be evident for scrambled images that contain the same low-level properties, but are not perceived as objects. To address this issue, we generated phase-scrambled versions of intact objects in two ways: 1) globally-scrambled – applied to the whole image; 2) locally-scrambled - dividing each image into an 8x8 grid and scrambling the contents of each window independently. A behavioral study revealed that both scrambling processes rendered images unrecognizable. We then used fMRI to measure patterns of ventral response to five object categories (bottles, chairs, faces, houses and shoes) with three image conditions (intact, globally-scrambled, locally-scrambled). Using multivariate pattern analysis, we found distinct and reliable patterns for all five categories in intact and locally-scrambled image types. In contrast, the globally-scrambled images only showed reliable patterns for faces and houses. In addition, we found that the similarity matrices for the intact and locally-scrambled images were significantly correlated (r=0.79, p< 0.001). However, the similarity matrices from the intact and locally-scrambled images were not correlated with the globally-scrambled images. These results suggest that similar patterns of response are elicited by intact and locally scrambled images. Taken together, these data suggest that category-selective patterns of response in the ventral visual pathway can be explained by image properties typical of different object categories.

36.3048 Understanding the topography of face and body selectivity in human ventral temporal cortex
Annie Chan[1] (wchan2@uthsc.edu), Edward Silson[2], Chris Baker[2]; [1]Department of Neurology, University of Tennessee Health Science Center, [2]Laboratory of Brain and Cognition, Section on Learning and Plasticity, National Institute of Mental Health

Faces and body-parts are amongst the most salient visual stimuli in our environment. Research from human and non-human primates has reported multiple clusters of selectivity for faces and body-parts in the ventral visual pathway. Body-selective regions are often found close to face-selective regions, suggesting some sort of organizational principle. However, the nature of this organizational principle is not well established. Here, we investigated the topographical organization and specificity of body- and face-selective regions in visual temporal cortex at high resolution (1.2 mm isotropic voxels) using a 7T MRI scanner. First, we identified regions selective for faces and body-parts. Given prior reports of a body-part topography in lateral occipital cortex, we separately tested both hands and feet, which might be expected to have the most distinct representations. Second, we mapped population receptive fields in each participant to determine the extent to which the location of face- and body-selectivity reflect underlying retinotopic biases. Third, we tested the representational structure in face- and body-selective regions in a condition-rich event-related experiment. As expected, we found that faces elicited strong responses along the mid fusiform sulcus, in a region that has often been referred to as the Fusiform Face Area. This face selectivity coincided with a foveal representation of the visual field, while hands and feet produced robust responses adjacent and lateral to the face selectivity. We found little evidence for alternating patches of face and limb selectivity. Instead, we observed parallel streams of limb and face selectivity, extending from lateral to medial areas of the ventral cortex. Further, analysis of the representational structure of limb and face selective regions revealed striking differences. Our findings highlight the fine-grained organizational structure in ventral temporal and the importance of underlying retinotopic biases.

36.3049 Concurrent fMRI analysis of part-whole structure and subjective object norms for items from the BOSS (Bank of Standardized Stimuli) data set.
Anthony Cate[1,2] (acate@vt.edu), Stephanie Roldan[1]; [1]Psychology Department, Virginia Tech, [2]Center for Human-Computer Interaction, Virginia Tech

Introduction: The perceived part-whole structure of common objects is strongly influenced by image features, but it also exists in the context of multiple cognitive processes that act on object knowledge, including familiarity and categorization. Methods: We investigated these relationships using whole-brain fMRI during passive viewing of photographs of common objects and behavioral measures of object properties. 20 participants viewed 27 diverse items from the Bank of Standardized Stimuli (BOSS; Brodeur et al., 2010) while undergoing fMRI and during a post-scan behavioral test. The BOSS provides norms for subjective ratings of the objects: we considered familiarity; visual complexity; manipulability; and category, object and viewpoint agreement. During every TR of scanning a luminance/contrast normalized grayscale image was displayed centrally for 1.5 s while participants performed a demanding fixation task. Stimuli were presented in a Type 1, Index 1 event-related sequence (Aguirre, 2007). Afterwards participants verbally identified the objects, displayed initially at high eccentricity (42°; 150 ms duration) and moved incrementally closer to fixation until correctly identified in both hemifields. Resulting critical eccentricities (CEs) were taken to reflect the number of parts perceived in each object, based on work by Pelli and colleagues (e.g. VSS 2004). CEs were consistent across participants and spanned a continuous range across objects. CEs and BOSS norms were included as orthogonal regressors (modeled as parametric modulations) in the same SPM8 analysis. Results: Right lateral fusiform activation was linked to holism (negative correlation with CE: high for one-part objects, low for many parts) and normative familiarity. We also present detailed whole-brain maps to compare the effects of the numerous behavioral measures. Conclusion: We identified holistic object perception networks while simultaneously controlling for potentially related cognitive factors. These included right hemisphere fusiform gyrus and inferior parietal lobule. Fusiform face-related cortex was selectively activated by (non-face) holistic and familiar objects.

36.3050 Curvature-biased cortical areas in human visual cortex
Xiaomin Yue[1] (yuex@mail.nih.gov), Amisha Gandhi[1], Leslie Ungerleider[1]; [1]Laboratory of Brain and Cognition, NIMH, NIH

A recent study comparing functional MRI activity in rhesus macaques evoked by distinguishing between round and rectilinear shapes strongly suggests that there exists a network of cortical areas selective for curvature processing. Additionally, these curvature-based areas partially overlap with the well-studied face-processing areas. However, further research is required to ascertain: 1) whether there are equivalent human homologues of monkey curvature-biased cortical areas; 2) if so, is there an anatomical relationship between the curvature-processing areas and the face-processing cortical areas in the human brain. FMRI was acquired in a 7T SIEMENS scanner (1.43 mm voxels) in response to visual presentation of different round vs. rectilinear shapes matched to those used in monkey fMRI. Stimuli included: 1) images of round and rectilinear real world objects, 2) computer-generated arrays of 3D shapes (e.g. spheres or pyramids). The independent runs were included to localize the known cortical areas, such as the face-selective, object-selective, scene-selective, and early visual areas. Our preliminary results reveal significant fMRI biases in the ventral visual pathway to round vs. rectilinear shapes; however, the rectilinear-biased areas are solely confined to bilateral parahippocampal gyrus. These results are consistent with those observed in macaques. Areas biased to round shapes include human V4, OFA, FFA1, EBA, and possibly V8. Curvature-biased areas in the human V4 correspond to the posterior curvature-biased patches in monkeys. The OFA, which has been shown to encode round shapes, seems to be the homologue of middle curvature-biased patches in monkeys. However, it remains unclear from the preliminary data where the human homologue of the monkey anterior curvature-biased patches is. The close proximity of curvature-biased areas and face-processing areas in human visual cortex is consistent with results collected from monkey fMRI experiments, suggesting a functional link between face and curvature processing in both human and non-human primates.

Acknowledgement: NIMH intramural research program

Lightness and Brightness

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

Poster Session, Pavilion

36.4001 Dissecting the influence of the collinear and flanking bars in White's effect

Barbara Blakeslee[1] (barbara.blakeslee@ndsu.edu), Ganesh Padmanabhan[1], Mark McCourt[1]; [1]Center for Visual and Cognitive Neuroscience, Department of Psychology, North Dakota State University

In White's effect equiluminant test patches placed on the black and white bars of a square-wave grating appear different in brightness/lightness. The effect is important because its direction is seemingly independent of the extent of black or white bar contacting the test patch and is therefore inconsistent with explanations in terms of either contrast or assimilation. We separated the influence of collinear and flanking bars by independently manipulating their luminance. Observers adjusted the luminance of a matching patch to match the brightness (apparent intensity) of test patches, which in a standard White stimulus would be described as located on a black bar or on a white bar of a 0.5 cpd inducing grating. Test patches were 1.0o in width and 0.5o or 3.0o in height. Test patch and mean luminance were 64 cd/m2. On each trial the luminance of the collinear (or flanking) bars assumed one of twenty values from 3.2 to 124.8 cd/m2 while the luminance of the flanking (or collinear) bars remained white (124.8 cd/m2) or black (3.2 cd/m2). Although the magnitude of induction varied, the pattern of results was similar across six observers. Matching luminance varied inversely with collinear bar luminance for test patches with either white or black flanks. Matching functions for test patches with white flanks were shifted to lower luminances than those for test patches with black flanks. Varying flanking bar luminance also produced inverse test patch matching functions, although with shallower slopes. Matching functions for test patches on white collinear bars were shifted to lower luminances than those on black collinear bars. This difference was greater than that for matching functions with white versus black flanks. We conclude that for the present conditions White's effect is a contrast-based effect in which collinear bar contrast is stronger than flanking bar contrast.

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36.4002 Preference of Negative Contrast in Behaving Rats

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Humans can detect negative contrast (black on gray) better and more easily than positive contrast (white on gray). The black-over-white preference in visual perception is accordance with the findings that negative-contrast stimuli can evoke larger neuronal responses than positive-contrast stimuli in primary visual cortex (V1) (Zemon et al., 1988; Olmen et al., 2008; Yeh et al., 2009; Xing et al., 2010). In contrast, strong white-dominant responses were recently found in rodent V1 with the voltage-sensitive dye (VSD) imaging technique (Polack & Contreras, 2012). Based on these findings, it is possible that rodents may prefer positive contrast to negative contrast. Here we used a two-alternative forced choice task to test the contrast preference in behaving rodents (Long Evans). We manipulated both the contrast (0%, 8%, 16%, 32%, 64%, 100%) and the mean luminance of the screen (high: 50 cd/m2, low: 20 cd/m2). Surprisingly, we found that rats can detect negative-contrast stimuli better than positive-contrast stimuli. The black-over-white bias is the largest at 100% contrast with the low mean luminance level (the mean difference of the correct rate is 12.27%, SE=2.94%, p=0.0013). On the other hand, rats on average had better performances in the high mean luminance condition than in the low mean luminance. The discrepancy between behavioral and neuronal results in rodents may be due to (1) the difference in the mean luminance (neuronal: 83 cd/m2; behavioral: 20 and 50 cd/m2) and (2) the duration of the stimuli (neuronal: 250 ms; behavioral: on until rats make a choice). Overall, our behavioral results show that rodents can detect negative contrast better than positive contrast. Future studies need to address the contradiction between the behavioral (negative-contrast preferences) and the neuronal (white-dominant responses in V1) results in rodents.

36.4003 Surface Perception of Lightness in Different Contexts

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We recently showed that a contrast-based model of lightness perception outperformed a number of other models in predicting lightness matches across different viewing conditions (Zeiner & Maertens, 2014; Maertens & Shapley, 2013). By considering regional variations in contrast range, the model successfully predicted lightness constancy across changes in illumination and for different transparent media. Here, we tested the model's predictive power for stimuli that involve a systematic variation of the surface reflectances that surround a target surface. Such changes – in the absence of illumination changes – are expected to produce failures of observers' lightness constancy which are known as type II constancy errors. We tested two exemplars of contrast-based models, the scaling contrast model (Zeiner & Maertens, 2014) and the contrast-ratio model (Singh, 2004). We used rendered images of custom-made checkerboards to test the perceived lightness of twelve surface reflectances as a function of the viewing context (plain view vs. light and dark transparency) and of the reflectances surrounding the target. The reflectances of the surround checks were selected so as to either vary around the mean luminance of all checks (average condition), or so as to vary around a relatively low or high luminance, resulting in extreme contrast values between target and surround. Observers matched the perceived surface lightness of the target check presented in the above conditions by adjusting the intensity of an external test probe. Both models predicted the observed lightness matches well across different viewing contexts (plain view vs. transparency). In contrast to the model predictions, we observed only small behavioral effects of the surround manipulation. Based on inspection of the extreme surround stimuli, we suspected that the local darkening or brightening of the adjacent checks, was itself sufficient to signal a different viewing context. An appropriate model adjustment indeed yielded a much better fit to the data.

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36.4004 Viewing strategies that aid lightness constancy in dynamic scenes

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Lightness of a surface depends on luminance sampled trough fixations (Toscani et al.,2013). This information changes when the surface moves across a light field and so do lightness matches (Zdravkovic, 2008). We studied luminance integration over time and space in a lightness matching task. A pendulum was presented in a virtual scene with clearly visible decreasing illumination from left to right. Observers either freely looked at the scene or had to fixate a spot on a dark or light region on the pendulum for the whole duration of each trial. The pendulum either moved across the whole scene starting from the light or the dark side or was kept motionless in these two regions of interest. The pendulum was matched lighter when observers were forced to fixate a light region than a dark one, showing that fixation positions do influence perceived lightness. Observers produced lighter matches when the pendulum was on the lighter side of the scene than when it was on the darker side. Lighter matches were also obtained when the pendulum moved from dark to light, as compared to the other way around. When eye movements were not constrained, this difference was less pronounced. In free viewing, observers tended to adjust their fixation positions as to counteract the illumination difference, preferring lighter regions on the pendulum when it was on the darker side and vice versa.Eye movements seem to play a compensatory role for illumination changes due to object motion. Our results emphasize the importance of fixation positions for achieving perceptual stability.

36.4005 **Assimilation challenges contrast-based models of lightness perception**

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Human observers perceive the lightness of surfaces accurately despite substantial variations in illumination and viewing conditions. It is known that the lightness of an image region is influenced by its surroundings, but the exact mechanism for this contextual modulation is not yet understood. We recently proposed a contrast-based lightness model (Zeiner & Maertens, 2014) to predict the perceived surface lightness from retinal image luminance. However, this type of model does not account for so-called assimilation effects, i.e. substantial lightness differences that have been reported in the absence of differences in either luminance or contrast. Here, we assessed the magnitude of contrast and assimilation effects in two types of stimuli that differed in photometric and geometric complexity. The more complex stimulus was a two-dimensional image of a checkerboard that was shown as a perspective projection of a three-dimensional object. It was composed of a number of different luminance values and contained a number of cues to depth. The less complex stimulus was a simultaneous lightness contrast type of display that was composed of image regions that emulated the luminances in the checkerboard but lacked its depth structure. Contrary to previous studies we observed strong assimilation effects. In the checkerboard assimilation and contrast effects were of similar magnitude. In addition, assimilation effects seemed stronger for incremental targets on incremental checks. This suggests a split between increments and decrements which is supported by neurophysiological data pointing to a fundamental separation between neurons driven by darks (OFF neurons) and neurons driven by lights (ON neurons) in primary visual cortex (e.g. Yeh et al., 2009; Kremkow et al., 2014). A comprehensive theory of surface lightness must explain why assimilation is so strong on the checkerboard as well as the large asymmetry between black and white.

Acknowledgement: Emmy Noether grant by German Research Foundation MA5127/1-1

36.4006 **Efficient brightness averaging of heterogeneous achromatic patches**

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Mean brightness in a variegated region may work as a clue to illumination intensity over the region and play an important role in the perception of object lightness. This study investigated whether brightness can be efficiently averaged for heterogeneous achromatic patches. Experiment 1 investigated discrimination thresholds for mean brightness between two arrays of 12 heterogeneous patches of different luminances. The thresholds were compared to brightness discrimination thresholds between two arrays of 12 homogeneous patches and to those between two single patches. The two arrays (or patches) were simultaneously presented for 200 msec and followed by a pattern mask. Results showed that mean brightness judgments for heterogeneous arrays were as accurate as simple brightness comparison for single patches, although they were slightly worse than brightness judgments for homogeneous arrays. This finding is consistent with efficient brightness averaging of different luminance patches. However, additional experiments revealed that inexperienced naive observers may use shortcuts for mean brightness judgments; they tended to choose as the brighter array the one containing a highest luminance patch or the one consisting of the larger number of patches. To investigate the effects of these confounding factors, Experiment 2 measured discrimination thresholds for mean brightness between two arrays composed of different numbers of heterogeneous patches (6 vs. 12 or 9 vs. 12). The highest luminance patch was included in the array consisting of either the smaller or the larger number of patches, and thus using this clue for mean judgments would lead to highly biased thresholds. Results were consistent with brightness averaging, but a small bias (varying in the magnitude among observers) was found to choose the array containing the highest luminance patch. Overall, the present findings suggest that brightness can be efficiently averaged, but with a greater weight to the highest luminance.

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36.4007 **Classification images reveal that local grouping within lighting frameworks drives the argyle illusion**

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The argyle illusion (Adelson, 1993) is a brightness illusion in which lines, triangles, and diamonds are arranged to resemble patterns on knitted garments. The standard explanation is that, due to shapes forming x-junctions, the visual system perceives strips of dark and light transparent filters over the argyle. Since diamonds under the two different filters have the same luminance, the visual system infers that the diamonds must be of different reflectances, thus perceiving a brightness difference. Using classification images, a technique which reveals image components that influence perceptual decisions, we examined whether the x-junction explanation was correct, i.e., whether x-junctions would be the most influential parts of the classification image. We chose two test diamonds, one from each of the filtered regions, and set their luminances to observers' PSEs. Other argyle elements were corrupted with white, Gaussian noise (SD=.18). Observers (n=3, 10,200 trials each) chose which test diamond appeared brighter (2AFC). Surprisingly, classification images did not show that x-junctions were the most influential stimulus elements; rather, local contrast better explained observer choices. We also found that diamonds immediately neighbouring the test diamonds contributed to the illusion, but only if the neighbours were under the same filters as the test diamonds. This suggests a localized grouping effect, where neighbours sharing the same lighting framework moderate perceived brightness of the test diamonds. We conclude that x-junctions do not play a decisive role in the argyle illusion, and that instead, stimulus patches are compared to local grouped elements. Our experiments point towards the importance of lighting frameworks for brightness perception, and demonstrate classification images as a general technique for examining mid-level lighting effects, such as shading and transparency.

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36.4008 **Investigating the Effect of Lateral Inhibition in the Retinal Circuitry on Lightness Contrast and Assimilation: A Model Study**

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The lightness of equiluminance regions of a light source appears different due to distinct properties of surrounding surfaces (lightness induction). For example, for a bar-grating stimulus in relatively low spatial-frequency, the same gray bars are perceived lighter when they are flanked by black bars, compared to those flanked by white bars (lightness contrast; Helson, 1963). However, the direction of this induction is reversed for a high spatial-frequency grating such that the gray among black bars appears darker (lightness assimilation), suggesting that the lightness is affected by stimulus spatial-frequency. More recently, Rudd (2010) also reported that the direction of lightness induction (contrast vs. assimilation) of a disk depended on the width and luminance of the ring surrounding the disk. We simulated these experiments with a biophysical retinal model and obtained qualitatively consistent results to the psychophysical data. For the stimulus conditions in which lightness contrast was observed, the model shows the classic center-surround lateral inhibition behavior that enhances signal contrast at the edge between neighboring surfaces. However, for a high spatial-frequency stimulus as in Helson (1963), the spatial high-frequency cutoff characteristics of the retinal MC pathway limits the effect of lateral inhibition such that the contrast enhancement occurs globally over the entire stimulus surface rather than at each edge between bars: thus, the signals of gray bars assimilate to those of the flanking bars. Also, a low and narrow ring as in Rudd (2010) fails to induce lateral inhibition and the signals at the edge of the disk assimilate to those of the ring. While lightness induction is not yet fully understood and in particular the mechanism for assimilation is yet of an unknown nature (Fiorentini 2004), our work would be the first to point out to retinal lateral inhibition as a starting point for the lightness contrast - assimilation phenomena.

Acknowledgement: European Research Council

36.4009 **A comparison of physical and visual light fields structures**

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Human observers are sensitive to light properties such as the intensity, direction and diffuseness. We study how well they are able to estimate the light field (the structure of the net flux transport) in rooms, by empirical measurement and comparison of the physical and visual light fields. We made regularized measurements of the physical light field in a room under three light conditions with a custom-made cubic illuminance meter based on six Konica Minolta T-10MA sensors. Next, we photographed the room and conducted a psychophysical experiment, in which the observer's task was to change the lighting (direction, intensity and ambient components) of a "probe" in order to make it appear like it belonged to the pictured scene. The probe, a white Lambertian sphere on a black monopod (defining the location of the probe in the scene), was superimposed on predetermined locations in the image. As a separate measure of the visual light field, the participants indicated the perceived ("subjective") light source position on the extended scene pictures and described it in words. For each light condition we made reconstructions of light fields consisting of light vectors in a grid: physical from measurements, visual from observers' settings on a probe, and simplified models of light fields with all vectors pointing to the subjective light source positions. Participants' interpretations varied remarkably in position and number of the subjective light sources. Many of them were far from veridical. We made pairwise comparisons between light field reconstructions. For the most prominent case, with a visible light source, the average angular difference between visual and physical light vectors was 57 degrees, whereas between visual and simplified model for subjective light sources it was 29 degrees. The results suggest that, overall, the visual light field's structure is simplified with respect to the physical one.

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36.4010 **Contour erasure and filling-in: Old simulations account for most new observations** Gregory Francis[1,2] (gfrancis@purdue.edu); [1]Department of Psychological Sciences, Purdue University, [2]Brain Mind Institute, École Polytechnique Fédérale de Lausanne, Switzerland

Two recent studies used similar stimulus sequences to investigate mechanisms for brightness perception. Anstis and Greenlee (2014) demonstrated that adaptation to a flickering black and white outline erased the visibility of a subsequent target shape defined by a luminance increment or decrement. Robinson and de Sa (2013) used a large flickering annulus to show a similar effect when the target was the same size as the inner edge of the annulus. Here, a neural network model (Francis & Kim, 2012), which previously explained properties of scene fading, is shown to also explain most of the erasure effects reported by Anstis and Greenlee and by Robinson and de Sa. The model proposes that in normal viewing conditions a brightness filling-in process is constrained by oriented boundaries, which thereby define separate regions of a visual scene. Contour adaptation can weaken the boundaries and thereby allow brightness signals to merge together, which renders target stimuli indistinguishable from the background. New model simulations with the stimuli used by Anstis and Greenlee and Robinson and de Sa produce model output very similar to the perceptual experience of human observers. Importantly, Robinson and de Sa interpreted their findings as evidence against a filling-in process, but the new simulations demonstrate that their findings support at least one type of filling-in process.

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36.4011 **At night even white cats are gray: scotopic lightness perception** Robert Ennis[1] (Robert.Ennis@psychol.uni-giessen.de), Matteo Toscani[1], Karl Gegenfurtner[1]; [1]Department of Psychology, Justus-Liebig-University Giessen

The anchoring theory of lightness perception proposes that the perception of white is linked to the brightest surface in a scene. A lot of evidence for some form of anchoring has been amassed, but mainly under photopic illumination conditions. There is hardly any research on lightness perception under scotopic conditions, when only rod photoreceptors are active. We tested whether anchoring also works under these conditions. In other words: are all cats really gray at night, even white ones? We printed 10 chips, such that they were equally spaced on the L* scale of the CIELUV color-space (under a D65 illuminant). 6 naive observers first viewed the maximally and minimally reflecting chips at 277 cd/m^2. They were instructed to memorize their percepts as 100% white and 0% white. Observers adapted to three light levels (1.2x10^(-4) (scotopic), 28, and 277 cd/m^2; counter-balanced) and viewed our chips, one at a time, in two, randomly-ordered blocks. For scotopic adaptation, observers wore fitted goggles with neutral density filters. They adapted for at least ten minutes and dark adaptation was confirmed by a foveal scotoma and the inability to sort colored chips by hue. Observers reported the perceived amount of white in each chip, in units of 10% along their memorized white scale. At both photopic levels, observers assigned an average rating of 95.85% to the maximally reflecting chip. When dark adapted, observers assigned an average rating of 75.83% to the maximally reflecting chip, with a monotonic decline for darker chips. This agrees well with our own phenomenological observation that the white chip appears gray in the scotopic range. We propose that cone activation may be necessary to perceive white.

Acknowledgement: Deutsche Forschungsgemeinschaft, grant GE 879/9

36.4012 **Edge influences on suprathreshold white brightness perception** Marcelo Costa[1,2] (costamf@usp.br); [1]Departamento de Psicologia Experimental, Instituto de Psicologia, Universidade de São Paulo, [2]Núcleo de Neurociências e COmportamento e Neurociências Aplicadas, Universidade de São Paulo

Edge plays special role in spatial perception and in determining the lightness information of the surface within borders. The aim of our study was to measure suprathreshold brightness in different levels of edges hardness. Steven's Power Law for circles modulating in luminance were estimated for 10 subjects (mean age 25 SD 3, 5 female). Stimuli and psychophysical procedures were built using Psyknematix software (v1.4.3, KiberVision, Montreal, Canada) installed in iMAC OS 10.8 X (Apple Inc., USA). Stimuli were presented on the iMAC display using 11 bit graphic board and consisted of two circles of 3 degrees of visual angle, separated by 10 degrees. We tested 7 levels of Michelson contrast: 7, 8, 10, 15, 26, 50, 100. Three edge filtering was tested (0.3, 0.8 and 1.5 degrees of smoothing). The subject task were to judge the brightness of the edge filtered circle compared with the circle of hard edge which was considered the Modulus and received an arbitrary level of 50, representing the amount of brightness perception. If the bright was perceived as two times more intense, the subject had to give a number 100. . If the bright was perceived as two times less intense, the subject had to give a number 25 and so on. In each trial, the same contrast level was presented in both circles. Five judgments were performed for each contrast level in each edge filtering. We found an increase in the Power Law exponent as the increase of filtering (for sigma of 0.3 = 0.37, sigma of 0.8 = 0.55, and sigma 1.5 = 1.03). All power function fitting had a correlation coefficient higher than 0.95. We conclude that there is a progressively increase in brightness perception as increase the edge filtering and a full performance in suprathreshold contrast perception is achieved with a half size stimulus smoothing.

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36.4013 **Neural circuitry of brightness induction: modeling and physiology** Hannah Choi[1,3] (myhannahchoi@gmail.com), Artak Khachatryan[1], Charm Le'Pre[1], Ehud Kaplan[2], Qasim Zaidi[4], Youping Xiao[1]; [1]Departments of Ophthalmology, Physiology and Pharmacology, The Graduate Programs in Neural and Behavioral Science, and Biomedical Engineering, The SUNY Eye Institute, State University of New York Downstate Medical Center, [2]Friedman Brain Institute Departments of Neuroscience, Ophthalmology, Structural & Chemical Biology, The Icahn School of Medicine at Mount Sinai, [3]Department of Applied Mathematics, University of Washington (Current), [4]Graduate Center for Vision Research, SUNY College of Optometry

An important function of the brain is adjusting perception to context, so that estimates of object properties are relatively consistent despite variations in retinal inputs. Brightness induction, including both contrast and assimilation, is a classical example of context effects on surface perception, but the underlying neural circuits are still unknown. We have developed a neural model in which each unit at the cortical site of induction receives inputs from receptive fields (RFs) that are spatially opponent and orientation selective, and also from recently found RFs that are neither spatially opponent nor orientation selective. The synaptic weights for both input types are Gaussian functions of the distance in visual space between the input and recipient RFs. The weights for spatially opponent RFs also depend on orientation preference and contrast polarity. The parameters for the synaptic weight function were adjusted for the model to reproduce contrast-linearity of induction and exponential fall-off in context effects with distance from the test. With these parameters fixed, the model reproduced a large variety of complex contrast and assimilation effects, including Mach bands, grating induction, Helson's line stimuli showing assimilation versus contrast, Todorovic effects, Bullseye effect and 2-D and 3-D variants of White's Effect without explicitly extracting image junctions. By simulating deficits in explanatory power when removing specific types of RFs and connections from the model, we predicted specific functional connectivity that can be tested physiologically. With electrode-array recordings in anesthetized macaques, we found many neurons in area V4 that responded in opposite-phase to brightness modulations of the surround, a classical signature of brightness contrast, whereas almost all neurons in V2 responded in the same phase as the surround modulation. Consequently, our preliminary results suggest that V4 is the site where the two types of RFs converge to generate brightness induction.

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Development: Disorders

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

Poster Session, Pavilion

36.4014 Axial Diffusivity in the ILF and IFOF is Related to Autism Symptom Severity

K. Suzanne Scherf[1,2,3] (suzyscherf@psu.edu), Jennifer Legault[3], Indira Turney[1], Daniel Elbich[1], Nancy Minshew[4], Marlene Behrmann[5,6]; [1]Department of Psychology, Pennsylvania State University, [2]Social Sciences Research Institute, Pennsylvania State Univeristy, [3]Department of Neuroscience, Pennsylvania State University, [4]Depts of Neurology and Psychiatry, University of Pittsburgh, [5]Department of Psychology, Carnegie Mellon University, [6]Center for the Neural Basis of Cognition

Atypical neural activation within the face-processing network is widely reported in adults and adolescents with autism; and, individual differences in symptom severity predict the magnitude of these atypical responses, particularly within posterior core regions of this network (Scherf et al., 2015). Also, recent evidence suggests that the inferior longitudinal fasciculus (ILF), a fiber tract that connects posterior core regions with more anterior extended regions, is developmentally disrupted in autism (Koldewyn et al., 2014). In typically developing children, the ILF shows changes in microstructural properties with age in terms of a reduction in mean and radial, but not axial, diffusivity (Scherf et al., 2014), which suggests ongoing myelination of this tract. In the current project, we investigated individual differences in the relation between symptom severity, age, and face recognition behavior and microstructural tract properties in 18 high-functioning adolescents (HFA) with autism. Participants were scanned using diffusion tensor imaging. Using Tract-Based Spatial Statistics, we created a mean white matter skeleton representing the centers of all tracts common to the group. From this, we computed axial, radial, and mean diffusivity (AD, RD, MD) maps and voxelwise regressions of age, scores from the Social Responsiveness Scale, and behavioral measures of face recognition on each diffusivity map. We found significant age-related changes in AD, but not RD or MD, in the right and left ILF and IFOF (inferior fronto-occipital fasciculus), which was not present in a previous study with TD individuals, and may reflect increasing impairments in axonal transport with age. We also found a positive relation in these tracts between AD and SRS, which indicates that HFA adolescents with more severe symptoms may have more axonal damage in these tracts. These alterations in microstructural properties of key fiber tracts likely contribute to disruptions in face-processing behavior, and social behavior more broadly, in autism.

Acknowledgement: PA Dept of Health and Human Services

36.4015 Differences in the anatomical connectivity patterns of the lateral geniculate nucleus between subjects with dyslexia and controls

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Introduction: Dyslexia is the most common neurodevelopmental disorder. It is characterized by normal intelligence but difficulties in skills associated with reading and writing. Reading is a complex skill that requires the coordination of multiple brain regions and relies on neural systems spread across the brain. Dyslexia has been linked to abnormal connectivity patterns throughout the cortex and to morphological abnormalities of the lateral geniculate nucleus (LGN). This is the first study to compare the anatomical connectivity of the LGN between subjects with dyslexia and controls. Methods: Diffusion (TR=5300ms, TE=95ms, b=1000s/mm2, resolution=1.56x1.56x3 mm3), T_1 (TR=2200ms, TE=2.96, resolution=1x1x1mm3) and proton density (PD) weighted images (TR=2970ms, TE=22ms, resolution=0.75x0.75x1mm3) were acquired in 12 subjects with dyslexia and 12 controls. Six independent experimenters manually traced the LGN on the PD. One experimenter traced the corpus callosum and optic chiasm on the T_1. This was done frame-by-frame in the coronal plane using FSLVIEW. The anatomical location of V1 and V5 was determined by transforming the 1mm MNI template to each subjects' anatomical space using non-linear transformation (ANTS). The following steps were taken to analyze the diffusion data: eddy current and head motion correction, brain extraction, diffusion tensors fitting, and probabilistic tractography. Tractography was run in ProbtrackX between the LGN and the optic chiasm and ipsilateral and contralateral V1/ V5. Results: The anatomical connectivity of the LGN with the optic chiasm and ipsilateral V1 was significantly reduced in subjects with dyslexia ($p < .005$). The contralateral connections between the LGN and V1/ V5 were higher in dyslexia ($p < .005$). Conclusion: The results obtained using probabilistic tractography provide the first evidence of changes in the anatomical connectivity of the LGN in subjects with dyslexia. We demonstrated that differences in the anatomical connectivity patterns can be found from the chiasm to V1. The functional implications of these changes are unknown.

Acknowledgement: Dana Foundation

36.4016 Signatures of motor output variability across a spectrum of neurological disorders reveal severity levels and unexpected ties

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In recent work we have uncovered minute fluctuations in the speed of pointing motions of individuals with Autism Spectrum Disorders (ASD) (Torres et al 2013, Wu et al 2014). During the movement segments towards a visual target, we detected in their hand motions excess fluctuations absent in typical controls. The human eye has limited capacity to detect these types of fluctuations at millisecond time scales during intentional movements. Their frequencies also escape the observer diagnosing the disorder, so abnormal patterns of motor variations are not even considered a core issue when diagnosing or treating ASD. We have detected them with proper instrumentation and new analytics, thus taking a radically different approach to ASD and providing objective metrics to characterize the noise-to-signal patterns present in these motions as they naturally unfold during perceptual and decision-making tasks. Here we present additional metrics to characterize this subtle form of intentional tremor in ASD in relation to patients with different degrees off severity in Parkinson's disease (PD), Essential Tremor (ET) and de-afferentation. The former two are disorders on a spectrum where tremor is visibly affecting the person. The third one is a specific loss of proprioception whereby the person can no longer sense kinesthetically the returning stream of movements intentionally produced. We characterize the similarities and the differences between individuals with ASD and these different subject types. The results from this work provide evidence that the fluctuations in the motor output variability that are often considered noise and discarded are in fact a rich signal useful to better understand, detect, subtype and track disorders on a broad spectrum.

Acknowledgement: NSF, The NJ Governor's Council for the Research and Treatment of Autism

36.4017 Motor imagery vs. object-based visual imagery in adolescents with Autism Spectrum Disorder

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Mental representation of actions is one of the essential components for social interaction and communication, and quite a few studies propose that social cognition deficits observed in ASD can be attributed to their aberrant action representation. Nevertheless, the hypothesis remains inconclusive primarily because most previous studies address this issue either through motor imitation that is contaminated by the requirement of overt motor replication, or through passive action observation that lacks active manipulation of action representation. In the current study, we aimed to investigate the characteristics of action representation in adolescents with ASD through motor imagery (MI) that requires both active manipulation and embodiments of action representation. We recruited 22 participants with ASD and 22 typically developing controls (TDC) to perform a hand-rotation and an object-rotation task. In the hand-rotation task (involves kinesthetic MI), participants were required to judge the laterality of a 3-D model image of a bare-hand (the transitive condition) or a hand-with-spoon (the intransi-

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tive condition) that rotates with different angles. In the object rotation task (involves object-based visual imagery), they were required to judge whether the drawer is on the right or on the left side of a desk that also rotates with different angles. Our results reveal that the two groups performed both tasks with compatible accuracy, but ASD is significantly slower than TDC only in the hand rotation task. Furthermore, both groups showed significant biomechanical constraint effects, indicating the usage of kinesthetic MI during the hand rotation task. Our findings suggest inefficient but not dysfunctional kinesthetic MI in individuals with ASD, an implication of preserved action representation. Unlike several previous findings in which ASD tends to use visual-spatial strategy to solve mental rotations of body parts, our data show that they can still spontaneously use kinesthetic MI when necessary.

Acknowledgement: MOST 103-2314-B-002 -030 -

36.4018 **Atypical Binocular Rivalry Dynamics of Simple and Complex Stimuli in Autism** Jan Freyberg[1] (jan.freyberg@gmail.com), Caroline Robertson[2, 3], Simon Baron-Cohen[1]; [1]Autism Research Centre, Department of Psychiatry, University of Cambridge, [2]Harvard Society of Fellows, Harvard University, Cambridge, MA, [3]McGovern Institute for Brain Research, MIT, Cambridge, MA

The dynamics of binocular rivalry are influenced by the balance of excitatory and inhibitory neural transmission in the brain. This balance is proposed to play an important role in the neural basis of Autism Spectrum Conditions (ASC). Binocular rivalry has therefore been proposed as a behavioural paradigm to test this theory. Two studies have compared rivalry dynamics between ASC and Control subjects, using stimuli of different levels of visual complexity. While both found results in the expected direction, only one found significant differences in rivalry dynamics between the two groups. First, we hoped to replicate our previous finding of a slower rate of rivalry with longer mixed percepts in ASC in a new, expanded sample of participants. Second, we tested whether this finding was selective for stimuli of a particular level of visual complexity (complex object or simple grating stimuli). 53 participants (26 with ASC, matched for age and IQ) completed twelve 40s trials of binocular rivalry (6 objects, 6 gratings) and 24 control trials. We analysed the rate of perceptual transitions and average percept durations. Repeated measures ANOVAs (with Stimulus Type as a between-subject and Diagnosis as a within-subject factor) revealed a lower rate of switches ($F(1, 51) = 4.3$, $p < 0.043$) and longer mixed percepts ($F(1, 51) = 14.7$, $p < 0.001$). These results remained significant when age and IQ were covaried. Group differences in mixed percept durations were confirmed with non-parametric comparisons to be significant in both stimulus conditions, while the difference in switch rate was significant only in the grating condition. We confirm a slower rate of rivalry in ASC, with and increased durations of mixed percepts, and find that this effect is present in simple grating stimuli. This result suggests that an increased excitatory/inhibitory ratio in autism may occur as early as primary visual cortex.

Acknowledgement: Medical Research Council, UK Autism Research Trust, UK

36.4019 **A systematic examination of early perceptual influences on low-, mid and high-level visual abilities in Autism Spectrum Disorder** Jacalyn Guy[1,2] (jacalyn.guy@gmail.com), Audrey Perreault[1,3], Laurent Mottron[4], Armando Bertone[1,4,5]; [1]Perceptual Neuroscience Laboratory for Autism and Development , [2]Integrated Program in Neuroscience, McGill University, [3]Centre of Research in Neuropsychology and Cognition (CERNEC), Department of Psychology, University of Montreal, [4]The University of Montreal Center of Excellence for Pervasive Developmental Disorders (CETEDUM), [5]School/Applied Child Psychology, Dept of Educational and Counseling Psychology, McGill University

Studies investigating visual perception in Autism Spectrum Disorder (ASD) have identified atypical abilities mediated by low-, mid-, and high-levels of processing (Mottron 2006, Bertone et al 2010a). Much of this research, however, has focused on isolated levels of processing (i.e. low or high). It is therefore unknown if a functional relationship exists between levels of information processing, and moreover, if alterations in early levels of visual analysis influence mid- and high-level perception in ASD. The goal of this project was to systematically assess whether manipulating either (i) the type (luminance vs texture), or (ii) access to early, local information differentially affects performance on tasks targeting low-, mid- and high-level perceptual processes in ASD. Three separate studies examined the effects of manipulating physical stimulus properties on progressively complex visuo-spatial tasks: low-level perception was assessed using luminance- and texture-defined gratings over a range of low to high spatial frequencies; mid-level perception was examined using luminance and texture-defined radial-frequency patterns manipulated to create "bumps" along their contours to optimize global (few bumps) and local (many bumps) processing; high-level perception was assessed using a face-identification task where access to local and global cues was manipulated by presenting faces from different orientations and viewpoints. For the low-level task, results revealed an increased sensitivity of the ASD group for high-spatial frequency information in the luminance-defined condition. For the mid-level task, the ASD group performed worse than the control group for luminance-defined RFPs with few modulations, but similarly for those with many modulations. For the high-level task, individuals with ASD were significantly worse identifying faces in the view-change condition in which local cues were limited. Our findings indicate that visual abilities mediated by low-, mid- and high-level mechanisms in ASD are differentially affected by the nature and access to early visual information during task completion.

36.4020 **Dissociation of chromatic discrimination ability in developmental disorders: Autism Spectrum Disorder and Williams Syndrome.** Matthew Cranwell[1] (m.b.cranwell@ncl.ac.uk), Deborah Riby[2], Ann Le Couteur[3], Brad Pearce[1], Anya Hurlbert[1]; [1]Institute of Neuroscience, Newcastle University, [2]Department of Psychology, Durham University, [3]Institute of Health and Society, Newcastle University

Atypical visual processing, particularly in dorsal stream functions, has been reported in both Autism Spectrum Disorder (ASD) and Williams Syndrome (WS), two developmental disorders which are typically said to have contrasting social profiles despite overlapping socio-communicative deficits. Here we aim to dissociate visual processing deficits between the two syndromes by examining ventral stream function, which underlies key aspects of socio-communicative ability such as face and object recognition; we specifically examine colour perception. Methods: Children (7-18 years) with ASD (N = 15) or WS (N = 26) and mental-age equivalent typically developing (TD) children (6-9 years) (N = 29) each completed two chromatic discrimination tasks: (1) the Farnsworth-Munsell 100-Hue Test (FM100), a manual cap-sorting task requiring the ordering of hues at equal lightness and saturation to form a smooth chromatic gradient, and (2) a computer-based threshold discrimination test, which assessed discrimination along cone-opponent ("red-green", "blue-yellow") and luminance cardinal axes using a controlled staircase procedure. Participants were required only to report, on each trial, the direction of a single arrow briefly shown against a grey background. Results: In FM100 performance, there was a significant difference between the WS and TD groups, but not between ASD and TD groups. Yet, in each group, performance was significantly related to non-verbal IQ, and this relationship was stronger in the ASD and WS groups. For the threshold task, a significant group by colour-axis interaction was found between TD and ASD, driven by significantly poorer "blue-yellow" discrimination in ASD. Between the WS and TD groups there were no significant differences in performance. Crucially, there were no significant correlations between threshold task performance and non-verbal ability. Conclusion: Chromatic discrimination is reduced in ASD but not in WS, relative to TD, but this dissociation is not revealed by a task which confounds visual discrimination ability with general intellectual ability.

Acknowledgement: Newcastle Vision Fund & Estate of David Murray Garside

36.4021 **Do children with autism show reduced susceptibility to the Ebbinghaus illusion?** Catherine Manning[1,2] (catherine.manning@psy.ox.ac.uk), Michael Morgan[3,4], Craig Allen[2], Elizabeth Pellicano[2]; [1]Department of Experimental Psychology, University of Oxford, [2]Centre for Research in Autism and Education (CRAE), UCL Institute of Education, London, [3]City University, London, [4]Max-Planck Institute for Metabolism, Cologne

Reports of reduced susceptibility to visual illusions in autistic individuals have generally been attributed to differences at the level of the percept. However, group differences could instead reflect differences in higher-level decision-making strategies. Here, we measured the perceptual biases of 28 children with autism aged 6 to 14 years and 32 age- and ability-matched typical children using a 2-alternative-forced-choice method with a roving pedestal designed to minimise response and decision biases (Morgan, Melmoth & Solomon, 2013, Visual Neuroscience 30:197-206). Children were presented with a reference stimulus and two comparison stimuli (see Figure 1), and asked to identify which comparison stimulus had a central circle most similar in size to that of the reference stimulus. One comparison stimulus was a pedestal, which had a central circle either 5% larger or 5% smaller than the reference stimulus. The other comparison stimulus had a central circle that was an increment larger than the pedestal. The pedestal size (+5%, -5%) was randomly interleaved throughout the task, so that children did not know which of the two comparison stimuli was the pedestal on a given trial. Children completed this task in two context conditions: with small surrounding

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circles on the reference and large surrounding circles on the comparison stimuli (S-L), and vice versa (L-S; see Figure 1). The data were fit with a cumulative normal psychometric function using the maximum likelihood estimate technique, modelling the effect of context condition as an equivalent pedestal with no effect on internal noise. Children with autism had typical levels of internal noise and exhibited a similar degree of perceptual bias to that of typically developing children. Our results are inconsistent with theories proposing reduced contextual integration in autism and suggest that previous reports of reduced susceptibility to illusions arise from differences in response or decisional criteria, not perceptual differences.

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36.4022 **A Two-Factor Structure within the Systemizing Trait of Autism Differentially Predicts Susceptibility to Lateral and Collinear Flanker Effects** Jeffrey Peterson[1] (jpeters7@uoregon.edu), Scott Reed[1], Rebecca Kenny[1], Paul Dassonville[1]; [1]Department of Psychology and Institute of Neuroscience, University of Oregon

Previous work has demonstrated that two separate components of the systemizing trait of autism differentially predict susceptibility to the mechanisms that drive the Rod-and-Frame illusion, with an Analytical Tendencies factor associated with reduced reliance on global cues, and an Insistence on Sameness factor associated with increased susceptibility to local orientation contrast effects (Reed & Dassonville, VSS 2012). However, it is unclear whether these associations reflect atypical contextual modulation only at higher levels of processing, or whether low-level visual processes (i.e., in primary visual cortex) may also be affected. To examine this, we compared scores on the Systemizing Quotient-Revised (Wheelwright et al., 2006) in the general population to individual differences in the contextual modulation of perceived orientation induced by lateral and collinear flankers, presented at the estimated size of V1 receptive fields. When an observer judges the orientation of a central line in the presence of lateral flankers, the perceived orientation of the line is biased in the direction opposite the tilt of the flankers (a repulsive effect), while the same judgments made in the presence of collinear flankers bias the perceived orientation of the line in the same direction as the flankers (an attractive effect). We found that higher scores on the Analytical Tendencies factor of the SQ-R were associated with reduced contextual effects of collinear flankers, but were unrelated to contextual interactions induced by lateral flankers. Conversely, higher scores on the Insistence on Sameness factor were associated with increased contextual effects of lateral flankers, but were unrelated to contextual effects induced by collinear flankers. These findings suggest that distinct systemizing tendencies differentially predict low-level contextual interactions that are thought to occur in primary visual cortex, and provide insight to the relationship between the functional structure of V1 and the behavioral tendencies associated with autism.

36.4023 **Don't look at the eyes: Live interaction reveals strong eye avoidance behavior in autism** Connie Wang[1] (cxw@caltech.edu), Eiko Shimojo[1], Shinsuke Shimojo[1]; [1]Division of Biology and Biological Engineering, California Institute of Technology

Atypical social gaze is commonly observed in individuals with autism (ASD) in real-world and clinical settings. Laboratory tasks using social stimuli have shown reduced gaze to face and eyes and reduced social orienting in high-functioning adults compared to neurotypical (NT) controls, although differences were often marginal, perhaps due to static stimuli or non-interactive tasks. In this study, we investigated gaze during live, naturalistic interactions between pairs of participants conversing freely about their interests, while gaze and video were recorded for both. Results from 8 NT and 7 ASD participants revealed distinct gaze patterns, distinguishing the groups. All NT participants displayed a consistent pattern of high gaze frequency and duration (mean=54%) to the eyes and low gaze to the mouth (mean=1%). ASD participants showed significantly lower gaze frequency (mean=10%, $p< 0.00000001$) and duration (mean=7%, $p< 0.000001$) to the eyes, with higher frequency (mean=33%, $p< 0.02$) and duration (mean=39%, $p< 0.02$) to the mouth, and no difference for the face (NT mean=77%, ASD mean=72%, n.s.). Only NTs showed a significant preference for the left eye in frequency ($p< 0.05$) and duration ($p< 0.04$). Mouth gaze split ASD participants into subgroups of high (N=4) or low (N=3) frequency, but long mouth fixations characterized ASD overall (640 ms) and distinguished ($p< 0.01$) from short fixations (210 ms) in NT. Together, these results show that live, interactive experiments can detect striking differences in social gaze between NT and ASD groups. The NT pattern is defined by high eye contact with occasional, passing glances at the mouth, while ASD shows a strong, spontaneous tendency to avoid the eyes and prolonged fixations to the mouth. Diversion of gaze to the mouth or other face regions (e.g. nose, cheeks, forehead) suggests a compensatory mechanism for eye avoidance that allows face gaze without direct eye-to-eye contact in ASD.

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36.4024 **Do Individuals With Autism Spectrum Disorder Process Own- and Other-Race Faces Differently?** Li Yi[1] (yili5@mail.sysu.edu.cn), Paul Quinn[2], Cong Feng[3], Kang Lee[4]; [1]Department of Psychology, Sun Yat-sen University, [2]Department of Psychological and Brain Sciences, University of Delaware, [3]Institute of Logic and Cognition, Sun Yat-sen University, [4]Dr. Eric Jackman Institute of Child Study, University of Toronto

A growing literature has demonstrated a robust other-race effect (ORE) in typically developing (TD) individuals. That is, they recognize and discriminate own-race faces more accurately than faces from other racial groups. Considering that there is inconsistency in the evidence regarding the existence of a behavioral ORE in autism spectrum disorder (ASD; Chien et al., 2014; Wilson, 2011), we investigated face scanning patterns using eye tracking, to provide a different measure of processing race information from faces. It has been shown that Chinese observers tend to focus on the central region (i.e., the nose) of Chinese faces and the eye region of Caucasian faces (Fu et al., 2012; Liu et al., 2011). The present study examined whether individuals with ASD would, like typical individuals, show differential patterns of visual scanning when viewing own- and other-race faces. The study included Chinese adolescents and young adults with ASD, age-matched TD individuals, and IQ-matched individuals with intellectual disability (ID). Participants completed a face recognition task with both Chinese and Caucasian faces, while their eye movements were tracked. Results indicated that (a) in terms of recognition, the ASD and ID groups, although not the TD group (due to a ceiling effect), displayed superior recognition of own-race relative to other-race faces; (b) different from TD and ID groups, individuals with ASD showed atypical face processing patterns regardless of face race; (c) similar to TD and ID individuals, individuals with ASD fixated on the eyes of other-race faces longer than those of own-race faces, whereas they looked at the nose and mouth of own-race faces longer than those of other-race faces. The results suggest that similar to TD individuals, individuals with ASD are sensitive to face race information: their visual scanning and recognition of faces are both influenced by asymmetrical experience with different types of faces.

36.4025 **A survey of the integrity of major white matter tracts in strabismic amblyopia** Yiran Duan[1] (yirand@gmail.com), Anthony Norcia[1], Jason Yeatman[2], Aviv Mezer[3]; [1]Stanford University, [2]University of Washington's Institute for Learning and Brain Science (ILABS), [3]The Hebrew University of Jerusalem

Chronic misalignment of the eyes (strabismus) during early visual development leads to many well-known functional consequences including loss of visual acuity and stereopsis in addition to a range of other deficits in form and motion processing. Much less is known about the effects of strabismus on the development of brain structure. In the current study, we performed a comprehensive survey of 28 major white matter tracts in 16 patients with amblyopia, comparing their results with 32 age-matched, neurotypical controls. We capitalized on two recent methodological developments to better characterize amblyopia: First, in addition to diffusion-based tractography, we employed a new quantitative T1 mapping procedure that has been shown to be sensitive to myelin in white matter. Second, we analyzed a tract –the Vertical Occipital Fasciculus– that bridges dorsal and ventral visual areas of the occipital lobe. We measured three properties for each tract: fractional anisotropy(FA), mean diffusivity(MD), and T1. A small global effect of amblyopia was reflected in consistently elevated MD and T1 values and decreased FA values in almost all of the tracts. Overall, the most affected property was MD. To assess which tracts were most affected, we rank-ordered the tracts on the basis of their MD effect size. The five most affected tracts showed effect sizes (d′) ranging from 0.74 to 0.58, and were, in decreasing order, the Anterior Frontal Corpus Callosum, Right VOF, Left Inferior Longitudinal Fasciculus (ILF), Left Optic Radiation and Temporal Corpus Callosum. Notably, the VOF is the only long-range tract that lies entirely within the occipital lobe. The ILF connects the occipital and temporal lobes and the two callosal tracts connect frontal and temporal lobe areas. Previous work has suggested that the optic radiation is affected in visual deprivation(Xie et al.,2007).We conclude that strabismic amblyopia has subtle, but widespread effects on white matter properties.

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36.4026 **Neuronal response properties in area MT of an awake amblyopic macaque monkey** Tom Van Grootel[1], Lynne Kiorpes[1]; [1]New York University, Center for Neural Science

Sunday PM

Amblyopia is a visual deficit associated with abnormal visual experience in early life. Spatial and temporal vision is impaired in amblyopic observers viewing through their amblyopic eyes, and they also have deficits on motion tasks. Cortical area MT plays an important role in perception of motion, and previous work in anesthetized monkeys showed little disruption of single neuron response properties in amblyopic macaques. We recorded from single neurons in MT of an awake, fixating macaque with strabismic amblyopia, and compared responsiveness, direction selectivity, and spatial and temporal tuning properties when viewing through each eye. Neurons driven by the amblyopic eye were under-represented in the recorded population. In normal monkeys, almost all MT neurons are driven binocularly. Of our sample of 162 neurons, 94 could be influenced by amblyopic eye stimulation. Of the 94, 42 were untuned to visual stimulation of the amblyopic eye. The remaining 52 showed well-tuned responses to amblyopic eye stimulation and had similar tuning properties when driven by the fellow eye. However, firing rates were substantially reduced, and in some cases latency was longer, with the amblyopic eye viewing. These results confirm and extend previous work on amblyopic MT obtained under anesthesia. In the awake state, a clear reduction in responsiveness was found when the amblyopic eye was viewing. The reduced firing rate might reflect an upstream impediment feeding forward to MT or a disordered local summation mechanism. The amblyopic eye deficits in motion perception may be explained by the reduced magnitude and selectivity of MT responses evoked by stimulation of the amblyopic eye.

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36.4027 An irreducible delay in manual and saccadic reaction time in amblyopia Christina Gambacorta[1,2,3] (christina.gambacorta@berkeley.edu), Suzanne McKee[3], Preeti Verghese[3], Dennis Levi[2,1]; [1]Vision Science Graduate Group, University of California, Berkeley, CA, [2]Department of Optometry, University of California, Berkeley, CA, [3]Smith Kettlewell Eye Research Institute, San Francisco, CA

Despite normal motor control, saccadic latencies are delayed in the non-preferred eye of patients with amblyopia (≈25-100ms1,2). This delay extends to manual reaction time when responding to targets with the amblyopic eye (≈50-100ms1,3,4). Previous researchers have shown a positive correlation between the delay and the magnitude of visual acuity impairment in the amblyopic eye5. This delay may be due to a difference in effective stimulus strength of the targets, since reaction times to weak stimuli are prolonged, decreasing as stimulus strength increases, until reaching a plateau6. Here, we measure saccadic and manual reaction times of normal and amblyopic subjects to the abrupt appearance of a Gabor patch at 5 degrees to the left or right of fixation, while varying the contrast of the patch. Even after adjusting for differences in effective stimulus strength, we find significant delays in both saccadic and manual response times when viewing with the amblyopic eye. We speculate that this irreducible delay may be a consequence of impaired ability to rapidly direct spatial attention with the amblyopic eye. 1 Mackensen, G. (1958). Reaktionszeitmessungen bei Amblyopia. Graefes Arch Ophthalmol 159:636 – 642. 2 Ciuffreda, K.J., Kenyon R.V. Stark L. (1978). Increased saccadic latencies in amblyopic eyes. Invest Ophthalmol Vis Sci 17: 697-702. 3 Von Noorden, G.K. (1961). Reaction time in normal and amblyopic eyes. Arch Ophthalmol 66:695-699. 4 Levi, D.M., Harwerth, R.S., and Manny, R.E. (1979). Suprathreshold spatial frequency detection and binocular interaction in strabismic and anisometropic amblyopia. Invest Ophthalmol Vis Sci 18:714-725. 5 Hamasaki, D.I. and Flynn, J.T. (1981). Amblyopic eyes have longer reaction times. Invest Ophthalmol Vis Sci 21:846-853. 6 Pieron, H. (1952). The Sensations: Their Functions, Processes and Mechanisms. London: Frederick Muller Ltd.

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36.4028 Global motion perception deficits in children with amblyopia as a function of spatial and temporal stimulus parameters

Kimberly Meier[1] (kmeier@psych.ubc.ca), Brian Sum[2], Deborah Giaschi[2]; [1]Department of Psychology, University of British Columbia, [2]Department of Ophthalmology and Visual Sciences, University of British Columbia

Introduction: There are conflicting results on whether children with amblyopia have deficits in global motion perception. Differences in the stimulus parameters used in different studies may have led to these discrepancies. Specifically, the speed of a global motion stimulus can be broken down into a ratio of spatial (Δx) and temporal (Δt) displacement parameters. We have shown that coherence thresholds for global motion direction discrimination are immature in 4-6 year olds when smaller Δx/Δt values are used to create the speed, but adult-like when larger values are used (Meier & Giaschi, 2014). We hypothesize that coherence thresholds in children with amblyopia will be elevated for parameters that take longer to mature, and similar to controls for parameters that mature earlier. Methods: Coherence thresholds were assessed in children with amblyopia (7-16 years, M = 11.21) and age-matched controls using a two-alternative forced choice direction discrimination task. Six combinations of spatial and temporal parameters were used: spatial displacement (Δx) was 1, 5, or 30 arc min; temporal displacement (Δt) was 17 or 50 ms. Children were assessed monocularly, and conducted one run per eye, for a total of 12 measurements. Results: Children with amblyopia had elevated coherence thresholds in the amblyopic eye for Δx = 1 and 5 arc min, but not Δx = 30 arc min, at both Δt = 17 and 50 ms. There was a similar trend in the fellow eye at Δt = 17 ms, Δx = 1 arc min. Conclusion: Children with amblyopia show deficits in global motion perception in each eye when they are tested with stimuli that use shorter spatial displacements, regardless of temporal displacement. This is consistent with the hypothesis that aspects of motion perception that take longer to mature are more susceptible to damage by amblyopia.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

36.4029 Entropy estimation of resting-state EEG variability in amblyopia Dave Saint-Amour[1] (saint-amour.dave@uqam.ca), Karine Lacourse[2], Mathieu Simard[1], Sarah Lippé[3]; [1]Department of Psychology, Université du Québec à Montréal, [2]Department of Electrical Engineering, École de Technologie Supérieure, [3]Department of Psychology, Université de Montréal

Human EEG studies have shown that development of visual processing is associated with changes in entropy, i.e., signal variability. In the present study we asked whether abnormal development associated with amblyopia alters brain signal entropy at adulthood. Brain's electrical resting state activity was recorded from occipital (Oz), central (Cz) and frontal (Fz) sites in 6 strabismic adults (mean age = 32 y) and 9 controls (mean age = 30 y) under monocular and binocular viewing conditions. Wavelet decomposition was applied to the EEG to extract 9 scales or frequency bands. Shannon entropy estimation as a measure of irregularity or variability of the signal was calculated for each frequency band. Results revealed no significant difference between the dominant and non-dominant eyes for the controls and, more surprisingly, the amblyopes. However, entropy was significantly different between groups for the frequency bands below 30 Hz at all electrodes, in particular theta band (3.9-7.8 Hz) at Oz. No significant difference between groups was found for binocular signals, although entropy was slightly higher in the amblyopes. These findings suggest that entropy can be a useful metric to better assess the nature of brain processing in amblyopia, not only for the amblyopic eye but also the fellow eye, which might also be associated with abnormal processing, as far as signal variability is concerned. Further research is needed to confirm these results on a larger number of participants and to link entropy to visual dysfunctions reported in amblyopia, either at neural (e.g., oscillatory synchronisation) or behavioural level, to improve our understanding of the underlying mechanisms.

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36.4030 Amblyopic deficits in visual search Herbert Goltz[1,2] (herb.goltz@sickkids.ca), Inna Tsirlin[1], Agnes Wong[1,2]; [1]The Hospital for Sick Children, [2]University of Toronto

Amblyopia is a neurodevelopmental disorder defined as a reduction in visual acuity that cannot be corrected by optical means. It has been associated primarily with other low level visual deficits such as reduced contrast sensitivity at high spatial frequencies and increased visual crowding. Research in the last decade demonstrated that amblyopia is also linked to higher-level deficits in global shape and motion perception and in contour integration. Deficits in visual attention have also been shown in counting briefly presented items, tracking objects and identifying items presented in rapid succession. Here, we demonstrated that amblyopia causes more general attentional deficits as manifested in visual search. We compared the performance of subjects with amblyopia (n=9) to those of controls (n=12) on a feature search and a conjunction search with Gabor patches. Eye movements were recorded and controlled by continuous fixation. To account for the low level deficits inherent in amblyopia, we first measured each subjects' contrast and crowding thresholds and then presented the display elements at suprathreshold levels such that visibility was equalized across the control and the experimental groups. The effectiveness of these precautions at eliminating low-level deficits as a confounding factor was confirmed by the results of the feature search task. Performance on this "pop-out" search, considered to be pre-attentive, was not significantly different between the two groups. In contrast, reaction times on conjunction search, a task requiring the engagement of visual attention, were significantly

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greater (by as much as 400 msec) in amblyopic eyes than in control or fellow eyes. Taken together, these data suggest that amblyopia is linked to greater and more generalized attentional deficits than previously known. Visual search is a necessary, basic component of everyday functioning and these deficits may result in significant repercussions for people with amblyopia.

Acknowledgement: NSERC to Inna Tsirlin

36.4031 Plasticity in adult amblyopia: a meta-review and analysis

Inna Tsirlin[1] (inna.tsirlin@sickkids.ca), Linda Colpa[1], Herb Goltz[1], Agnes Wong[1,2]; [1]The Hospital for Sick Children, [2]University of Toronto

Amblyopia is a neuro-developmental disorder involving a decrease in visual acuity that cannot be explained by ocular abnormalities. It affects 2-3% of the population and is the prevalent cause of monocular blindness. Patching of the amblyopic eye is a powerful treatment in early childhood but its effectiveness decreases with age, which has been attributed to decreased plasticity in the adult brain. In the last few decades new treatment methods including dichoptic training, perceptual learning and video games, were developed that improved visual acuity and/or stereoacuity in adult amblyopia. To understand the factors involved in adult plasticity in amblyopia, its clinical significance and to compare the treatments, we have used mean and individual participant data (IPD) meta-analyses on 19 studies with close to 200 individual scores. Our analysis showed that the average improvement in visual acuity (0.19 logMAR) was above mean test-retest reliability for acuity tests (0.14 logMAR) with 67% of subjects improving by more than this amount. Moreover, half of the subjects improved their stereo acuity by 2 octaves or more. The most important factor was the severity of amblyopia at the onset of treatment. Subjects with more severe amblyopia improved more on visual acuity and less on stereo sensitivity than those with the milder condition. Better binocularity was a predictor of improvements in stereo sensitivity. The different treatments, though employing very diverse strategies, yielded largely similar degrees of improvement on both measures. This suggests that any task involving sufficient engagement of the amblyopic eye could induce plasticity. We interpret this effect as the result of improvement in visual attention to the input from the amblyopic eye. Interocular suppression, which leads to amblyopia, could occur due to signal modulation by visual attention. Forcing visual attention to favor the amblyopic eye's input might release those suppressive influences, thus improving visual function.

Acknowledgement: NSERC Fellowship to Inna Tsirlin

36.4032 The effect of pharmacological intervention on contrast sensitivity deficits in phenylketonuria

Marcus Watson[1] (mwatson@cfri.ca), Nataliya Yuskiv[2], Christine Chapman[1], Sylvia Stockler[2], Deborah Giaschi[1]; [1]Department of Ophthalmology and Visual Sciences, The University of British Columbia, [2]Department of Pediatrics, Division of Biochemical Genetics, The University of British Columbia / BC Children's Hospital

Patients with the autosomal recessive disorder phenylketonuria (PKU) have elevated phenylalanine levels that impede production of tyrosine, a precursor to dopamine. Lowered dopamine levels lead to a number of deficits, including lowered visual contrast sensitivity (Diamond & Herzberg, 1996; Gramer et al, 2013; Stemerdink et al, 1999). In the present study we measured contrast sensitivity and blood phenylalanine and tyrosine levels on multiple visits in 10 PKU patients, 5 of whom began a course of sapropterin dihydrochloride (Kuvan®), which reduces phenylalanine levels (in some patients). The expectation was that initial contrast sensitivity would correlate with phenylalanine and tyrosine levels, and that in patients who responded well to sapropterin dihydrochloride, reduced phenylalanine levels would correspond to increased contrast sensitivity. Contrast thresholds for each PKU patient and age-matched controls were determined using a four-alternative forced-choice grating discrimination task with an adaptive staircase (the Freiburg Visual Acuity Test, Bach, 1996; 2007) at five spatial frequencies, on multiple visits (1-4 per patient). On Visit 1, prior to sapropterin dihydrochloride treatment, contrast thresholds were an average of 67% higher in PKU patients than in their age-matched controls, but no correlation between performance and phenylalanine or tyrosine levels was detectable. During sapropterin dihydrochloride treatment, however, phenylalanine levels dropped by half, and contrast sensitivity deficits disappeared entirely. Practice also played a role in improvement: threshold elevations were 10% lower on Visit 2 among those patients who had not begun treatment. Control participants displayed a similar degree of improvement on their second visit. Results during treatment suggest that sapropterin hydrochloride may be effective in reducing both phenylalanine levels and corresponding perceptual deficits in PKU patients. The practice effect, however, raises the possibility that only some of the contrast sensitivity deficit in PKU patients is the result of dopamine-related impairments in the retina or visual cortex.

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Visual Memory: Capacity and resolution

Sunday, May 17, 2:45 - 6:45 pm
Poster Session, Pavilion

36.4033 The number of objects determines visual working memory capacity allocation even for complex items

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We examined whether visual working memory (WM) capacity allocation is determined solely by complexity, with the number of objects being redundant, as suggested by flexible resource models. Participants performed the change detection task with random polygons as stimuli, while we monitored the contralateral delay activity (CDA), an electrophysiological marker whose amplitude rises as WM capacity load increases. In Experiment 1, we presented random polygons together with other complex items (e.g., shaded cubes and Chinese characters) and decreased the resolution with which random polygons need to be maintained in WM by introducing only between-category changes (e.g., polygon to cube). The results indicated that the polygon still consumed more WM capacity relative a simple object. In Experiment 2, we compared the WM maintenance of one whole polygon to two halves of a polygon, thus equating complexity but manipulating the number of items. Additionally, we compared the whole polygon to a single half of a polygon, equating the number of items but varying the complexity level. The results suggested that only the number of objects determined WM capacity allocation: the CDA amplitude was lower in the whole polygon condition relative to the two halves condition, even though both contained the same amount of information. Furthermore, the CDA was identical when comparing one whole polygon to one polygon half, even though these conditions differed in complexity. Experiment 3 extended these results by showing that two polygon-halves moving separately but then meeting and moving together, were gradually integrated to consume similar WM capacity as one polygon half. Interestingly, we also found an object benefit in accuracy, corroborating the important role of objects in WM. Our results demonstrate that WM capacity allocation is highly sensitive to objecthood, as suggested by discrete slot models.

36.4034 Competitive interactions automatically compromise visual working memory.

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Competition between visually presented stimuli is associated with longer reaction times, reduced BOLD response and reduced neural firing. Previously we observed that competition affects working memory (WM) performance (Ahmad, Nobre, Shapiro & McNab, submitted). In that study we manipulated competition during WM encoding by varying the spatial proximity between two items (Near vs. Far conditions). Participants were required to report the colour of a target item on a colour wheel. We demonstrated that the effect of competition extends to WM. Relative to the Far condition, the Near condition was associated with reduced WM precision and an increase in the number of times the colour of the un-cued item was erroneously reported. We also observed that pre-cues directing attention to one of the items failed to reduce the effects of competition on WM. Here we present an experiment in which we examined whether the effect of competition upon WM could be reduced with a different top-down manipulation. We examined whether prior knowledge of the trial type (Near vs. Far) would enable participants to reduce the effects of competition on WM. Prior knowledge was manipulated using a mixed versus blocked design. We again observed that the Far condition, relative to the Near condition, was associated with greater precision ($F(1,27)= 24.12$, $p< .001$) and a lower probability of reporting the colour of the non-target ($F(1,27)= 66.13$, $p< .001$). However, there was no interaction with prior knowledge for either precision ($F(1,27)= 0.57$, $p=0.456$) or probability of reporting the non-target ($F(1,27)= 2.38$, $p=0.135$). Together with the previous pre-cue experiment, the results indicate that it may not be possible to overcome the effects of competition on WM with top-down control.

Sunday PM

36.4035 **An equivalent noise method for measuring delay-induced degradation in VSTM.** Nicholas Van Horn[1] (van-horn.73@osu.edu), Alexander Petrov[1]; [1]The Ohio State University

The fidelity of visual short-term memory (VSTM) representations become compromised with time. A novel technique of adaptive noise estimation is shown to be a useful methodological tool for measuring the time course of memory decay. Differences in noise equivalence estimates between retrieval type suggest task-dependent effects of time on memoranda. Method: Sixteen observers memorized the orientation of a sample Gabor. After a short (1 sec) or long (4 sec) delay, a second test Gabor was presented. For recall trials, observers reproduced the sample orientation by rotating the test Gabor. For discrimination trials, observers indicated a binary same/different response. Adaptive methods estimated discrimination and recall error psychometric functions. Filtered noise was adaptively added to the sample Gabor on short-delay trials to produce equivalent performance to that measured on low-noise, long-duration trials. Results: Increased storage duration impaired discrimination (-20% accuracy) and recall error (+8% magnitude). Performance under adaptive noise successfully tracked that of low-noise, long-delay conditions. A mixed-effects regression analysis provided a common currency for translating between retention delay and stimulus noise. Discrimination noise equivalence, the amount of stimulus noise required to produce impairments similar to long-delays, was estimated to have a mean of 0.39, 90% CI [.18, .68]. For recall, mean noise equivalence was 0.16, 90% CI [.03, .37]. Conclusion: The equivalent noise method for estimating VSTM decay provides a novel technique for measuring the time course of memory fidelity. Trending differences in equivalence across tasks suggests that more noise is necessary to offset the effect of retention duration for discrimination compared to recall. A likely interpretation is that decay is non-linear, such that delay-induced effects are larger for the brief response time (RT) profile of discrimination (mean RT = 924 msec) versus recall (mean RT = 2396 msec).

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36.4036 **The role of the occipital cortex in capacity limits and precision of visual working memory** Amanda van Lamsweerde[1] (amanda.vanlamsweerde@ndsu.edu), Jeffrey Johnson[1]; [1]Department of Psychology, Center for Visual and Cognitive Neuroscience, North Dakota State University

Several lines of evidence suggest a role for the occipital cortex in the storage of information in working memory (WM). For example, single pulse TMS to retinotopic visual cortex reduces shape change detection performance, but only during the time period when performance is sensitive to masking (van de Ven et al., 2012). Furthermore, although BOLD response in the occipital cortex is elevated during encoding but not maintenance, features such as color, orientation, or motion of remembered stimuli can be decoded from the occipital cortex by analyzing patterns of activity during WM maintenance (Emrich et al., 2013; Harrison & Tong, 2009; Serences et al., 2009). Furthermore, pattern classifier sensitivity is correlated with the precision of representations, but not capacity (Emrich et al., 2013). This suggests that the visual cortex may serve a storage function in WM and that visual cortex activity may determine the precision of WM representations. To test this hypothesis, single pulse TMS was applied to visual cortex at 0, 100, or 200ms after the offset of the memory stimulus. TMS-related changes in the capacity and precision of WM representations, as well as the likelihood of mis-binding objects to locations (swap errors), were analyzed. Occipital simulation decreased capacity and swap errors, and produced a small, non-significant increase in precision when applied immediately at stimulus offset, but not when applied 100 or 200ms later. Preliminary analysis of data from a follow-up experiment (n=5) revealed no change in capacity or precision when arrhythmic trains of high-frequency rTMS were applied to the occipital cortex either 125ms or 575ms after stimulus offset. This suggests that the occipital cortex contributes to VWM capacity, but the quality of representations may be specifically dependent on the number of items encoded into VWM; furthermore, occipital-based representations may not be vulnerable to disruption after initial encoding.

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36.4037 **Categorical modulation of contents in visual working memory by simple foveal discrimination** Gi-Yeul Bae[1] (freebird71@gmail.com), Steven Luck[1]; [1]University of California-Davis

Studies have shown that visual working memory interacts with attention, but there are many varieties of attention, and how these varieties of attention modulate the contents of visual working memory is not well understood. Here, we investigated how a simple foveal discrimination task affects the contents of visual working memory using a dual-task paradigm. In the working memory portion of the paradigm, participants attempted to remember the orientation of a single object and then report its orientation after a short retention interval. On a subset of trials, we presented a letter during the retention interval. In the discrimination condition, participants were asked to report which of two letters (e.g., C or D) was presented by means of an immediate button-press response. In the no-discrimination condition, the letter was task-irrelevant and required no response. In the no-letter condition, no letter was presented. The memory data were fit by a mixture model for each target orientation to estimate response dispersion (i.e., precision) and central tendency (i.e., bias) for each orientation value. In all three conditions, cardinal orientations produced less precise response distributions than oblique orientations. In addition, responses for oblique orientations were biased away from the nearest cardinal orientation. These effects were largest when subjects performed a discrimination during the retention interval (the discrimination condition), smaller when they expected to perform a discrimination but no discrimination target was presented (the no-letter condition), and smallest when a stimulus was presented during the retention interval but could be ignored (the no-discrimination condition). In a follow-up experiment, we found the same pattern of results with a simple auditory discrimination (e.g. high/low pitch tones). These results indicate that the processes involved in making a simple visual or auditory discrimination cause visual working memory representations to become less precise and more influenced by category boundaries.

36.4038 **Trial feedback and incentive structures decrease failures of working memory** Kirsten Adam[1] (kadam@uoregon.edu), Edward Vogel[1]; [1]Department of Psychology, University of Oregon

Trial by trial fluctuations in attentional control can lead to failures of working memory (WM), in which the subject is no better than chance at reporting the items from a recent display. In three experiments, we used a whole-report measure of visual WM to examine the impact of pre- and post-trial information on the rate of these failures. We hypothesized that subjects' knowledge about the upcoming task load (pre-trial) or instantaneous feedback about performance (post-trial) would reduce failures and improve average WM performance. In each experiment, subjects remembered an array of colored objects (~200 ms) across a blank delay (~1300 ms) and then reported the identity of all items. We defined performance failures as the trials in which subjects were at chance for reporting all items in the array (0 or 1 correct items). To manipulate pre-trial information, we presented subjects (N=18) with a cue before the memory array that was either informative (the set-size) or uninformative (an "X") about the upcoming trial load (2 to 8 items). We found that failure rate and overall performance were identical for both conditions, suggesting that subjects could not take advantage of this pre-trial information. To test the impact of post-trial information, we compared no feedback to feedback about the number of items correct (N=15) after each trial. Feedback decreased failure rates from 15% to 10%. In the third experiment (N=49), we used a point-based incentive structure in the feedback condition in which failure trials resulted in lost points and consistent successful performance received "streak" points. Again feedback decreased failure rates from 11% to 6% and benefitted all subjects irrespective of average capacity. Together, these results suggest that while pre-trial knowledge of task load is ineffective, post-trial feedback is highly effective at decreasing the rate of WM failures within a session.

36.4039 **Pre-cues increase capacity at the expense of precision in visual working memory.** Andrea Bocincova[1] (andrea.bocincova@ndsu.edu), Amanda van Lamsweerde[1], Jeffrey Johnson[1]; [1]Department of Psychology, Center for Visual and Cognitive Neuroscience, North Dakota State University

Activity in a network of frontal, parietal, and occipital cortical areas has been associated with retention in visual working memory tasks. While parietal and occipital cortex are thought to encode and maintain information about objects and their spatial locations, the role of the frontal cortex in pure storage functions remains unclear. According to a recent biophysical network model of WM, the frontal cortex regulates capacity via excitatory feedback to posterior storage areas (Edin et al., 2009). Such feedback has been proposed to boost capacity at the cost of reduced precision. A recent study by Roggeman et al. (2013) confirmed the predicted trade-off in a task requiring the short-term retention of spatial locations. Moreover, a follow-up fMRI experiment revealed a correlation between the trade-off effect and increased BOLD responses in frontal and parietal cortex. In the present study, we used similar methods to determine whether the observed trade-off effect generalizes to color WM. Specifically, participants performed a cued color WM task requiring retention of either 2 or 4 items in WM. To

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elicit the postulated boost input, at the beginning of each trial a cue was presented (75% valid) indicating whether 2 or 4 items would be presented on that trial. Behavioral results confirmed the predicted trade-off between capacity and precision, and the cue-related change in capacity predicted changes in precision on a subject-by-subject basis. Additionally, analysis of event-related potentials (ERPs) revealed a significant cue-related modulation of the P1 ERP component in response to the memory display; the P1 was higher amplitude in Cue4/SS4 versus Cue2/SS4 condition. Additionally, we also observed a cue-related increase in theta-band oscillatory coupling between frontal and posterior electrodes. However, this difference was not predictive of cue-related changes in either capacity or precision.

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36.4040 Detailed visual memory capacity is present early in life

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Previous studies have shown that adults can remember 2,500 images with great accuracy and fidelity (Brady et al., 2008). However, little is known about the extent of visual memory capacity early in life. Such detailed visual memory may be surprising, given the importance of generalization in domains such as word and concept learning (Jenkins et al., 2014). We adapted the method of Brady et al. to test the fidelity of children's visual memory. Twenty-four 4-5 year-olds and twenty-four 6-7 year-olds were first shown 116 images of everyday objects (e.g., apple, ball), each presented for 3s. Children were then tested for recognition of familiar vs. new items. Three conditions varied the test pairings. In the Novel Category condition, familiar items were paired with categorically distinct items (e.g., a doll and a telephone). In Different Exemplar, familiar items were paired with items from the same category (e.g., two backpacks). In Different State, familiar items were paired with the same item in a different state (e.g., a closed container and the same container with an open lid). Children performed far above chance (50%) in all conditions: (4's: 95% Novel Category, 94% Different Exemplar, 86% Different State; 6's: 98%, 91%, 88%, respectively). For both ages, accuracy was lower for the Different State than the Novel Category condition. A subset of children (n = 10) were tested 18-21 days later and still performed above chance on the recognition test. The data show that children retain a great degree of visual detail from a large set of images; they can recall a specific category member and its particular state. This occurs spontaneously, as children were never instructed to remember the pictures. These results suggest that the ability to encode a high level of detail across a large number of images is well developed early in life.

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36.4041 Comparing Monkey and Human Multi-Item Memory

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Are memory capabilities of humans and monkeys similar or does one species have superior abilities? In particular, does language afford better memory facilities? We compared monkey and human memory capabilities in a delay-match-to-multiple-item memory task. In each trial, a series of samples was presented and participants detected and responded to a repetition of any previous item seen in the same trial. Two difficulties are included that are not present in standard delay-match-to-sample tasks: The repetition can be for any image in the trial, not only for the first, so participants must remember all seen images. Secondly, repetition of images that appeared in a previous trial are not considered valid, and should be ignored. Thus, participants need remember all the images of the trial and if the current repeated image was seen in the current trial. In general, we used novel images that had not been seen before, introducing a few catch images from previous trials, which should be ignored. Performance Hit rate is similar for monkeys and humans, about 90% except for the longest trials. The False Positive (FP) rate is very different, however, about 80% for monkeys, 30% for humans, for images from the preceding trial. When monkeys are intensively trained with a limited set of images, they necessarily develop a reset mechanism allowing them to reject the frequent presentation of images seen in earlier trials. Interestingly, they are able to transfer this reset capability to task performance with novel (and catch) images, reducing the FP rate to below 20%. Thus, there is a surprising similarity between human and monkey performance following intensive training with a limited set of images, forcing acquisition of a reset mechanism. This similarity is found even for human performance without such prior training. We conclude that human participants have an inherent reset mechanism before visiting our laboratory.

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36.4042 Measuring the memory quality of a task irrelevant feature of an attended object

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We have a good understanding of how well people can remember a relevant feature of an attended object (e.g. color of a color patch; Bays et al., 2009), but we know relatively little about how an attended object's task irrelevant features are encoded (e.g. shape of a color patch). Previous research suggests that we have some categorical knowledge of irrelevant features (Eitam et al., 2013), but knowing the precision with which this information is stored is essential for understanding the capacity of working memory. To better understand the memory of irrelevant features, we presented participants with a colored arrow, and for the first 25 trials, consistently asked participants about its color using a color wheel. On trial 26, we cued participants to recall the direction of the arrow in a surprise test (i.e. the critical trial). To determine how participants are responding on the critical trial, we compared the log likelihood of different combinations of von Mises distributions' fit to the behavioral data, with the distributions varying from precise to guessing (i.e. uniform distribution). From this comparison process, we find that some participants remember the irrelevant information imprecisely, relative to a relevant feature response distribution, while other participants are simply guessing. Importantly, after the surprise test, all participants could easily recall the arrow's direction but this improvement in direction memory came at a significant cost in precision for color memory. We attribute these findings to varying levels of attention to different features during memory encoding. To understand how these tradeoffs occur at a mechanistic level, we simulated featural attention in the Binding Pool model of visual Working Memory (Swan & Wyble 2014) according to findings from monkey neurophysiology (McAdams et al., 1999). The model accurately simulates imprecise retrieval for irrelevant features and the cost of adding features to a memory.

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36.4043 Measuring Stroop interference in the absence of response generation using the attentional blink

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Stimulus-stimulus compatibility effects, such as Stroop interference, have been studied for many years as differences in reaction times when stimuli have varying levels of compatibility. However, it is not known whether such interference can be observed in the absence of a response, which would definitively answer questions about whether such interference can exist in a purely perceptual task. To answer this question we measured the difference in the attentional blink of a neutral word caused by a preceding word that was a congruent, incongruent or neutral Stroop stimulus. During the experiment, a fixation cross was presented at the beginning of each trial that was followed by the first target (T1) which was a congruent, neutral or incongruent word presented for 80 msec. On half of the trials, a mask was presented immediately after T1 for 80 msec. The second target (T2) was a neutral word that appeared at one of several latencies following T1 and was always masked. Participants reported the color of both words and always ignored the words themselves. Analyzing accuracy of the T2 on trials when the T1 was accurately reported, we observed a main effect of T1 congruence and an interaction between T1 congruence and inter-target lag. This revealed that the attentional blink was deeper for incongruent T1s. Surprisingly, omitting the first target mask did not reduce the effect of congruence. These results provide the clearest evidence yet that incompatible stimulus attributes reduce the speed of processing during stimulus identification, even in the complete absence of the need to generate a speeded motor response. These results also strongly support computational models in which the identification or encoding of a stimulus can be slowed by the presence of stimulus-stimulus conflict (Kornblum, Stevens, Whipple and Requin 1999; Wyble, Sharma, and Bowman 2008).

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36.4044 The focus of spatial attention determines the number and quality of individual faces retained in working memory

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The capacity of visual working memory for faces is extremely limited, but direct evidence for the cognitive locus of these limitations is currently lacking. Some accounts of working memory for complex objects such as faces assume that a fixed number of three or four items are encoded regardless of object complexity. According to fixed-capacity accounts, the apparent severe capacity limitations for complex objects arise during the sample-test comparison process rather than reflecting the actual number of items retained. We provide direct electrophysiological evidence (using the N2pc and CDA components as markers of attentional selection and working memory maintenance) that memory capacity limits for faces arise from the limited capacity of focal spatial attention during memory encoding. Participants performed a match to sample task with lateralised memory displays that contained one face (Load One) or two faces (Load Two). We show that only a single face is focally attended on most trials, and that the allocation of spatial attention predicts whether a particular face will be retained in memory. ERPs also reveal that on a minority of trials, two faces are simultaneously encoded. However, this type of divided attention delays face matching responses, and impairs sample-test comparison processes, as reflected by attenuated N250r components relative to trials with focal attention on the stored matching face. These results demonstrate a trade-off between the number of items stored in memory and the fidelity of visual working memory representations. We suggest that the capacity and distribution of selective spatial attention is a dynamic resource that constrains both working memory capacity and resolution. Because visual working memory representations are maintained through the allocation of selective spatial attention, they are position-dependent. This hypothesis is supported by an additional ERP experiment, which demonstrates that interference between visual memory representations occurs in a position-specific manner.

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Sunday PM

36.4045 Visual Working Memory Capacity for Own- and Other-race Faces: Effects of Set Size and Face Features Yongna Li[1] (cogpsyli@ruc.edu.cn), Weiying Li[1], Zhe Wang[1]; [1]Department of Psychology, Renmin University of China

Both the number of item to-be-memorized and the complexity of each item contributes to the limited capacity of visual working memory. As a special complex object, visual working memory of human faces has been found to be affected by many factors. The current experiment examined how race, set size of study array, and face feature types (internal feature only vs. both internal and external features) played a role in a delayed match-to-sample probe recognition task. In this task, participants first studied a set of faces (either two or four faces in each condition), they then had to judge whether a probe face was a studied one or a new one by keypressing after a 900-ms retention interval. Results indicated interactions of race, set size, and feature type. For own-race (Chinese) faces, visual working memory capacity estimated by Cowan's K increased for faces with both internal and external features when two faces were displayed in the study array but decreased when four faces were displayed. For other-race (Caucasian) faces, visual working memory capacity increased for faces with both internal and external features in both two- and four-face conditions. This suggests that representations of own- and other-race faces in visual working memory are affected by different factors in different manners. However, people can retain same amount of information in visual working memory for own- and other-race faces. External face feature may increase visual working memory capacity by increasing the resolution of face representations.

36.4046 The Role of Working Memory in Selective Attention Melissa Trevino[1] (mtrevino@uh.edu), Bruno Breitmeyer[1], Jane Jacob[2]; [1]Psychology, University of Houston, [2]Psychology, University of Westminster

Previous studies have shown that when working memory (WM) has reached its processing limit due to maintaining a substantial amount of information, its cognitive resources are depleted for subsequent cognitive functions, such as for selective attention (SA) (de Fockert et al., 2001; Downing, 2000). Using a dual-task paradigm combining a change-detection task and a flanker task, we investigated how WM maintenance affects SA across and within spatial and feature-based information categories (processing feature information such as the color of an item in WM as well as in SA would be considered within-category; storing the spatial location of an item in WM while attending to the color of the item in SA would be considered across-category). Participants ran in eighteen dual-task conditions that varied by WM load (1, 3, 5 load), and information categories of the WM task (colors, shapes, location) and of the flanker task (colors, shapes). Participants also ran in nine corresponding WM-only conditions and two flanker-only conditions. Interference effects (the reaction time difference between incongruent and congruent flanker-target pair trials) were computed for the flanker task. We expected larger interference effects for the within-category conditions than across-category conditions, as stimuli from the same category would be depleting cognitive resources that are available for that particular category, whereas stimuli that are from different categories will access separate cognitive resource stores. Results reveal larger interference effects for the within-category conditions compared to across-category conditions for only color stimuli rather than for shape stimuli. Across the three loads and the three types of WM tasks, larger interference effects were seen in the color-flanker task compared to the shape-flanker task. Thus, maintaining information in WM subsequently impairs SA but the poor performance of SA varies depending on the information category of the task.

36.4047 Visual Working Memory Performance is Determined by the Allocation of Attentional Resources: Evidence from Probabilistic Cueing Holly Lockhart[1] (hl10ze@brocku.ca), Naseem Al-Aidroos[2], Stephen Emrich[1]; [1]Brock University, Psychology Department, [2]Guelph University, Psychology Department

There is a great deal of debate over the number and quality of items that can be represented in visual working memory (VWM). One theoretical model of VWM predicts that working memory has a discrete capacity limit of three to four items; while other models predict that VWM is a limited pool of resources that can be distributed fluidly. However, the question remains: What is the mechanism determining VWM performance? One such mechanism could be the allocation of attention. To test this prediction participants performed a working memory task for colour information by reporting the colour of a probed sample item on a colour wheel. In Experiment 1, six sample items were presented with probabilistic spatial cues directing attention toward likely target locations; in Experiment 2, four sample items were presented. Probabilistic cues designated the locations of the sample items that were likely to be probed. Responses were examined with a three-component mixture model as well as overall error and compared on the basis of the number of cues and predictive value per cue. The number of cues presented were between one and the maximum number designated by the load; predictive values varied from 100.0% to 33.33%, with uncued items probed between 0% and 22.22% of trials. Results from both studies indicate that the predictive value of cues is a better predictor of working memory performance than the number of cues across all measures for both cued and uncued items. These results suggest that subjects were able to selectively allocate working memory resources to sample items based on the predictive values conveyed by the attention cues. Consequently, consistent with continuous resource models of VWM, attention may by a limiting mechanism in VWM performance.

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36.4048 Categorical Perception of Topological Relations between Objects Andrew Lovett[1] (andrew.lovett@northwestern.edu), Steven Franconeri[1]; [1]Department of Psychology, Northwestern University

In many types of perception, change are easier to spot a when they are categorical - crossing thresholds between blue and green, or between oblique and straight. Here we show that categorical perception applies powerfully to topological relations between two objects. We showed two pairs of simple objects to participants, and asked them to detect potential changes to the distances between the objects across a 1 second delay. Participants (N=15) were far better at detecting changes that crossed categorical thresholds (M=88%), e.g., from touching to intersecting or from intersecting to containing, compared to changes of equal size that did not cross these boundaries (M=73%) ($p < .001$). With large memory loads, participants appear to rely heavily on abstract and efficient categorical representations of interobject relations. But under conditions of low memory load, this advantage may be hidden to us. When participants were asked to detect changes to only a single pair, performance for categorical changes (M=93%) and non-categorical changes (M=88%) was more similar (though still significantly different, $p = .005$). A significant interaction between categorical status and memory load ($p < .001$) confirmed that the effect was far stronger when load was higher. Previous research shows that humans are skilled at encoding and remembering categorical information. Here we show that this broader principle applies to the perception of spatial relations between objects - a key area of visual processing that has received surprisingly little attention.

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36.4049 Visual short-term memory demonstrates retinotopic visual field asymmetries Summer Sheremata[1] (ssheremata@gwu.edu), George Malcolm[1], Sarah Shomstein[1]; [1]Department of Psychology, George Washington University

Visual short-term memory (VSTM) maintains information across eye movements and distraction. However, VSTM holds a very limited amount of information, with memory capacity reaching a maximum of 3 ± 1 objects. Activity in the parietal cortex mirrors these restrictions, plateauing at a subject's maximum capacity. Parietal cortical activity also shows hemispheric asymmetries in representing memory items across the visual field. Consistent with these asymmetries, memory performance demonstrates a left visual field bias for single-feature objects (Sheremata & Shomstein, 2014). It is, however, an open question which coordinate system, retinotopic or spatiotopic, underlies VSTM biases. Eye position was monitored while subjects performed a color change-detection task for items presented to the left and the right of the monitor while subjects fixated different positions across the visual field. In separate conditions, subjects fixated either the center of the screen (control condition) or locations peripheral to the stimuli. If VSTM is represented in spatiotopic coordinates, then visual field asymmetries should be independent of eye position. If, however, VSTM is retinotopically represented, then visual field performance should be modulated by eye position, reversing when subjects fixate peripheral visual field locations. Results supported retinotopic representations in VSTM, as evidenced by a reversal of visual field asymmetries as compared to the control condition. Further manipulations controlling for spatiotopic location and non-spatial encoding corroborated our findings. These results demonstrate that VSTM, like visuo-spatial processing, is coded in retinotopic coordinates.

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36.4050 Evaluating and excluding swap errors in analogue report

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When observers retrieve simple visual features from working memory, two kinds of error are typically confounded in their recall. First, responses reflect noise or variability within the feature dimension they were asked to report. Second, responses are corrupted by ``swap errors'', in which a different item from the memory set is reported in place of the one that was probed. Independent evaluation of these error sources is vital for understanding the structure of internal representations and, in particular, how binding information is maintained. However, previous methods for disentangling these errors have been critically dependent on assumptions about the noise distribution, which is a priori unknown. Here I address this question with novel non-parametric methods, which estimate swap frequency and feature variability with the minimum of prior assumptions, and without a fitting procedure. The results indicate that swap errors are considerably more prevalent than previously appreciated (accounting for more than a third of responses at set size 8). These methods also identify which items are swapped in for targets: when the target item is cued by location, the items in closest spatial proximity are most likely to be incorrectly reported, thus implicating noise in the probe feature dimension as a source of swap errors. Finally I show how swap errors can be excluded from the raw histogram of observer responses to uncover the true distribution of error in the reported feature dimension. I will discuss the implications of these results for neural models of working memory storage.

Acknowledgement: Wellcome Trust

36.4051 The BDNF Val66Met polymorphism is associated with improved performance on a visual-auditory working memory task in varsity athletes

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Cognitive functions are often impacted by concussions and neurocognitive tests are used to assess the recovery process. However, these tests lack sensitivity in tracking the recovery process, which may depend on genetic polymorphisms. Brain derived neurotrophic factor (BDNF) is an important nerve growth factor linked with development and neural plasticity. The Val66Met (rs6265) polymorphism has been associated with reduced activity-dependent BDNF secretion, indicating reduced plasticity and greater stability of cortical networks. While most studies found that Met carriers have poorer scores on memory tests, not all studies are in agreement. The purpose of our study was to examine the consequences of Val/Met genotype on the performance of a cognitively demanding dual task, which involved visual spatial working memory (Corsi block test) and an auditory tone discrimination task. Participants were varsity athletes (n=33). All athletes were cleared to play at the time of testing; however, 19 players had a history of at least one concussion. BDNF genotyping was performed using saliva samples, which showed that 18% of athletes were Met allele carriers. The main outcome for the cognitive task was dual task cost (i.e., the percent reduction in performance on the auditory task while concurrently performing the visual task). Since subjects were asked to focus on the Corsi block test, performance on this task was similar during single and dual conditions. Regression analysis revealed that BDNF genotype accounted for 13% of variance in the auditory cost, while the presence of a concussion explained 11% of variance. Met carriers were significantly more accurate in the auditory task in the dual condition in comparison to the Val/Val athletes. These results are in agreement with a recent study which showed that subjects with the Met allele had significantly better performance on a visuomotor adaptation task.1 1Barton et al (2014). J Vis, 14(9): 4; doi:10.1167/14.9.4

Acknowledgement: PROPEL Centre for Population Health Impact

Face Perception: Neural dynamics

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

Poster Session, Pavilion

36.4052 Face recognition: Early temporal negativity is Sensitive to Perceived (rather than Physical) Facial Identity

Stella Faerber[1] (stella.faerber@uni-jena.de), Jürgen Kaufmann[1,2], Stefan Schweinberger[1,2]; [1]DFG Research Unit Person Perception, Friedrich-Schiller-University of Jena, [2]Department for General Psychology, Friedrich-Schiller-University of Jena

Increased early negativity to repeated faces over right inferior temporal regions around 200-300 ms has been related to the reactivation of mental representations of individual identities of familiar faces. Since this modulation is typically larger for same-image (compared to different-image) repetitions of a familiar face, it is debated whether it reflects physical stimulus similarity between prime and target, or reactivation of perceived representations of identity. In an EEG-study participants performed a four-choice identification task on famous target faces (1500 ms), which were always preceded by the same average face (500 ms, prime-target SOA 1500 ms). Crucially, by adapting participants to specific anti-faces (5000 ms), we induced different illusory facial identites (cf. Leopold et al., 2001) in the same physical prime stimulus. Importantly, right temporal negativity (~155-400) was significantly larger for "Primed" than "Unprimed" trials (when pre-prime adaptation involved the anti-face specifically corresponding to the target face, vs. a non-corresponding anti-face). We conclude that right temporal negativity in the time range of the P200 and N250r is a neural correlate of the activation of mental representations of individual familiar faces, even when the physical stimulus is kept constant.

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36.4053 The neural correlates of categorization and individuation of own-race and other-race faces

Grit Herzmann[1] (gherzmann@wooster.edu); [1]Department of Psychology, The College of Wooster

Categorization and individuation of own-race and other-race faces consistently leads to opposite effects. Categorization is faster for other-race faces, individation is faster for own-race faces. Explanations for these findings suggest that own-race faces are processed on the level of the individuum in both tasks which hampers categorization but facilitates individuation. They also suggest a lack of holistic processing for other-race faces which is proposed to be due to either a lack of motivation according to socio-cognitive theories or a lack of perceptual learning according to perceptual expertise theories. This study recorded event-related potentials while Caucasian participants matched two sequentially presented faces based on race (categorization) or identity (individuation). Face stimuli consisted of Caucasian faces, Chinese faces, and African-American faces. Confirming previous findings, other-race faces were categorized faster but individuated slower than own-race faces. The N250, taken to reflect individuation or subordinate level processing, yielded three important findings. First, it was largest for other-race faces in both tasks showing that individuation of other-race faces requires more neural resources and speaks against a motivational cause for the lack of holistic processing and thus socio-cognitive theories. Second, African-American faces elicited larger N250 amplitudes than Chinese faces in the categorization task but not in the individuation task suggesting a special role of skin color during categorization but not individuation. Finally, sequential (i.e., repeated) presentation of the faces influenced the N250. For own-race faces, N250 repetition effects were the same in both tasks. For other-race faces, N250 repetition effects were larger in the individuation than the categorization task. These results provide evidence that own-race faces are processed in the same way in both tasks. They also provide further evidence against socio-cognitive theories because a larger repetition effect in the individuation task for other-race faces is in contrast to the proposed motivational lack for holistic processing.

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36.4054 **From eye to face: support for neural inhibition in holistic processing** Roxane Itier[1] (ritier@uwaterloo.ca), Karisa Parkington[1]; [1]Psychology Department, University of Waterloo

The N170 is an early face-sensitive ERP component that has been shown to be sensitive to face configuration disruptions but also to eyes presented in isolation. The Lateral Inhibition Face Template and Eye Detector (LIFTED – Nemrodov et al., 2014) model proposes that the N170 reflects both the activity of an eye detector and holistic processing of the face; holistic processing would be achieved through the inhibition of neurons coding foveal information by neurons coding parafoveal information. Here we investigated this possible inhibition mechanism by monitoring the variations of the N170 to the presentation of facial stimuli ranging from an isolated eye to a full face, encompassing all the intermediate stages of configuration disruption where the rest of the facial features were added one by one (e.g. eye with nose, eye with mouth, eye with nose and mouth etc.). Fixation was always enforced on one or the other eye using an eye-tracker. The N170 was largest for the isolated eye condition and decreased substantially with the sole addition of the face outline. The progressive addition of the other facial features linearly reduced its amplitude which was smallest for the full face. Similar reductions in latency were found with a remarkable 30-40ms decrease in latency between the isolated eye and the full face conditions. Variations in amplitude and latency reductions were seen between hemispheres as a function of which eye was fixated. Results overall support the idea of an inhibition process that depends on the type of features situated in parafovea and their distance from the fixated eye, with the face outline as a major contributor to holistic face processing.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (NSERC)

36.4055 **Effects of stimulus inversion on the attentional selection and working memory encoding of individual faces** Joanna Parketny[1] (j.parketny@bbk.ac.uk), Martin Eimer[1]; [1]Birkbeck College

Effects of face inversion have been widely demonstrated behaviourally. Face inversion is known to impair the speed and accuracy of face recognition (e.g., Yin, 1969). Event-related brain potential (ERPs) studies have shown that face inversion also affects the perceptual encoding of faces, as reflected by a delay and amplitude increase of the face-sensitive N170 component (e.g., Bentin et al., 1996). However, the impact of face inversion on the attentional selection and encoding of individual faces in visual working memory has not yet been investigated with on-line electrophysiological measures. In the present study, we recorded ERPs in a task that required participants to report the presence or absence of a learned previously unfamiliar target face that could appear together with a non-target face in a bilateral search array. In different trials, face pairs were presented either in an upright or upside-down orientation. A robust face inversion effect was observed for target-present responses, which were delayed by approximately 50 ms for upside-down faces. Face inversion also affected the N2pc component (reflecting the attentional selection of a target face) and the subsequent sustained contralateral negativity (SPCN, which marks the activation of a working memory representation of the selected face). The N2pc emerged approximately 15 ms later for inverted as compared to upright faces, demonstrating that inversion delays the allocation of attention to target faces. The SPCN was attenuated for inverted as compared to upright target faces, suggesting that working memory representations were activated less strongly by inverted faces. This is in line with recent behavioural evidence that face inversion reduces the precision of visual face memory (Lorenc et al., 2014). These results provide novel electrophysiological evidence for the impact of face inversion on speed and efficiency of visual attention during the selection and identification of individual faces.

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36.4056 **Effects of aging on the horizontal selectivity of behavioural and ERP measures of face identification** Rabea Parpia[1] (parpiarr@mcmaster.ca), Ali Hashemi[1], Patrick Bennett[1], Allison Sekuler[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Horizontal orientations comprise the primary diagnostic structure for face perception (Dakin & Watt, J Vis 2009), and young adult observers' ability to selectively use horizontal structure more than vertical structure (horizontal tuning) predicts both face identification accuracy and the face inversion effect magnitude (Pachai et al., Front Psychol 2013). Here, we ask if the age-related decline of face identification accuracy (Konar et al., Vis Res 2013) is associated with age-related changes in horizontal tuning. Because the N170 ERP component is delayed and smaller in response to faces lacking horizontal structure (Hashemi et al., VSS 2014), we also examined whether age-related behavioural changes in horizontal tuning were associated with age-related changes in both the N170 and the N250. We measured identification accuracy and ERPs in younger (M=22±3.8 years) and older (M=73±7.3 years) adults with a 6-AFC face identification task. Base stimuli were generated using a ±45 deg orientation filter centered on either the horizontal or vertical orientation, with additional stimuli generated by increasing orientation bandwidth by ±9 deg steps, totalling 10 orientation-filtered conditions plus 1 unfiltered condition that included all orientations. In younger observers, adding horizontal structure improved accuracy significantly more than adding vertical structure. However, in older adults, the addition of horizontal and vertical structure produced similar, small increases in accuracy. Thus, older adults exhibited less horizontal selectivity than younger adults. Interestingly, orientation filtering affected the N170 similarly in the two age groups, but the N250 was modulated by orientation filtering only in younger adults,consistent with the notion that the two ERP components represent different stages of face processing.The decreased behavioural horizontal tuning seen with age is reflected in the N250's decreased sensitivity to orientation filtering, providing behavioural and electrophysiological support for the idea that face identification relies on effective use of horizontally oriented structure.

Acknowledgement: NSERC, CIHR, Canada Research Chairs

36.4057 **Spatial frequency hemispheric specialization for filtered faces depends on temporal constraints** Rui de Moraes Júnior[1,3] (ruidemoraesjr@gmail.com), Rafael Vasques[1], André Cravo[2], Jocelyn Faubert[3], Sérgio Fukusima[1]; [1]Department of Psychology, University of São Paulo, [2]Center for Mathematics, Computation and Cognition, Federal University of ABC, [3]School of Optometry, University of Montreal

This study aimed to investigate how the brain hemispheres use spatial frequencies (SF) information at early stages of visual processing for facial recognition. Thirty participants performed a matching task in which a target face was presented centered on the screen and followed by a probe face in each trial. The probe face was presented lateralized under 3 SF conditions (high, low and broad spatial frequencies) and 2 exposure time conditions (70 and 150 ms). The participants had to judge whether both faces in each trial were from the same person. The results of d' suggest that the right hemisphere is specialized for low SF processing in high temporal constraint, but the left hemisphere is not for high SF. However, high-pass faces were better processed by the left hemisphere. The response time in short time conditions showed that facial recognition is better in the right hemisphere. High-pass faces are slowly processed by the left hemisphere, but with longer exposure time it becomes equivalent to the recognition of low-pass and broadband faces. We conclude that there is a right hemisphere dominance for low SF in brief exposures, but as time progresses high SF are better processed and asymmetry effects are attenuated. Keywords: Spatial frequencies; Coarse-to-fine processing, Brain asymmetry; Face perception.

Acknowledgement: FAPESP and NSERC

36.4058 **Tracking the separation of visual representations of face identity and emotional expression in real time** Katie Fisher[1] (kfishe05@mail.bbk.ac.uk), John Towler[1], Martin Eimer[1]; [1]Birkbeck, University of London

Leading models of face recognition assume that the processes of identity and emotional expression recognition occur in distinct cognitive and neural systems. Although there is strong evidence for the separation of these abilities, it is currently unclear whether this division occurs during visual-perceptual processing or at later modality-unspecific stages of face recognition. To track the time course of face identity and expression matching processes, and to find out when these processes separate during visual-perceptual stages of face recognition, we employed the N250r component as an event-related brain potential (ERP) marker of the match between visual working memory and perceptual representations. Two different face images were presented sequentially on each trial. In different tasks, participants had to decide whether either the identity or the expression of the two faces was the same or different. Changes or repetitions of the other task-irrelevant dimension (expression or identity) were varied orthogonally. In both the identity and expression matching tasks, the matching process, as reflected by N250r onset, started earlier when the irrelevant dimension was also repeated. N250r components to a matching task-relevant feature were delayed and attenuated when the task-irrelevant feature changed. Behavioural matching performance was also superior on trials where the currently irrelevant dimension was repeated. These findings demonstrate that face identity and expression are not processed independently. Even when only one of these dimensions is task-relevant, both are initially encoded in an inte-

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grated representation, and this can result in interference from the irrelevant dimension on visual-perceptual identity or expression matching processes.

Acknowledgement: Economic Social Research Council, UK

36.4059 Independent control of cortical representations for expression and identity of dynamic faces

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Humans can easily extract who someone is and what expression they are making from the complex interplay of invariant and changeable visual features of faces. Recent evidence suggests that cortical mechanisms to selectively extract information about these two socially critical cues are segregated. Here we asked if these systems are independently controlled by task demands. We therefore had subjects attend to either identity or expression of the same dynamic face stimuli and examined cortical representations in topographically and functionally localized visual areas using fMRI. Six human subjects performed a task that involved detecting changes in the attended cue (expression or identity) of dynamic face stimuli (8 presentations per trial of 2s movie clips depicting 1 of 2 facial identities expressing happiness or anger) in 18-20 7min scans (20 trials/scan in pseudorandom order) in 2 sessions. Dorsal areas such as hMT and STS were disassociated from more ventral areas such as FFA and OFA by their modulation with task demands and their encoding of exemplars of expression and identity. In particular, dorsal areas showed higher activity during the expression task (hMT: $p< 0.05$, lSTS: $p< 0.01$; t-test) where subjects were cued to attend to the changeable aspects of the faces whereas ventral areas showed higher activity during the identity task (lOFA: $p< 0.05$; lFFA: $p< 0.05$). Specific exemplars of identity could be reliably decoded (using linear classifiers) from responses of ventral areas (lFFA: $p< 0.05$; rFFA: $p< 0.01$; permutation-test). In contradistinction, dorsal area responses could be used to decode specific exemplars of expression (hMT: $p< 0.01$; rSTS: $p< 0.01$), but only if expression was attended by subjects. Our data support the notion that identity and expression are processed by segregated cortical areas and that the strength of the representations for particular exemplars is under independent task control.

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36.4060 Recognition memory for faces is modulated by attractiveness beyond distinctiveness and emotional valence – an ERP study.

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Accurate memory for faces is important for numerous social interactions, but is modulated by physiognomic characteristics. Recently, it was shown that attractive faces are remembered less accurately than unattractive faces when distinctiveness is controlled for (Wiese, Altmann, & Schweinberger, 2014). It is still unclear, however, if this effect is constituted by a disadvantage for attractive faces, a benefit for unattractive faces, or both. To clarify, we conducted a recognition memory experiment including attractive, mid-attractive and unattractive faces, matched for deviation-based distinctiveness (Wickham & Morris, 2003). In addition to behavioural measures, event-related potentials were analysed. Memory was most accurate for unattractive faces, followed by attractive faces, with poorest performance for mid-attractive faces. Item analyses confirmed that this effect remained significant when emotional valence was taken into account. Furthermore, participants responded less conservatively to attractive compared to both mid- and unattractive faces. Replicating earlier findings, an attractiveness effect in the early posterior negativity (EPN) during learning, with larger amplitudes for attractive than unattractive faces, correlated significantly with the memory advantage for unattractive faces. Higher amplitudes with increasing attractiveness were found both in the EPN at test and in the late positive component (LPC) during both experimental phases. Finally, an old/new-effect with larger amplitudes for hits than correct rejections (Rugg & Curran, 2007) was found between 500-700 ms at test, but did not interact with attractiveness. Our findings show an effect of attractiveness on face memory beyond distinctiveness and emotional valence. As the EPN is typically enhanced for affective stimuli, processing of emotionally relevant attractive faces during learning could hamper their encoding into memory. This, however, cannot explain poor performance for emotionally neutral mid-attractive faces. We suggest an explanation based on a modified face-space model, in which mid-attractive faces are more frequent, and hence less well distinguishable, than both attractive and unattractive faces.

36.4061 Hometown population influences the N170 response to faces

Alyson Saville[1] (alyson.saville@ndsu.edu), Benjamin Balas[1]; [1]Center for Visual and Cognitive Neuroscience, Department of Psychology, North Dakota State University

Biased exposure to faces belonging to distinct categories (e.g., race) and global visual deprivation can both impact face recognition. More rich experience with faces leads to more robust performance. Visual recognition is tuned to facial appearance by experience and experience (or a lack thereof) constrains observers' processing abilities. Here we examined face processing in a population that occupies a unique place between biased exposure and deprivation: Observers from depopulated regions. Does an overall lack of unique faces in the environment lead to measurable differences in behavioral and neural responses to faces? We recruited participants from small (< 1000 persons, N=19) and large (>30,000 persons, N=18) communities to determine how face exposure during development affected face memory and ERP responses to faces. We characterized face recognition abilities using two measures: (1) The Cambridge Face Memory Test (Duchaine & Nakayama, 2006) and (2) N170 responses to upright and inverted images of faces and non-faces (chairs). We anticipated that impoverished experience with faces would lead to poorer behavioral performance and N170 responses that were less face-specific (e.g. a reduced face inversion effect). Accuracy in the CMFT was significantly worse ($t(35)=1.98$, $p=0.028$) for small town participants (72.9%) compared to their large-town counterparts (79%), suggesting that behavioral performance does depend on the sheer number of faces available in the environment. Furthermore, N170 amplitudes also exhibited a two-way interaction between stimulus category and group ($F(1,32)=4.05$, $p=0.05$) driven by a reduced difference between face and non-face amplitudes in participants from small towns. Besides typical main effects of stimulus category, orientation, and hemisphere, we also found a history of limited face experience has consequences for later neural processing of faces. Face processing is therefore constrained by the richness of the visual environment in terms of facial appearance, even when visual function and the overall visual environment are normal.

36.4062 The N170 is mostly sensitive to pixels in the contralateral eye area

Guillaume Rousselet[1] (Guillaume.Rousselet@glasgow.ac.uk), Gilman Hannah[1], Robin Ince[1], Philippe Schyns[1]; [1]Institute of Neuroscience and Psychology, College of Medical, Veterinary and Life Sciences, University of Glasgow

In humans, the N170 event-related potential (ERP) is an integrated measure of cortical activity that varies in amplitude and latency across trials. Recently, we quantified the coding function of the N170 single-trial variability in possibly the simplest socially relevant task: face detection (Rousselet et al. Journal of Vision 2014). On each experimental trial, observers saw face and noise pictures sparsely sampled with Gaussian apertures ("bubbles"; Gosselin & Schyns, Vision Research 2001). Using reverse correlation and mutual information, we found that the presence of pixels around the eye contralateral to the recording electrode modulated single-trial ERPs at lateral-occipital electrodes, and most strongly so during the rising part of the N170. This result is consistent with previous studies using different face sets and tasks (e.g. Smith et al. Psychological Science 2004, Schyns et al. Current Biology 2007), and suggests that the first processing step indexed by the N170 is the coding of the contralateral eye area. Here, in a series of control experiments, we show that this result holds for faces of different sizes, faces expressing different facial expressions of emotions, and after contrast normalisation. However, the N170 contralateral eye sensitivity was absent for very small faces, and was delayed and strongly reduced by contrast reversal. Because contrast reversal preserves local edges, and eye saliency, but affects the distribution of contrasts across the face, the lower brain sensitivity to eye pixels in that condition suggests that it reflects some form of feature processing in the context of the face. The feature in question could be the iris/pupil area, which had the strongest effect on the N170 to large faces. We conclude that the N170 is a critical time-window in human face processing mechanisms, reflecting predominantly, in a face detection task, the encoding of a single feature: the contralateral eye.

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36.4063 **Processing of the same face features is delayed by 40 ms, weaker and differentially coded across hemispheres in healthy ageing** Katarzyna Jaworska[1] (k.jaworska.1@research.gla.ac.uk), Fei Yi[1], Robin Ince[1], Philippe Schyns[1], Guillaume Rousselet[1]; [1]Institute of Neuroscience and Psychology, College of Medical, Veterinary and Life Sciences, University of Glasgow, United Kingdom

Previously, Rousselet et al. (Frontiers in Psychology 2010, 1:19) reported a 1ms/year delay in face visual processing speed in a sample of 62 subjects aged ~20-80, using event-related potentials (ERPs). This result was replicated in another 59 subjects, and was independent of stimulus luminance and senile miosis (Bieniek et al. Frontiers in Psychology 2013, 4:268). To go beyond differences in average brain activity and interpret previous findings, here we investigated what information is coded by early face ERPs in younger and older observers. In a detection task, nineteen older (7 female, median age: 66, 60-86) and eighteen younger (9 female, median age: 23, 20-36) observers each categorized 2,000 pictures of faces and noise textures revealed through 10 Gaussian apertures ("bubbles"; Gosselin & Schyns, Vision Research 2001, 41:2261). Using reverse correlation and Mutual Information (MI), we found that the presence of the left eye elicited fastest detection in both age groups, even though older observers relied more on the eyes to be accurate, suggesting a strategy difference. In both age groups, presence of the eye contralateral to the recording electrode modulated most single-trial ERPs at lateral-occipital electrodes, but this association was about 54% weaker in older observers, and delayed by about 40 ms. We also observed a differentiated coding of the eyes across groups: in younger observers, both the N170 latency and amplitude coded the contralateral eye (Rousselet et al. Journal of Vision 2014, 14(13):7, 1–24), whereas it was only the N170 amplitude in older adults. The latency modulation in younger adults was also higher in the right than in the left hemisphere and very similar across hemispheres in older adults. Our results suggest that ageing is associated with both quantitative differences in face processing (general delay, weaker feature sensitivity, decreased hemispheric lateralization), and qualitative differences (nature of information coding).

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36.4064 **Objective electrophysiological evidence for increased visual discrimination of novel 3D objects following extensive training** Aliette Lochy[1] (aliette.lochy@uclouvain.be), Renaud Laguesse[1], Friederike Zimmermann[1], Verena Willenbockel[2], Bruno Rossion[1], Quoc Vuong[2]; [1]Psychological Sciences Research Institute, Institute of Neuroscience, University of Louvain, Belgium, [2]Institute of Neuroscience, Newcastle University, UK

Although human adults can learn to individualize novel 3D multiparts objects, there is little evidence that their visual representations are modified following learning. To address this issue, we developed 3D objects where the global structure, parts and their configuration, as well as the texture can be parametrically manipulated to create large sets of stimuli with individual variations. Importantly, parts are configured so that stimuli appear as "face-like" in one orientation. We trained two groups of 11 subjects to become experts at individuating 26 novel object exemplars, either in face-like or non-face-like orientation. Importantly, non-face-like oriented stimuli were not perceived as faces. Training consisted of 14 sessions (~20 hrs) during two weeks, where novel objects were seen from different viewpoints in a variety of tasks. Pre and post training, we measured electrophysiological discrimination responses using a fast oddball periodic visual stimulation providing robust and objective (i.e. at a predefined frequency) visual discrimination responses (1Liu-Shuang et al., 2014). In each of only 4 trials per condition, an identical object picture (unseen at training) was presented at 6 Hz for 60 seconds, and different individual objects appeared at regular intervals (1/5, i.e. at 1.2 Hz). Following training, a discrimination response at 1.2 Hz and its harmonics (e.g., 2.4 Hz, etc.) over lateral occipital sites increased significantly for face-like configurations. Strikingly, despite equivalent amount of training for both configurations, there was no such increase of the EEG visual discrimination response for non-face-like configurations. These results indicate that visual representations of novel objects are modified following training, and suggest that a face-like configuration is essential to observe these effects. 1Liu-Shuang, J., Norcia, A.M., Rossion, B. (2014). An objective index of individual face discrimination in the right occipito-temporal cortex by means of fast periodic oddball stimulation. Neuropsychologia, 52, 57-72.

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36.4065 **The effect of head orientation on face detection in natural images as evidenced by fast periodic visual stimulation** Charles Or[1] (charles.or@uclouvain.be), Talia Retter[1], Bruno Rossion[1]; [1]Psychological Sciences Research Institute & Institute of Neuroscience, University of Louvain, Belgium

Face detection is typically fast and accurate, but some faces are detected faster and better than others in natural images. While some studies have shown that low-level visual cues contribute to rapid face detection, there is less information concerning the contribution of high-level factors. Here, we tested whether face detection differs for full-front vs. 3/4 head views using fast periodic visual stimulation (FPVS). This approach can isolate cortical responses for the detection of faces – as compared to other object categories – objectively, rapidly and implicitly in natural images, without contribution from low-level visual cues (Rossion et al., 2015). High-density electroencephalogram (EEG) was recorded from 16 observers presented with 40-s sequences containing natural images of objects sinusoidally contrast-modulated at a fixed rate of 12.0 Hz (F). Natural face images were introduced at fixed intervals of F/9 ('oddballs', 1.33 Hz). In Condition 1, all faces were posed full-front. In Condition 2, they were at 3/4 views (either left or right, but only in one orientation within a sequence). In Condition 3, the oddball alternated between full-front and 3/4 views throughout the sequence (frequency of each view, F/18 = 0.67 Hz). In all conditions, significant responses were recorded at 1.33 Hz and its harmonics, mainly over the right occipito-temporal region, indicating a high-level face-detection response. Interestingly, Condition 3 also showed significant responses at 0.67 Hz and its harmonics over the same cortical region, implying a differentiable face-detection response to full-front vs. 3/4 views. Analysis in the time domain revealed a sequence of face-selective components, with peak latencies approximately 12 ms earlier for full-front than 3/4 views emerging as early as the first face-selective component (130-150 ms). These findings indicate that a full-front view presents an advantage in face detection, arising in part from a faster high-level brain response.

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36.4066 **Emotional face discrimination as revealed by electrophysiological periodic visual responses** Milena Dzhelyova[1] (dzhelyova@yahoo.com), Bruno Rossion[1]; [1]University of Louvain

Being able to read social information is vital for an individual. A wealth of social cues is provided by the face, in particular emotional expressions. To address the question of how the brain discriminates emotional faces, we recorded electroencephalogram from 18 participants during a fast periodic oddball paradigm, which provides an objective, implicit and robust quantifiable measure of visual discrimination. The same face with a neutral expression was presented at a rate of 5.88 Hz during an 80 sec sequence. Every five faces, the same face displaying an emotional expression of fear, disgust or happiness (in different sequences), was presented, thus resulting in a sequence NNNNFNNNNFNNNNF (e.g., neutral-fear oddball sequence). The oddball 1.18Hz (5.88Hz/5) response and its harmonics (e.g., 2f = 2.36 Hz) were used to measure emotional face discrimination. This emotional face discrimination response was observed bilaterally at occipito-temporal sites. Furthermore, inverting the faces significantly reduced the brain response over the occipito-temporal regions for the oddball frequency, suggesting that it reflected high level processes related to the emotional faces. The response to happy faces was characterised with more dorsal distribution than angry and disgusted faces. The latter face type was characterised with more anterior scalp topography than the angry faces. An additional analysis confirmed the topographical differences and hinted at partly distinct neural generators. A complementary time domain analysis revealed several components discriminating neutral from emotional faces and an additional experiment comparing the mode of stimulus presentation – sine vs. square wave – suggested that these 3 components peaked at 120 ms (positive); 170 ms (negative) and 250 ms (positive) after stimulus onset. These observations provide new insights into the temporal dynamics of facial expression processing and show that the fast periodic oddball paradigm can be successfully employed to address processes underlying social perception.

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36.4067 **The spatio-temporal signatures of category-selective responses to natural images as evidenced with fast periodic visual stimulation**
Corentin Jacques[1] (corentin.g.jacques@uclouvain.be), Talia Retter[1], Bruno Rossion[1]; [1]Psychological Sciences Research Institute and Institute of Neuroscience, University of Louvain, Louvain-la-Neuve, Belgium

Humans are extremely rapid at categorizing visual inputs, an ability which relies on occipito-temporal brain processes. Functional neuroimaging studies have identified the spatial organization of neural responses in these regions to ecologically-relevant categories such as faces, bodyparts or houses. However, much less is known about the spatio-temporal dynamics of these category-selective responses at the system level of organization. Here we investigate this issue by recording scalp electroencephalogram (EEG) during fast periodic visual stimulation (FPVS) with natural images (Rossion et al., 2015). Eleven subjects viewed 60 seconds sequences of natural images of various object categories displayed at a base frequency of 6 Hz (6 images/second), in which images of either faces, bodyparts or houses appeared every 5 images (oddball frequency =6Hz/5 =1.2Hz). Category-selective oddball responses manifest at the 1.2Hz oddball frequency and harmonics (2.4Hz, 3.6Hz, etc.). While significant oddball responses were observed for all categories over occipito-temporal regions, responses were much stronger for faces than for limbs and houses. Further, scalp topography pattern analyses point to distinct neural sources across category-selective responses, with responses to faces, bodyparts and houses respectively maximal at ventral occipito-temporal, lateral occipito-temporal, and dorso-medial occipital channels. Time-domain analyses indicate that EEG responses are dissociable across categories at multiple spatio-temporal windows from around 110ms to 500ms post-stimulus onset, with faces eliciting up to five distinct selective responses. These observations go well beyond traditional face-selective EEG responses as identified using transient stimulus presentation (i.e., N170) by indicating that multiple ecologically-relevant categories generate unique spatio-temporal signatures over posterior scalp regions. Finally, these findings highlight the power of the FPVS approach to reveal the spatio-temporal signatures of high-level visual processing at the system level. Rossion, B., et al. (2015). Fast periodic presentation of natural images reveals a robust face-selective electrophysiological response in the human brain. Journal of Vision.

Acknowledgement: Fonds de la Recherche Scientifique (FNRS), Politique Scientifique Belge (BELSPO)

Face Perception: Behavioral characteristics

Sunday, May 17, 2:45 - 6:45 pm
Poster Session, Pavilion

36.4068 **Measuring the flexibility of orientation selectivity in face processing by varying task demands**
Matthew Pachai[1] (pachaim@mcmaster.ca), Allison Sekuler[1], Patrick Bennett[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Observers preferentially process information conveyed by the horizontal orientation band when identifying faces (Dakin and Watt, J Vis 2009; Goffaux and Dakin, Front Psychol 2010). However, ideal observer analysis reveals that such horizontal selectivity is optimal in face identification tasks (Pachai et al, Front Psychol 2013). Therefore, it remains unclear whether horizontal selectivity results from a flexible system tuned to the most diagnostic band for a given task, or a general bias present during all face-related tasks. To disambiguate these hypotheses, we asked observers to perform two face-related tasks for which the diagnostic orientation band differed. On each trial, one of six identities was presented with the head turned slightly to the left or right. Observers were asked on different trials, either blocked or intermixed, to judge the stimulus identity or viewpoint direction. Stimuli were masked with high-contrast orientation-filtered noise (horizontal or vertical, bandwidth = 90 deg) and a low-contrast white noise to enable ideal observer analysis. The dependent measure was the d'=1 RMS contrast threshold, which should be elevated from baseline proportionally to the weight placed by the observer on the masked orientation band during the task in question. A simulated ideal observer confirmed the differential diagnosticity of orientation bands in the two tasks: more masking produced by horizontal noise in the face identification task, and more masking produced by vertical noise in the viewpoint direction task. However, human observers exhibited more masking from horizontal noise in both the identity and direction tasks, regardless of whether these tasks were blocked or intermixed. This result demonstrates an inability to preferentially process vertical facial structure even when it is optimal for the task at hand, and suggests that horizontal selectivity may represent a general face processing strategy.

Acknowledgement: NSERC, Canada Research Chairs

36.4069 **Effects of size, fixation location, and inversion on face identification**
Allison Sekuler[1] (allisonsekuler@mac.com), Matthew Pachai[1], Ali Hashemi[1], Patrick Bennett[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

One possible explanation for the face inversion effect (FIE) is that inversion swaps the eye and mouth locations relative to fixation, and attention typically is directed to the top of a stimulus for faces. As the eye region is the most informative for face discrimination, automatically attending to the upper-half of a face would cause observers to use less diagnostic regions for inverted faces. Consistent with this hypothesis, cueing attention to the eyes modulates the FIE measured both behaviourally (Hills et al., JEP:HPP 2011) and with EEG (de Lissa et al., Neuropsychologia 2014). However, past studies used old/new recognition or gender discrimination tasks rather than identification tasks, and they did not consider the effects of stimulus size. The size manipulation is interesting in light of a recent suggestion that specialized face processing is engaged only by large stimuli (Yang et al., J Vis 2014). To address these issues, we measured accuracy and ERPs in a 6-AFC identification task that varied fixation location (center, left eye, right eye, mouth), orientation (upright or inverted), and face width (3.2 or 8.1 deg). Behavioural results showed significant main effects of: i) face size (higher accuracy for large faces), ii) fixation location (lower accuracy for mouth fixations), and iii) orientation (lower accuracy for inverted faces). However, we observed no fixation x orientation interaction, thus fixation location did not modulate the FIE. The size x orientation interaction also was not significant, which is inconsistent with the suggestion that small and large faces differentially recruit face-specific mechanisms. Finally, we found a significant N170 latency FIE that, consistent with previous studies, was larger with eye fixations. Together, these results clarify the roles of size and fixation in identification tasks, and further implicate the eyes in both behavioural and electrophysiological markers of face processing.

Acknowledgement: NSERC, Canada Research Chairs program

36.4070 **Seeing People in Motion Enhances Person Recognition**
Noa Simhi[1,2] (noa.louisa@gmail.com), Galit Yovel[1,2]; [1]School of Psychological Sciences, Tel Aviv University, [2]Sagol School of Neuroscience, Tel Aviv University

The majority of studies on person recognition have examined the processing of static faces. The few studies which have examined person recognition from dynamic videos of the whole person (e.g. O'Toole et al., 2011) have done so within the same media – examining person recognition from videos after exposure to dynamic displays vs. person recognition from still images after exposure to still images alone. In this study we examined the contribution of previous exposure to motion information to whole person recognition from still images, where no dynamic information is available. To this end used a matching task in which we presented either videos of a person walking or multiple still images from the same videos and asked participants to recognize the identities shown from novel still images of either the full body, face or body alone. We found that after exposure to videos the body contributed to person recognition beyond the face; however when no dynamic information was available, person recognition from the full body was no better than person recognition from the face alone. Furthermore, we found that when less facial information was available in the videos, the body contributed more to person recognition. Finally, since person recognition from images of the body alone proved to be at chance in these experiments, we demonstrated that the inclusion of a non-informative head context alongside body only images improved person recognition, thereby suggesting that full body context is important for person recognition. Overall, these findings indicate that exposure to people in motion enhances person recognition from still images beyond person recognition based on the face alone. This suggests that body motion improves the representation of body form, thereby making the body more informative to person recognition even from still images.

36.4071 **Where do people look on faces in the real world?**
Matthew Peterson[1] (mfpeters@mit.edu), Nancy Kanwisher[1]; [1]McGovern Institute for Brain Research and Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology

Almost all prior research on where people look on faces has been conducted in the lab, using fixed-head eye trackers while people view static images or movies of faces. Yet this situation is radically different from real-world face

Sunday PM

perception, where eye movements are likely to be influenced by the fact that the face you are looking at may be looking back at you. Here, we asked if the pattern of stable individual differences in face-looking behavior observed in the lab (Peterson & Eckstein, 2013; Mehoudar et al., 2014) generalizes to real-world vision. To measure in-lab behavior, subjects' eye movements were recorded with a fixed-head eye tracker while they performed a speeded (500ms) famous-face identification task using static images. Preferred face-fixation behavior was defined as the mean initial into-face fixation location. Real-world face-looking behavior was measured with a mobile eye tracker while subjects socially interacted with others, and walked around the MIT campus, passing people in hallways and open areas. Consistent with previous work, we found large individual differences in the preferred location of laboratory-measured face-fixations, ranging from just above the brows to the mouth. Preliminary data suggests that this pattern of behavior is conserved in real-world viewing conditions. These results suggest that, at least for the critical initial into-face fixations that support identification, gaze measured in the lab accurately reflects real-world looking behavior.

Acknowledgement: This material is based upon work supported by NEI grant 13455 to Nancy Kanwisher

36.4072 Mismatch prevalence influences response bias and discriminability in unfamiliar face matching

Dawn Weatherford[1] (dweatherford@astate.edu), Barret Schein[2]; [1]Arkansas State University, [2]Arkansas State University

Determining if an individual matches their identification card holds important consequences on tasks such as granting age-restricted access to goods and services as well as airport security. Unfamiliar identity matching represents a complex visual search task, with diagnostic facial cues indicating matches and mismatches. Recent evidence supports that, like other visual search tasks, low prevalence (e.g., 10%) of mismatched identities between face pairs increases error rates for mismatch trials. Binary match/mismatch decisions have indicated that criterion shifts, and not changes in discriminability or motor execution, underlie the effect. However, confidence-based responding has yet to be explored. Across 140 trials, participants either viewed a high (90%), medium (50%), or low (10%) prevalence of mismatches. Using a 1-6 confidence scale, participants rated a face in the context of an identification card as either a match or mismatch to an isolated face that was either the same or different person. To encourage accuracy, incorrect decisions were followed by corrective feedback. Within-participants analyses replicated previous findings demonstrating sensitivity to contextual prevalence cues as the trials progressed, such that criterion shifts, but not discrimination, differed among prevalence conditions. However, receiver operating characteristic (ROC) curves showed some evidence for greater discriminability in high and medium prevalence conditions as compared to the low prevalence condition, but only for high confidence responses. This is new finding deserves further exploration. Looking at ROC curves can provide important insight into discriminability that may be masked by binary response restrictions. Additionally, increased error rates due to low mismatch prevalence in real-world situations are incredibly important, as misidentifying individuals may have serious ramifications. Because real world mismatch prevalence is likely much lower than the present conditions (i.e., < 10%), increasing discriminability as a function of perceptual training may serve a useful role in maximizing identity matching performance.

36.4073 Intrinsic Memorability Predicts Short- and Long-Term Memory of Static and Dynamic Faces

Mintao Zhao[1] (mintao.zhao@tuebingen.mpg.de), Isabelle Bülthoff[1]; [1]Max Planck Institute for Biological Cybernetics

Does a face itself determine how well it will be recognized? Unlike many previous studies that have linked face recognition performance to individuals' face processing ability (e.g., holistic processing), the present study investigated whether recognition of natural faces can be predicted by the faces themselves. Specifically, we examined whether short- and long-term recognition memory of both dynamic and static faces can be predicted according to face-based properties. Participants memorized either dynamic (Experiment 1) or static (Experiment 2) natural faces, and recognized them with both short- and long-term retention intervals (three minutes vs. seven days). We found that the intrinsic memorability of individual faces (i.e., the rate of correct recognition across a group of participants) consistently predicted an independent group of participants' performance in recognizing the same faces, for both static and dynamic faces and for both short- and long-term face recognition memory. This result indicates that intrinsic memorability of faces is bound to face identity rather than image properties. Moreover, we also asked participants to judge subjective memorability of faces they just learned, and to judge whether they were able to recognize the faces in late test. The result shows that participants can extract intrinsic face memorability at encoding. Together, these results provide compelling evidence for the hypothesis that intrinsic face memorability predicts natural face recognition, highlighting that face recognition performance is not only a function of individuals' face processing ability, but also determined by intrinsic properties of faces.

Acknowledgement: This research was supported by the Max Planck Society.

36.4074 Face Transformation in Recollection and Familiarity

Winnie Chan[1] (winyc@graduate.hku.hk), William Hayward[2,3], Sing-Hang Cheung[1]; [1]University of Hong Kong, [2]School of Psychology, University of Auckland, [3]ARC Centre of Excellence for Cognition and Its Disorders, University of Western Australia

Three classical face recognition tasks (viewpoint, inversion, spatial frequency) were assessed using the remember/know procedure to examine how different transformations of the face influence recollection and familiarity in recognition memory. In the viewpoint task, participants studied front-view faces and were tested with front, three-quarter and profile views. Participants gave significantly higher remember responses to front view faces than three-quarter views, with profile views lower still. However, no difference in know responses among the three viewpoints was found. A viewpoint effect was observed in remember responses We then conducted the inversion task, in which participants studied both upright and inverted faces, and then were tested on each type. An inversion effect was observed with remember responses but not know responses. There was no difference in know responses between upright and inverted faces if participants studied upright faces. However, higher know responses were found for inverted faces than upright faces when participants studied inverted faces. These results indicate that feelings of familiarity can only be transferred from upright faces to inverted faces but not the other way round. The poor observed performance with inverted faces is indicative of a disruption of holistic processing. Therefore, in the final experiment we separated different spatial frequencies from faces to examine recollection and familiarity with low- and high-spatial frequency faces. Participants studied intact faces and were tested with intact, HSF and LSF faces. High numbers of remember responses were observed for intact faces only. No differences were found for either HSF and LSF. Based on the results of these three studies, recollection appears to be comparatively more sensitive to face transformation than familiarity. However, the extent to which configural processing is the basis for recollection is not yet clear.

Acknowledgement: University Research Committee

36.4075 Reconstructing a representational space of learned faces

Nicola van Rijsbergen[1] (nicola@psy.gla.ac.uk), Guillaume Rousselet[2], Philippe Schyns[3]; [1]Institute of Neuroscience and Psychology, College of Medical, Veterinary and Life Sciences University of Glasgow, [2]Institute of Neuroscience and Psychology,College of Medical, Veterinary and Life Sciences, University of Glasgow, [3]Institute of Neuroscience and Psychology, College of Medical, Veterinary and Life Sciences, University of Glasgow

When we learn to discriminate between new faces, we memorize the information that best identifies and discriminates them. To study these face memories, we first parameterized the information of 97 face identities using a recursive sinusoidal basis (12 orientations, 2 polarities and 5 spatial frequencies), and computed the principle components of this space (excluding 4 face identities). We trained participants to discriminate these 4 identities by naming them. Participants trained until they reached 100% accuracy (< 40 trials). By construction, the memorized diagnostic information enabling 100% accuracy must be expressible as specific parametric values in the reduced sinusoidal basis. To understand these face memories, for each participant we performed reverse correlation using randomized parameters in the sinusoidal basis (Gosselin & Schyns, 2003, Mangini & Biedermann, 2004, van Rijsbergen et al. 2014). Trials were presented in blocks of 10, for a total of 600. Before each block a memory screen was shown containing the four test identities labeled with their names. On each of the 10 subsequent trials participants selected one of the named identities from an array of three faces randomly generated with the sinuisoidal basis. Crucially, participants did not know in advance of these trials which of the four memorized identities they would be asked to select until after the memory screen disappeared. Every 120 trials, participant memory performance was retested. Ideal observers provide the limit of identity representation. After 15,000 trials an Ideal Observer achieved a parameter correlation of 0.2 with the test identity. A PCA observer that randomizes combinations of principle components reached maximum performance in 200 trials, but failed to learn one identity. A hybrid observer that switched learning strategies from principle components to individ-

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ual parameters over time, performed better across all 4 identities, suggesting that human performance could be sped up by combining the two

Acknowledgement: BBSRC grant BB/J018929/1 and Leverhulme Trust grant F/00 179/BD.

36.4077 **Reduced Sensitivity to Variation in Normality and Attractiveness for Other-Race Faces** Catherine Mondloch[1] (cmondloch@brocku.ca), Xiaomei Zhou[1]; [1]Brock University

Adults recognize young faces and own-race faces more accurately than older and other-race faces, respectively. We recently reported that young and older adults are more sensitive to deviations from normality in young than older adult faces and that there is more between-participant variability (i.e., less consensus) in attractiveness ratings for older than young faces, suggesting that superior recognition of young adult faces is attributable to the dimensions of face space being optimized for young adult faces, presumably as the result of experience (Short & Mondloch, 2013; Short et al., 2014). In the current studies, we extended these findings to own- and other-race faces. In Experiment 1, Chinese and Caucasian adults (n= 24 per group) were shown own- and other-race face pairs in which one member of each pair was undistorted and the other had compressed or expanded features. They were asked to indicate which member of each face pair was more normal (a task that requires referencing a norm) and which was more expanded (a task that simply requires discrimination). Both Chinese and Caucasian participants were more accurate in judging the normality of own- than other-race faces, $p < .001$, with no effect of face race in the discrimination task, $p = .60$. In Experiment 2, Chinese and Caucasian adults rated the attractiveness of 40 own-race and 40 other-race faces. Consensus among Chinese adults ($n = 40$) did not vary as a function of face race, $p = .526$; testing of Caucasians is ongoing. Collectively, these results provide direct evidence that perceptual experience with own-race faces optimizes the dimensions of faces space for own-race faces.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

36.4078 **Perception of identity: Robust representation of familiar other-race faces despite natural variation in appearance** Xiaomei Zhou[1] (vz12ep@brocku.ca), Catherine Mondloch[1]; [1]Department of Psychology, Brock University

The other-race effect (better recognition of own- compared to other-race faces) has been framed as a problem with discriminating among other-race identities. Another impairment in recognizing other-race faces is the ability to recognize the same identity across a set of images that incorporate natural variability in appearance (e.g., changes in expression, lighting conditions, head orientation), known as within-person variability. We recently reported that within-person variability affects identity perception more for unfamiliar other-race faces than unfamiliar own-race faces (Zhou, Laurence & Mondloch, 2014). In the current study we examined how within-person variability affects identity perception in familiar other-race faces (i.e., whether participants would mistake two images of the same other-race person as belonging to different people even when viewing photographs of familiar identities). Chinese participants (n=100) were given 40 images of two identities (20 images/model) and asked to sort them into piles according to identity such that each pile had all images of the same person. The two identities belonged to one of four categories: familiar own-race, familiar other-race, unfamiliar own-race, or unfamiliar other-race. There was a significant interaction between familiarity and race of faces, $p = .007$. When faces were unfamiliar, participants sorted photos into significantly more piles (i.e., perceived more identities) for other-race faces ($M = 11.56$) than for own-race faces ($M = 7.28$), $p = .006$. This own-race advantage was eliminated when the identities were familiar (Mean piles = 2.12 and 2.24 for own- and other-race faces respectively). We are currently replicating this finding by testing Caucasian participants (n=60) with Caucasian and African American faces that are either familiar (NBA players) or unfamiliar (College basketball players). Our study adds new evidence of a fundamental difference between familiar versus unfamiliar face recognition; the other-race effect is limited to unfamiliar faces.

Acknowledgement: NSERC

36.4079 **Are Faces Important for Face Recognition?** Linoy Schwartz[1] (linoy.schwartz@gmail.com), Galit Yovel[1,2]; [1]Sagol School of Neuroscience, Tel Aviv University, [2]School of Psychological Sciences, Tel Aviv University

Face recognition studies have emphasized the role of rich perceptual experience in underlying both the other race effect - better recognition of own rather than other race faces - as well as our superior recognition of familiar relative to unfamiliar faces. However, recent studies have highlighted the role of individuation in better recognition of own versus other race faces. In this study we therefore examined the role of perceptual exposure and individuation in familiar face recognition. An old-new face recognition task was used in order to assess the sole contribution of each of these factors to the learning of unfamiliar faces: rich perceptual information (viewing a face in different angles and illuminations), simple individuation (association of a face with an uninformative but unique label) and association of a face with person-related semantic information, such as a name or an occupation. During the test phase subjects were presented with faces in different poses and illuminations than those learned during the study phase, together with new faces, and were asked to indicate whether they have seen these people before. The results indicate that mere perceptual information such as viewing a face in different angles and illuminations does not improve face recognition, whereas association of a face with person-related information (e.g., name, occupation) does improve face recognition significantly. This improvement was not generalized to other types of individuations in which a face was associated with unrelated labels such as object names or symbols, or incongruent labels such as opposite-gender names. These findings highlight the important role of person-related semantic information in face recognition. These results further suggest that visual information alone may not contribute to face recognition and it is the conceptual information that we have about faces that significantly contributes to our face recognition abilities.

36.4080 **"That's my teacher!": Children's recognition of familiar and unfamiliar faces in images containing natural variability** Sarah Laurence[1] (slaurence@brocku.ca), Catherine Mondloch[1]; [1]Department of Psychology, Brock University

Adults' ability to recognize unfamiliar faces across images that capture within-person variability is poor, whereas their familiar face recognition is extremely good (Jenkins, White, Van Montford & Burton, 2011). Very little is known about children's ability to recognize personally familiar faces and most of what we know about unfamiliar face recognition comes from studies measuring recognition of only one or two highly controlled images of an identity. Therefore the purpose of the present study was to examine the effect of within-person variability on identity perception across childhood. Children aged between 6 – 11 years were presented with a teacher's house (either their teacher [n = 27] or an unfamiliar teacher [n = 21]) and a pile of pictures. Half of the pictures were of the teacher and the other half were of a physically similar unfamiliar identity, and all the pictures captured natural within-person variability in appearance. Children were asked to put all of the pictures of the teacher, but not the other woman, into the house. Children familiar with the teacher were highly accurate ($M\ d' = 3.10$) with no improvement with age ($r(25) = -.001$, $p = .995$). However, children unfamiliar with the teacher were less accurate ($M\ d' = 1.15$), their performance (d') improved with age ($r(19) = .62$, $p = .002$), with most errors comprising misses (failing to put a teachers' photo into the house). In an ongoing study, data-to-date ($n = 19$) show a familiar face recognition advantage for younger children (4-5 years), although the younger children made more errors ($M\ d' = 2.51$) than older children. These findings suggest that children's familiar face recognition is adult-like at age 6, whereas unfamiliar face recognition continues to improve across childhood. Understanding within-person variability is essential for understanding the development of expertise in face recognition.

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36.4081 **The role of similarity in coding ensemble identity of face groups** Markus Neumann[1,2] (markus.neumann@uwa.edu.au), Francesca De Bonis[2], Gillian Rhodes[1,2], Romina Palermo[1,2]; [1]ARC Centre of Excellence in Cognition and its Disorders, [2]School of Psychology, The University of Western Australia

When people see a group of faces, they tend to code the average property, such as the mean identity. In some experiments, participants extracted this ensemble representation rather than the individual identities. This has led to the suggestion that coding an ensemble is the "default mode" when processing identity for groups of faces (de Fockert & Wolfenstein, 2009). These studies used groups of very similar identities, which participants may have found difficult to distinguish as individuals, and which may have facilitated the coding of an ensemble. If ensembles are the default way to represent groups, then they should have a coding advantage over those of individual identities also for groups that consist of easily distinguishable faces. Here, we tested whether an advantage of the ensemble identity varies with the similarity of the group identities. The identities in each group were experimentally manipulated to range from extremely similar to very dissimilar. In Experiment 1, participants viewed groups of four faces, followed by a set average (blends between group identities) or an individual exemplar, and indicated whether this was a member of the group or not. Our results showed that for sets of dissimilar faces, participants more frequently endorsed individual exemplars than set averages as members. For similar faces, which participants tended to see as the same person, participants endorsed set averages more frequently than exemplars. However, this set average advantage was attenuated when the design was modified, such that participants had to select between the set average and the exemplar, to directly test participants' preferences for ensemble or exemplar representations. In sum, there was no ensemble advantage for easily distinguishable faces, and even for very similar faces, the ensemble advantage was not as robust as expected, suggesting that ensemble representations may not be the default mode to code identity of face groups.

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36.4082 House pareidolia occurs more frequently than face pareidolia in peripheral vision

Zhengang Lu[1] (zhengang.lu@dartmouth.edu), Jessica Goold[1], Ming Meng[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College

Human observers sometimes falsely perceive patterns in random images as significant. This phenomenon of pareidolia is frequently reported for seeing faces in particular. On the other hand, the visual system of humans is thought to be hardwired and specially tuned to process faces due to the social significance of faces. If the visual system is highly sensitive to differentiate faces and non-faces, falsely perceiving a face in random images should be very rare. Previous neuroimaging studies have shown fovea preference for face representation (Levy et al., 2001; Malach, Levy, and Hasson, 2002). A recent study, using centrally presented noise patterns, further revealed face-related activation in the right fusiform face area when participants perceived face pareidolia versus letter pareidolia (Liu et al., 2014). However, it remains possible that sensitivity to discriminate faces and non-faces is poor in peripheral vision, leading to face pareidolia may appear to occur more frequently than other types of pareidolia. To test this hypothesis, we presented noise patterns randomly in the left or right visual field, and asked participants to report whether they saw a face or a house. In 80% of the trials, random noise patterns were shown. Whereas in only 10% of the trials a degraded face image was blended with a noise pattern and shown to participants; in the rest 10% of the trails a degraded house image was blended with a noise pattern and shown to participants. Surprisingly, for the random noise trials, participants reported seeing significantly more house pareidolia than face pareidolia. Taking response bias into account, participants were more sensitive for detecting faces than houses even in peripheral vision. No significant differences were found between the left and right hemifields. These results question the notion that human observers naturally tended to falsely "see" face patterns in random images.

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36.4083 The effect of emotional expression on perceived facial age

Tzvi Ganel[1] (tganel@bgu.ac.il); [1]Department of Psychology, Ben-Gurion University of the Negev, Beer-Sheva, Israel

People smile and express other emotional expressions in social interactions to convey different types of nonverbal communications. In the current project, I have studied the effects of different emotional expressions, in particular that of facial smile, on the perceived facial age. Smiling, as well as other facial expressions such as anger or fear, could potentially change the way that a person is perceived along different facial dimensions. Notably, these dimensions include perceived age. For smiling faces, it is commonly assumed that they are perceived as younger compared with faces carrying a neutral expression. In a series of experiments, I report a counter-intuitive effect in the opposite direction. Across different experimental conditions and stimulus sets, smiling faces were consistently perceived as older compared with neutral faces of the same persons. A similar effect was found for other facial expressions beyond smile. I suggest that this effect is due to the observer's failure to ignore emotion-associated wrinkles along the region of the eyes. These findings point to a misconception regarding the relationship between facial smile and perceived age and shed new light on the processes underlying human age perception.

36.4084 Face age affects the way we visually process and recognize faces: a study with adult and infant faces

Valentina Proietti[1,2,3] (v.proietti@campus.unimib.it), Francesca Dell'Amore[1], Emanuela Bricolo[1,2], Viola Macchi Cassia[1,2]; [1]University of Milano-Bicocca, Department of Psychology, [2]Milan Center for Neuroscience, [3]Brock University, Department of Psychology

Young adults generally recognize own-age faces more accurately than other-age faces, but less is known about the perceptual mechanisms underlying this bias. With the hypothesis that visual scanning strategies may be at the origins of the advantage for own-age faces, we monitored eye movements while young adults (N=19) performed an old/new recognition memory task with adult and infant faces. After a learning phase, where 24 faces (12 adult, 12 infant) were randomly presented (3 sec/each), participants had to recognize the familiar identities among 24 distractors. Eye-movements were recorded throughout the task. Adults used a more conservative strategy (c) in responding to adult compared to infant faces ($p< .01$) and made more false alarms (FA) for infant compared to adult faces ($p< .02$). In both the learning and the recognition phases the proportion of looking time on the eye region of interest (ROI) was greater for adult compared to infant faces ($p< .02$); conversely the proportion of time spent looking at the cheeks and forehead ROI was greater for infant compared to adult faces ($p< .02$). Dwells (transitions between ROIs) were larger for adult than for infant faces ($p< .01$), suggesting the use of a more dynamic scanning strategy for the former than for the latter. The proportion of looking time on the eye ROI positively correlated with response performance (d'; $p< .05$). Overall, results are in line with earlier demonstrations that both the familiarity of identity (Heisz & Shore, 2008) and the familiarity of face category (Goldinger, He, & Papesh, 2009; Wu, Laeng, & Magnussen, 2012; but see Blais, Jack, Scheepers, Fiset, & Caldara, 2008) affects the scanning behavior in adult participants. Critically, our correlational results are the first to indicate that the eyes are a diagnostic feature for identity recognition.

36.4085 Representing Young and Older Adult Faces: Shared or Age-Specific Prototypes?

Lindsey Short[1] (lshort@redeemer.ca), Valentina Proietti[2], Catherine Mondloch[2]; [1]Department of Psychology, Redeemer University College, [2]Department of Psychology, Brock University

We recently reported that the dimensions of face space are more well refined for young than older adult faces (Short & Mondloch, 2013). In the current study, we examined two alternative ways in which young and older adult faces might be represented in the context of a norm-based coding model. According to one model, adults possess a single age-generic norm that codes for both young and older faces, with face age represented as a dimension or set of dimensions within face space. Alternatively, there may be separable prototypes for young and older faces, with the representation of older faces being less well refined. In Experiment 1, 40 young adults participated in an opposing aftereffects experiment in which young and older faces were distorted in opposite directions (compressed versus expanded) during adaptation. Before and after adaptation, participants indicated which member of ±20% same-identity face pairs looked more normal; half of the pairs were older faces and half were young. Following adaptation, adults' normality preferences simultaneously shifted in opposite directions for the two face ages, $p < .001$, providing evidence for age-contingent opposing aftereffects. In Experiment 2, we sought to confirm these findings by examining the extent to which aftereffects transfer across face age categories. Pre- and post-adaptation trials were identical to those in Experiment 1; however, during adaptation, participants ($n = 80$) were adapted to either compressed or expanded faces from a single age category (young/old). Aftereffects, though significantly greater than chance for both face ages, were larger for the face age that matched adaptation than for the face age that did not, $p < .01$, indicating partial transfer of aftereffects across age categories. Collectively, these results suggest that adults process young and older adult faces with regard to separable prototypes with some shared coding dimensions.

Acknowledgement: NSERC

See page 3 for Abstract Numbering System

Multisensory Perception: Visuo-auditory interactions 1

Sunday, May 17, 2:45 - 6:45 pm
Poster Session, Pavilion

36.4086 Synchronization is better to a visual than to an auditory beat

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Daily music experience involves synchronizing movements in time with a perceived periodic beat. It has been established for over a century that beat synchronization is substantially less stable for the visual than for the auditory modality. This auditory advantage of beat synchronization gives rise to the hypotheses that the neural and evolutionary mechanisms underlying beat synchronization are modality-specific. Here, however, we found that synchronization to a periodically bouncing ball that was close to real-world moving visual experience was more stable than synchronization to an auditory metronome, demonstrating that humans can synchronize better to a visual than to an auditory beat. This finding challenges the auditory advantage of beat synchronization, and has important implications for the understanding of the biological substrates of beat synchronization.

36.4087 Fast and slow adaptation to multisensory asynchrony: Temporal recalibration at two time scales

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Following prolonged exposure to asynchronous signals (whether audio-visual, audiotactile or visuotactile), the brain adapts or 'recalibrates' to reduce perceived asynchrony. Van der Burg, Alais and Cass (2013) showed temporal recalibration can also occur very rapidly for audiovisual stimuli, requiring only a single, asynchronous trial. Does rapid recalibration also occur between audiotactile and visuotactile stimuli? In separate audiovisual, audiotactile or visuotactile experiments, using the same participants, design, task, and spatially collocated stimuli (unlike the previous study), participants adapted to 180 asynchronous stimuli (+100ms or –100ms in separate blocks). Participants then performed a series of 180 synchrony judgements on the same stimulus pair at various SOAs [±400, ±200, ±100 ms]. Psychometric functions were fitted and the point of subjective synchrony (PSS) obtained. We conducted two analyses: 1) we pooled synchrony responses into 40-trial bins and plotted a walking average of the PSS over the test period; 2) we used inter-trial analyses to examine whether temporal recalibration occurred rapidly based on the stimulus order in the immediately preceding trial. The 'walking average' results revealed significant 'modality order' effects of prolonged adaptation for all conditions. Initial PSS shifts were equivalent for all three pairings (~25ms) and declined to baseline over time, although the AV effect lasted longer (36s) than VT (29s) and AT (27s). Inter-trial analysis revealed rapid temporal recalibration occurred for AV (21ms) and AT (14ms) conditions, but not for VT (1ms). Rapid recalibration magnitude did not decline and was stable throughout testing. The rapid AT recalibration effect here, absent in our previous study, strongly implicates spatial collocation as necessary for the AT effect. AV does not require collocation for fast or slow adaptation. VT shows no rapid recalibration but will recalibrate at a slow time-scale following sustained adaptation.

36.4088 Cleaving to cues that are no longer informative: Audio-visual asymmetry in cue utilization.

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Previous research has shown that spatial attention benefits from multimodal cues. When cues predict visual features such as location, shape, and color of targets, perceptual and motor processing for the targets are facilitated. In real-world settings such as on-road driving, however, there is no guarantee that cues are always informative and informative cues in the past are still informative now. Given these changes in cue reliability, we tested how the reliability of multimodal, visual and auditory cues affects the cue utilization for a visual task. In the first learning session, participants were asked to report the shape of the target (L or T) appearing either left or right of the fixation point. Visual (color) and/or auditory (pitch) cues preceded the target and perfectly indicated the location of target. In the second session, we made either visual or auditory cue uninformative by reducing the reliability of either cue to 50% while keeping the reliability of the other cue 100%. Our results indicated that even when the cues did not predict the target location in the second session, the participants were not able to completely ignore the uninformative cues. Furthermore, the adjustment for removal of informational value differed between auditory and visual cues; The participants were faster when the preceding visual cues lost any informational value than when the preceding auditory cues became irrelevant to the task. These results suggest that the utilization and combination of multimodal sensory cues are not simply determined by the reliability of cues at present and the informational values learned in the past but also weights on or biases toward sensory modalities.

36.4089 Audio-visual synchrony increase the saliency of visual direction changes: Evidence from individual differences and probe detection performance

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Spatially uninformative tones typically enhance detection performance of stimuli with synchronous visual transients. This finding has been attributed to an increase in the saliency of the visual transient due to audio-visual integration on a perceptual level. However, evidence from eye-tracking experiments also observed prolonged fixations induced by the brief tones. These prolonged fixations might result in more efficient searches for targets independent of audio-visual integration. In order to distinguish between these alternatives, we explored search efficiency for audio-visually synchronous objects in displays that involved up to four moving objects. All objects randomly changed their direction of motion once within intervals of up to 1.15 s. A spatially uninformative tone was either synchronous with the direction changes of one of the objects or unrelated to any direction change. Collapsed across all participants, we observed an inefficient visual search for objects that change their motion direction simultaneously to the tone (i.e., no pop-out; 2:1 ratio between target-absent and target-present trials). However, search efficiency varied remarkably between individual observers. In a follow-up experiment, these individual differences could be predicted from the performance in an unrelated useful field of view task (i.e., a perceptual task), but not from the performance in an unrelated working memory task. This finding indicates that the benefit in detecting audio-visually simultaneous targets emerges on a perceptual level. Finally, we observed that probe discrimination performance was faster on objects that changed their motion direction simultaneously to a tone than on objects with purely visual direction changes. This finding supports the idea that simultaneous auditory transients are capable to increase the saliency of visual transients. Therefore, we conclude that the detection advantage of audio-visually synchronous targets cannot be attributed to changes in the fixation behavior. Instead, synchronous auditory and visual transients indeed increase the saliency of stimuli due to audio-visual integration.

36.4090 Audiovisual integration directing attention to the temporal dynamics of biological motion

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People are adept at recognizing biological motion portrayed by a handful of dots (Johansson, 1973). Visual processing of biological motion is influenced by accompanying information from different sensory modalities (Arrighi et al., 2009; Saygin et al., 2008; Thomas & Shiffrar, 2010) or neighboring biological motion (Ikeda et al., 2013; Thornton et al., 2004). In this study, we investigated the interaction between the two by manipulating 1) the temporal synchrony between visual and auditory information of the biological walkers and 2) the congruency of gait direction between target and flanker walkers. Participants performed a 2-AFC gait direction discrimination (right vs left) of a central target walker flanked by two peripheral point-light figures walking out-of-phase relative to the central figure. There were four audio-visual synchrony conditions: three conditions in which an electronic "beep" onset was synchronous with either the footsteps of the target ("target match"), the flankers ("flanker match"), or between those two ("mismatch"); and a condition with no sound. To ensure sufficient exposure to the audio-visual synchrony, the flankers and sound were presented for two gait cycles prior to the onset of the central target, which had a gait direction either congruent or incongruent with the flankers. We found statistically significant main effects of sound and congruency on RT. Specifically, participants were slower to report the target gait direction when the timing of the auditory cue matched or was slightly offset (mismatched) from the steps of the task-irrelevant flankers, and RTs were slower on trials with incongruent target and flanker gait direction. Pairwise comparisons revealed significant effects of congruency only when the audio timing matched the target gait or was not presented, but not in the other two conditions. These results suggest bimodal temporal integration directs attention to temporal dynamics of biological motion, mitigating the interference of spatially proximal neighboring motion.

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36.4091 Cross-modal facilitation driven by metacognition

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Some properties can be signaled by multiple sensory modalities. This creates an opportunity to benefit, in terms of heightened sensitivity, from redundancy. Here we show, for audio-visual rate perception, that benefits resulting from cross-modal redundancy involve metacognition. People judged which of two intervals had contained a more rapidly changing stimulus, defined either by luminance flicker, auditory flutter, or both. People then rated decisional confidence, as high or low. Overall, people were more sensitive in audio-visual trials than in either auditory or visual trials. This advantage was not, however, apparent for trials involving equal levels of confidence. High-confidence audio-visual performance was equivalent to high-confidence trials concerning the best uni-modal signal for that participant. Low-confidence audio-visual performance was equivalent to low-confidence uni-modal performance, averaged across presentation modality. As there was a high correlation between performance and confidence, these data suggest cross-modal facilitation was based on metacognitive processes – on accurate and reportable estimates of the precision with which rate had been encoded in either modality on a trial-by-trial basis. This would be advantageous overall, as cross modal presentation would enhance the probability of a disproportionately precise rate estimate having been encoded in one of the two modalities. This advantage would be lost for comparisons of high confidence trials, as audio-visual performance is being compared to uni-modal trials marked by similarly high levels of confidence and performance. Cross-modal benefits would be lost for comparisons of low-confidence trials, as low-confidence signals that no precise estimate has been encoded in either modality during audio-visual presentations. We suggest that cross-modal facilitation in other contexts will also involve metacognitive processes.

Acknowledgement: The Australian Reseqarch Council

36.4092 A bias-free measure of crossmodal audiovisual action adaptation

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Actions can be perceived through multiple sensory modalities including vision and audition. It is currently uncertain if audiovisual actions are coded multimodally or in discrete unimodal areas. In order to test if actions are coded multimodally, we used a crossmodal adaptation paradigm to test whether the perception of hand action sounds was influenced by prior adaptation to visual and auditory actions. We generated an action sound continuum between the sound of a hand knocking and slapping by blending the sounds between the two action extremes. Following adaptation to auditory knocks, subsequent ambiguous test sounds appeared more like slaps; following adaptation to auditory slaps, subsequent ambiguous test sounds appeared more like knocks. Smaller but significant auditory aftereffects were generated by adaptation to purely visual information, whilst visual adaptation to visually presented orthographic action information did not generate auditory aftereffects. We also tested whether crossmodal adaptation improved action sound sensitivity around the adapting stimulus to rule out the possibility of observer response bias (Morgan 2013). Just-noticeable differences (JNDs) were calculated for knock sounds after participants adapted to auditory, visual, and audiovisual knocks, or did not adapt. Participants completed a two-interval forced-choice (2-IFC) adaptive staircase procedure, in which they judged which sound was more like a knock. JNDs were derived from a psychometric function fitted to the data. Auditory, audiovisual, and importantly visual only adaptation improved sensitivity to knock sounds when compared to no adaptation. A further experiment confirmed that auditory sensitivity to knock sounds was most enhanced following adaptation to visual knock actions compared to visual slap actions. These results suggest that adaptation to actions, irrespective of the adaptor modality can selectively enhance mechanisms underlying the coding of actions to improve perceptual sensitivity. Such crossmodal action aftereffects may result from adaptation of multimodal neurons tuned to specific actions.

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36.4093 In-Phase is not Always Best: Auditory salience reverses crossmodal influences on visual detectability

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Previous studies have shown that auditory information can facilitate visual processing by improving visual sensitivity (for example, Caclin, et al., 2011; Gleiss & Kayser, 2014, Lippert et al., 2007, McDonald et al.,2000; Strömer et al., 2009). We tested the role of auditory salience in modulating crossmodal influences on visual detectability. We used a two-alternative forced choice procedure to obtain visual detection thresholds. The visual stimulus, an 11x110 square, centered 150 left or right of monitor center, fluctuated in luminance at 1 Hz, under two auditory conditions: (1) a high salience auditory stimulus (60 dB): a white noise modulated in loudness at 1 Hz and fluctuated in-phase (IP) or out-of-phase (OP) with the visual stimulus or (2) a low salience auditory stimulus (35 dB): a white noise modulated in loudness at 1 Hz and fluctuated IP or OP with the visual stimulus. Visual stimuli were presented at one of five luminances, randomized across trials. Auditory stimuli were task-irrelevant, containing no lateralized spatial information. Observers indicated their judgment via an eye movement, first look within a region of interest left or right of center. For each observer, percent correct data across visual luminance were fit with a Weibull function to determine visual threshold (75% correct performance). We found improved visual thresholds in IP, relative to OP, for the low salience auditory stimulus. However, in the same observers, same paradigm, we found improved thresholds in OP, relative to IP, for the high salience auditory stimulus. The out-of-phase benefit reported here in adults replicates our results in 3-month-old infants run in a similar paradigm, using forced-choice preferential looking. Our new results extend this work and show that auditory salience can reverse the in-phase benefit we find in the same subjects, the effect expected of in-phase, synchronous crossmodal interactions.

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36.4094 Visual spatial uncertainty influences auditory change localization

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Human auditory localization ability is generally good for single sources, with errors subtending less than 5 degrees at the midline, and increasing to roughly 12 degrees in the periphery. Errors are generally larger in conditions where task demands are high, such as when multiple simultaneous sources are present. The current study shifts focus from the size of localization errors to the frequency of localization errors, examined under conditions of high and low visual uncertainty. In this study the ability to localize the addition of a new source to a mixture of 4 simultaneous sources was examined under two conditions of visual uncertainty. The task for participants was to listen to two auditory scenes separated by a brief blank interval. The scenes contained sounds edited to 1000ms duration that were representativeof outdoor urban spaces. Each first scene contained four sound sources; the second always contained a change, the addition of a new sound source. At the end of the second scene participants indicated where the change occurred, by pointing to the change location. Change locations were represented as either nine clearly visible and identifiable sound producing targets (speakers) in the free-field (low visual uncertainty condition) or change locations were obscured by occurring within an array of 90 visual targets (positioned 2 degrees apart), creating conditions of high visual spatial uncertainty. In general, performance was poorer when the audio-visual correspondence was reduced. Further, the pattern of results is consistent with other multisource localization studies; performance was most accurate when changes occur directly in front of the listener. Accuracy declined as changes were presented further in the periphery, and the impact of change position was greater under conditions of high visual spatial uncertainty (low audio-visual correspondence).

36.4095 Visual-auditory localization in central and peripheral space

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Normally sighted adults can combine visual and auditory cues to location optimally by weighting each according to its reliability (Alais & Burr, Curr Biol 2004). Here we investigated the extent to which observers take into account natural variations in sensory precision across the visual field. This will provide a baseline for studying cue combination in patients with

Sunday PM

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central or peripheral vision loss. Visual localization thresholds deteriorate towards the periphery, where sampling precision is limited by the sparser distribution of retinal photoreceptors. Freefield auditory localisation thresholds also deteriorate towards the periphery, but usually at a slower rate to vision. We assessed whether normally sighted adults continued to combine visual and auditory signals optimally when presented in (i) central (1-17°) and (ii) peripheral (36-53°) space. Eleven normally sighted adults (18-42yrs) were presented with blocks of audio-only (100ms white noise burst), visual-only (25ms flash from 5-50 LEDs, spanning 25 degrees) and, audio-and-visual-combined stimuli, either centrally (N=6) or peripherally (N=5). On each trial, participants indicated whether the standard (central: 1°; peripheral: 36°) or comparison (+0-16° relative to standard) was further right. Psychometric functions were fitted to these responses. Congruent bimodal trials measured improvements in sensitivity when two cues were available together (via slope), while bimodal trials with ±1° conflicts measured cue weighting (via PSE). Initial results show higher single-cue thresholds in the periphery, but improved performance with bimodal stimuli in both central and peripheral conditions. This shows that normally sighted adults combine visual and auditory estimates to improve their precision in both central and peripheral space. These data will provide a baseline for understanding whether and how patients with Stargardt's disease (central vision loss) or retinitis pigmentosa (peripheral vision loss) learn to re-weight sensory signals following visual impairment.

Acknowledgement: NIHR BRC at Moorfields Eye Hospital, UCL Institute of Ophthalmology

36.4096 **Predictive coding of auditory and contextual information in early visual cortex – evidence from layer specific fMRI brain reading** Lars Muckli[1] (Lars.Muckli@glasgow.ac.uk), Luca Vizioli[1], Lucy Petro[1], Federico De Martino[2], Petra Vetter[3]; [1]Centre for Cognitive Neuroimaging, Institute of Neuroscience and Psychology, University of Glasgow, [2]Psychology and Neuroscience, Maastricht Brain Imaging Centre, Maastricht University, [3]Departments of Neurosciences and Clinical Neurology, University of Geneva

David Mumford (1991) proposed a role for reciprocal topographic cortical pathways in which higher areas send abstract predictions of the world to lower cortical areas. At lower cortical areas, top-down predictions are then compared to the incoming sensory stimulation. One question that arises within this framework is the following: Do descending predictions remain abstract, or do they translate into concrete level predictions, the 'language' of lower visual areas? We have exploited a strategy in which feedforward information is blocked or absent in parts of visual cortex: i.e. along the non-stimulated apparent motion path, behind a white square that we used to occlude natural visual scenes, or by blindfolding our subjects (Muckli & Petro 2013). By presenting visual illusions, contextual scene information, or by playing sounds, we were able to capture feedback signals to non-feedforwardly-stimulated areas of visual cortex. MVPA analysis of the feedback signals reveals that they are more abstract than the feedforward signal. Furthermore, using high resolution MRI, we found that feedback is sent to the outer cortical layers of V1. We also show that feedback to V1 is induced even by auditory information processing (Vetter, Smith & Muckli 2014). Auditory-induced feedback is especially strong in the periphery of V1, and contains abstract categorical information. I argue that these feedback signals function to provide abstract predictions, i.e. priors in a Bayesian framework, biasing future processing already at an early processing stage of V1. Mumford (1991) On the computational architecture of the neocortex – the role of the thalamocortical loop. Biol Cybernetics Muckli & Petro (2013) Network interactions: non-geniculate input to V1. Curr Opin Neurobiol. Vetter, Smith & Muckli (2014) Decoding Sound and Imagery Content in Early Visual Cortex. Current Biology Clark (2013) Whatever Next? Predictive Brains, Situated Agents, and the Future of Cognitive Science. Behav Brain Sci

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36.4097 **Audiovisual integration in people with one eye: Normal temporal binding window and sound induced flash illusion but reduced McGurk effect** Stefania Moro[1,2] (smoro@yorku.ca), Jennifer Steeves[1,2]; [1]Department of Psychology and Centre for Vision Research, York University, Toronto, Canada, [2]The Hospital for Sick Children, Toronto, Canada

Introduction. Previously, we have shown that people with one eye have enhanced sound localization (Hoover, Harris & Steeves, 2012, EBR) and lack the visual dominance commonly found in binocular and patched viewing controls (Moro & Steeves, 2011, EBR). These results persist despite evidence that their integration of the auditory and visual components of multisensory events, when determining spatial location, is optimal (Moro, Harris & Steeves, 2014, MSR). Currently, we conducted three behavioural studies to further explore audiovisual integration in people with one eye compared to binocular and patched viewing controls. Experiment 1. We investigated the temporal component of audiovisual integration, by measuring the temporal binding window (TBW). Participants performed an audiovisual simultaneity judgment task and people with one eye showed no difference in width of TBW compared to controls despite slower performance. Experiment 2. We measured the sound induced flash illusion (SF) where participants indicated the number of light flashes paired with multiple tones. People with one eye performed no differently from controls. Experiment 3. We measured the McGurk audiovisual illusion. People with one eye showed a reduced McGurk effect compared to controls. Conclusions. It is possible that these mixed findings reflect differences in levels of processing between the three tasks. Higher level audiovisual processing (McGurk) compared to lower level audiovisual processing (TBW and SF) might benefit more from potential changes in underlying neural connectivity with eye enucleation early in life. These findings provide further evidence for changes in sensory neural connectivity in people with one eye that may serve as cross-modal adaptation for the loss of binocularity during early brain development.

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3D Perception: Slant, curvature, and shape

Sunday, May 17, 2:45 - 6:45 pm
Poster Session, Pavilion

36.4098 **Adaptation sharpens object representations: Evidence from shape discrimination thresholds** Maria Olkkonen[1] (mariaol@sas.upenn.edu), Marcelo Mattar[1], Geoffrey Aguirre[2], Russell Epstein[1]; [1]Department of Psychology, University of Pennsylvania, [2]Department of Neurology, University of Pennsylvania

One potential benefit of neural adaptation is the sharpening of neural representations to optimize performance in changing environments. This has been previously observed for low-level features such as color and orientation. Here we test whether adaptation sharpens complex object representations by characterizing the effect of adaptation on behavioral shape discrimination thresholds. We constructed a parametric 3D shape space whose axes correspond to different frequencies and orientations of sinusoidal modulations of a sphere. Two distinct reference shapes (A and B) were selected from this space, along with two "clouds" of fifty stimuli sampled near each reference by jittering the amplitude and orientation components of the references. Test stimuli were derived from a morph continuum between shapes A and B. In separate blocks, observers were first adapted to either cloud A or B with an initial 1-minute RSVP stream of adaptors, and then performed approximately 100 interleaved match-to-sample trials for the two references. Each trial began with a 5-second top-up adaptation, followed by a test stimulus from the morph continuum flashed for 200 ms at fixation, followed by either reference A or B and the same test item displayed on both sides of fixation until response. Observers indicated which item in the second interval matched in shape to the item in the first interval. Differences between the test and reference stimuli were controlled separately for the two references by interleaved staircases that converged on the 79% discrimination threshold. Results (N=3) indicate significant adaptation for both shape clouds: thresholds for reference A were lower after adaptation to cloud A compared to cloud B (median improvement 27%, range 14%-180%), and vice versa for reference B (median improvement 28%, range 20%-34%). These results offer novel evidence for the sharpening hypothesis in the perception of object shape.

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36.4099 **Stereoscopic camouflage: Can conflicting object segregation cues hinder depth perception?** Philip Cammack[1] (ppkf@st-andrews.ac.uk), Julie Harris[1]; [1]School of Psychology and Neuroscience, University of St Andrews

Depth from binocular disparity is an important cue for segregating an object from its background, and potentially breaking camouflage. In this study we explored whether depth from disparity is hindered by luminance 'camouflage', where luminance edges on an object are not coincident with disparity-defined edges. We presented participants with random dot stereograms containing a binocular disparity-defined circle. In some stimuli, luminance edges were located at a smaller, or larger radius than that of the disparity-defined circle. We used a 2afc task, asking observers to decide which of two stimuli contained the greatest peak depth, and obtained thresholds and biases for depth perception. We found biases in the peak perceived depth that depended on the radius of the luminance-defined circle. When the radius of the luminance defined circle was smaller than the disparity-defined object, there was little effect on the perceived peak depth. However, if the luminance patch had a larger radius than the disparity defined circle, we found a significant perceptual bias, with the peak depth being underestimated and the threshold increased. We will present a simple model suggesting that peak depth is being estimated using the some form of average over the disparities contained within the luminance defined circle. Our results demonstrate that depth perception of an object is affected by simple manipulations of luminance edges. The interaction of luminance and disparity suggests a possible route to beat the camouflage breaking properties of disparity-defined depth.

36.4100 A New Slant on "Two Eyes Are Better Than One": Large Continuous Perspective Changes (≥45°) Allow Metric Slant Perception Using Cyclopean (or Stereo-) Motion

Xiaoye Michael Wang[1] (wang492@indiana.edu), Aaron Fath[1], Mats Lind[2], Geoffrey Bingham[1]; [1]Indiana University, Bloomington, Indiana, [2]Uppsala University, Uppsala, Sweden

Introduction In Lind et al. (2014) (and a number of previous studies), large continuous perspective changes (≥45°) were shown to allow perception of metric 3D shape using stereo- and monocular motion information. None of the previous studies investigated large perspective changes with either use of stereo- or monocular motion alone or in slant perception. The current study explored the effects of small versus large perspective change on the accuracy of metric slant perception under different visual information conditions. Methods We used random dot anaglyphs to display planar surfaces with different upward slant angles rotating around a vertical axis through the surface center and viewed under stereo, monocular, or combined visual information conditions. Within each visual information condition, there were 5 rotation angles from 25° to 65°. Each rotation angle was crossed with 24 different slant angles, from 27° to 73° with 2° increment. The participants' task was to adjust a line to match the 3D slant of the surface. Results Linear regression of perceived on actual slant for each rotation angle and visual information condition showed that participants underestimated the slant in the monocular condition compared with the stereo and combined conditions. For both stereo and combined conditions, slant judgments were less accurate for rotation angles less than 45° and accurate after the rotation angle reached 45°. However, increasing rotation angle did not affect performance in the monocular condition. Conclusion The current study extended to slant perception the previous finding that large perspective changes (≥45°) allow accurate perception of metric shape. The results also showed that this result requires stereo-motion information, and is not effective when only monocular motion information is available.

36.4101 Structure from motion without projective consistency

Xiaoli He[1] (xiaoli.he@rutgers.edu), Jacob Feldman[1], Manish Singh[1]; [1]Department of Psychology, Rutgers University

Structure-from-motion (SFM) studies have shown that people are good at perceiving 3D structure in dynamic dot displays consistent with rigid object rotation. However, observers can still perceive volumetric structure even when image motion is inconsistent with rigid rotation. As an extreme case, in dynamic figure-ground displays containing textural motion, observers perceive the convex/symmetric regions as rotating in 3D, despite constant dot speed everywhere (projectively inconsistent with 3D rotation; Froyen et al. 2013, JOV; Tanrikulu et al., 2013, 2014, VSS). It is unclear, however, to what extent this extreme "tolerance" is due to the figure-ground competition in those displays. Here we examined the case of a single object in isolation, and manipulated the discrepancy of image motion from 3D rigid rotation. We started not with 3D objects, but with a 2D velocity field within a vertically-oriented ellipse. For an ellipsoid rotating about its principal axis, its orthographic-projected speed profile is a cosine function along each orthogonal "rib". We manipulated the proportion α of cosine motion vs. constant linear motion (range 0-1), and the motion direction θ relative to the orthogonal ribs (range 0-60°). Observers used a 7-point scale to rate the degree to which the display depicted a volumetric object. Volumetric percepts increased significantly with α and decreased significantly with θ, and were surprisingly tolerant to deviations from the projectively correct α=1, θ=0. For α, volumetric ratings increased between 0-0.6 but plateaued beyond 0.6. The effect of θ was surprisingly small, with even θ=45° yielding high volumetric ratings. Thus even with an isolated object, the 3D percept was surprisingly tolerant to discrepancies from projectively correct rigid object motion. These results argue for a more nuanced view of 3D interpretation in which strict projective consistency plays a less prominent role than in conventional SFM accounts.

36.4102 Perception of 3D structure and natural scene statistics: The Southampton-York Natural Scenes (SYNS) dataset.

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We are interested in the relationship between human vision and the environment in which it operates. To this end, the University of Southampton (UK) and York University (Canada) have collaborated to build the Southampton-York Natural Scenes (SYNS) public dataset. To represent the diverse environments that humans experience, we sampled scenes from 19 outdoor and 6 indoor scene categories across Hampshire, UK. Outdoor categories, identified by the UK Land Use dataset, include cropland, coastal dunes, woodlands, industrial estates, wetlands, residential areas, farms and orchards. Indoor categories include residential, theatres, cafes and offices. Each scene is represented by three types of co-registered data: (i) Ground truth 3D structure: 360˚ x 135˚ depth maps from a laser rangefinder (LiDAR), (ii) High dynamic range images (360˚ x 180˚) captured by a SpheroCam and (iii) 18 Stereo image pairs (35˚ x 24˚), tiling a 360˚ horizontal panorama, captured by a custom-built high-resolution stereo rig, with camera separation matched to average human interpupillary distance. LiDAR data were analysed to determine the distribution of surface attitude over slant and tilt in natural scenes. Surface normals were computed for patches centred on each LiDAR point, with the optimal patch size determined by cross-validation. Overall, the joint distribution over slant and tilt is dominated by the ground plane. For elevations above the horizon, other regularities are also apparent, including elevated probability density at the cardinal tilt axes (vertical surfaces), and a peak at fronto-parallel, as predicted by the geometry of projection. We relate these natural scene statistics to human perception of surface attitude and find a general correspondence, with human tilt perception biased toward the ground plane and slant perception biased toward fronto-parallel. These results suggest that human perception of surface attitude is governed in part by the ecological statistics of our visual environment.

Acknowledgement: EPSRC

36.4103 Estimating 3D surface properties of natural scenes

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The University of Southampton (UK) and York University (Canada) have collaborated to build the Southampton-York Natural Scenes (SYNS) public dataset. Our goal is to provide a resource that can be used to relate properties of the human visual system to the statistics of natural scenes. At each scene a 3D point cloud was captured with a Leica P20 LiDAR system over a nearly spherical field of view. Registered spherical high dynamic range monocular imagery and panoramic stereo pairs were also recorded. To derive statistical models of natural surfaces, and to relate these surface models to photometric information in associated imagery, we must first develop reliable methods for estimating surface properties from point cloud data. A standard method for identifying the surface normal at a selected 3D point is to compute the smallest eigenvector of the spatial covariance matrix of k points lying closest to selected point. The main problem with this approach is determining the optimal neighbourhood size k. Here we evaluate a novel adaptive method based upon leave-one-out cross-validation. Specifically, at each point we sweep over a broad range of potential neighborhood sizes (k = 4…100), each time computing k estimates of the surface normal based on k-1 points and measuring error as the deviation of the remaining validation point from the estimated tangent plane. The optimal k is that which yields the lowest mean k-fold cross-validation error. We demonstrate that this adaptive method works reliably for diverse scenes in urban and rural environments. Typically a very local neighbourhood (mode of k = 8) is selected, but the distribution has a strong positive tail, particularly for urban environments, where planar surfaces can be estimated more reliably with larger neighbourhoods. We discuss how higher-order geometric surface properties of natural scene data can estimated using similar methods.

Acknowledgement: EPSRC

36.4104 Distortions of material and shape induced by misperceived depth of field

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An image of a scene depends on both the physical attributes of the surfaces it depicts and the characteristics of the lens used to capture it. The visual system can often tell when an image has been captured using a shallow depth of field or a specific focal length, and variation in image 'defocus' blur has been studied extensively as depth cue. The tilt-shift effect demonstrates how depth of field manipulations can induce strong differences in perceived scene scale, but the image features used by the visual system to differentiate defocus from other sources of image blur are unknown. Here, we show that misinterpretation of image blur can cause depth of field manipulations to induce illusory distortions in perceived shape and material, and reveal the conditions that produce this effect. We manipulated the depth of field and focal length used to render images of 3D surfaces varying in relief height and specularity, and measured differences in perceived surface gloss and depth of field (using paired comparison tasks) and perceived 3D shape (using the gauge figure task). We found that depth of field manipulations that preserved the sharpness of a surface's occluding edge led to larger changes in perceived gloss and shape, and smaller changes in perceived depth of field, than conditions where the occluding edge was blurred by defocus. These differences were also larger for more specular surfaces. Our results reveal that changes in the occluding edges of surfaces are important cues in the perception of shallow depth of field, and that defocus blur can be misattributed to changes in specular roughness or shading gradients when these cues are absent.

36.4105 **Role of 3D rotational symmetry in visual perception**

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A 3D shape is N-fold rotational-symmetric if the shape is invariant for 360/N degree rotations about an axis. Mach pointed out that human observers are sensitive to rotational-symmetry in a 2D image, but less sensitive than to mirror-symmetry, which involves invariance to reflection across an axis. We have previously shown that observers are also sensitive to mirror-symmetry of a 3D shape, and the assumption of mirror-symmetry helps to perceive the veridical 3D shape from its 2D image. Now we examine whether rotational-symmetry of a 3D shape plays a role in visual perception. We compared the perceptual and geometrical properties of 3D rotational-symmetry to those of 3D mirror-symmetry. We found that these two types of symmetry have similar geometrical properties. Both types of symmetry, with an additional constraint (planarity of contours), provide invariants for a 3D to 2D projection. Namely, a relation between projections of a pair of contours with either type of symmetry can be represented by a subset of 2D Affine transformations. Consequently, we show formally that a 3D shape with either type of symmetry can be recovered from a single 2D image, by using the symmetry as an a priori constraint. Unlike for mirror-symmetry of a 3D shape, observers do not seem to reliably detect N-fold 3D rotational-symmetry unless N is roughly 20 or higher. When N is infinity, the N-fold rotational-symmetric 3D shape becomes a surface of revolution, and every 2D projection of a surface of revolution is itself 2D mirror-symmetrical. We will show how rotational-symmetry appears in a 3D shape as a secondary product of its mirror-symmetry by increasing the number of folds of its mirror-symmetry (Note that infinite-fold 3D mirror-symmetry is also a surface of revolution). These considerations suggest that the human visual system is sensitive to 3D rotational-symmetry only through its accompanying 3D mirror-symmetry.

Acknowledgement: NIH EY013312 to QZ

36.4106 **Ambiguous Cylinders: A New Class of Solid That Evokes Anomalous Perception**

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We have discovered a new type of optical illusion in which a single solid generates impressions of two quite different cylinders when it is seen from two special viewpoints. By positioning a solid and a mirror in such a way that the two special viewpoints can be experienced simultaneously, the viewer sees both the solid itself and its mirror image, but as apparently different objects. From this, the viewer understands logically that what he/she is perceiving is different from the real shape of the solid, but the visual system of the viewer does not correct the misperception of the solid's shape. In this sense, this anomalous perception belongs to the class of optical illusions, and we are naming it the ambiguous cylinder illusion. The ambiguous cylinder illusion can be explained as the result of an interaction between depth ambiguity in a single image and a human preference for a rectangular structure. From a mathematical point of view, a single image cannot uniquely specify the three-dimensional shape of an object appearing in the image, because the image does not convey depth information, and hence there is ambiguity in the object. From a psychological point of view, on the other hand, the human visual system prefers certain interpretations more strongly than other interpretations. In particular, if the solid is composed of planar faces, then the system seems to prefer the interpretation of a rectangular structure to other interpretations. In the case of an image of a cylindrical object, the human visual system seems to consider that the object is generated by cutting a cylinder with a plane perpendicular to the axis of the cylinder. We will show that ambiguous cylinders can be created successfully on the basis of this hypothesis.

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36.4107 **Comparing sensitivity estimates from MLDS and forced-choice methods in a slant-from-texture experiment**

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Maximum likelihood difference scaling (MLDS) is a method for the estimation of perceptual scales based on an equal-variance, Gaussian, signal detection model (Maloney & Yang, 2003). It has recently been shown that perceptual scales derived with MLDS allowed the prediction of near-threshold discrimination performance for the Watercolor effect (Devinck & Knoblauch, 2012). The use of MLDS-based scales to predict sensitivity is psychophysically attractive, because the MLDS scale estimation promises to require a comparatively small amount of data relative to classical forced-choice procedures, such as the method of constant stimulus. However, the relationship between estimates from MLDS and forced-choice procedures is not yet well characterized with respect to their bias and variability. It also remains to be tested whether their close correspondence applies to stimuli other than the Watercolor effect. Here, we studied these issues by comparing the MLDS and forced-choice methods in a slant-from-texture experiment. We used a 'polka dot' texture pattern which was slanted 0 to 80 deg away from fronto-parallel and viewed through a circular aperture (Rosas et al., 2004). We first obtained perceptual scales describing the relationship between physical and perceived slant using MLDS with the method of triads. Based on individual scales we measured slant discrimination thresholds at different performance levels (d'=0.5, 1 and 2) for four different standard slants using standard forced-choice procedures. We obtained a high correspondence between slant thresholds obtained from the two methods. The variability of the estimates, however, depended heavily on the amount of data for MLDS, somewhat questioning its efficiency. Furthermore, the correspondence between the two methods was reduced in the lower region of the MLDS scale. We conclude that MLDS scales can be used to estimate sensitivity, however, we would advise caution with respect to the generalizability of the correspondence between MLDS and forced-choice based sensitivity measures across experimental tasks.

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36.4108 **The effect of the bounding contour on the perception of surface shape**

Erich Graf[1] (erich@soton.ac.uk), Wendy Adams[1], James Elder[2]; [1]Psychology, University of Southampton, UK, [2]Centre for Vision Research, York University, Canada

The shape of the bounding contour of a smooth object is known to constrain the local shape of the 3D object at its rim: convex points on the contour must project from convex points on the surface, while concave points project from saddle points (Koenderink 1984). While mathematically the bounding contour does not strictly constrain solid shape at points interior to the contour, the fact that silhouettes can convey a compelling sense of 3D shape suggests that the contour may carry useful statistical cues to surface shape some distance from the rim. Here, we use a novel psychophysical method to quantify the effect of the bounding contour on 3D surface shape interior to the bounding contour of an object. Subjects viewed smooth, random 'potato' objects, illuminated primarily by a single point light source positioned on one side of the object. We partially occluded the potato shape on the side opposite the lighting direction, and a cutaway in the occluder revealed a silhouetted surface and bounding contour. We manipulated both curvature sign and magnitude of this contour section across trials. The subject's task was to orient a gauge figure to indicate perceived surface attitude at interior locations over a range of distances from the windowed bounding contour. We found that locations near the boundary were perceived to have larger slant values relative to interior points. Additionally, perceived surface attitude was modulated by both sign and

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magnitude of contour curvature. We discuss these results in the context of the joint ecological statistics of bounding contour and surface shape.

36.4109 **Biases in perceived slant and tilt of real surfaces** Arthur Lugtigheid[1] (lugtigheid@gmail.com), Wendy Adams[1], James Elder[2], Erich Graf[1], Alex Muryy[1]; [1]Centre for Vision and Cognition, University of Southampton, UK, [2]Centre for Vision Research, York University, Toronto, Canada

Underestimation of slant is a well-known bias in human surface attitude perception. Does this frontoparallel bias have a rational basis? If we consider a single tilt axis, and assume a world in which surfaces are uniformly distributed across slant, then a frontoparallel bias is predicted: surfaces with smaller slants project to larger regions of the visual field than more slanted, foreshortened surfaces and therefore should be observed more frequently. However, in natural scenes, surface slant is non-uniformly distributed and surface tilt varies widely. Here we consider the joint estimation of slant and tilt and relate it to natural scene statistics. On each trial, observers viewed a real, textured surface presented at one of 36 different orientations. The surface was viewed monocularly, through a small aperture, to reduce the reliability of slant and tilt cues, and therefore maximise the effect of biases related to perceptual priors. The use of a real surface eliminated cue conflicts that occur when slanted stimuli are rendered on a frontoparallel screen, which could otherwise lead to underestimation of slant. Observers reported perceived slant and tilt by rotating an unseen haptic paddle to match the orientation of the viewed surface. Consistent with previous reports of a frontoparallel prior, our results suggest a strong tendency to underestimate surface slant. However, slant underestimation was greater for ceiling planes than wall or floor planes. Evidence for a bias toward floor planes is also apparent in the tilt data, and reversals of perceived tilt were more frequent for ceiling planes than ground planes. Analyses of natural scenes statistics from the Southampton-York Natural Scenes (SYNS) dataset suggest that these perceptual biases are well-matched to the distribution of surface slant and tilt in natural scenes.

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36.4110 **Local Surface Patch Classification Using Multilinear PCA+LDA on High-Order Image Structures Compared to Human Observers** Christopher Kallie[1] (kallie.1@osu.edu), Eric Egan[1], James Todd[1]; [1]Psychology, The Ohio State University

What information do we use to determine the curvatures of local surface patches? In a 5-AFC decision task, observers judged the curvatures of local surface patches viewed through an aperture, including Bells, Dimples, Furrows, Humps, and Saddles that were cylindrically projected onto a sphere. Numerous high-order image structures were computed from stimulus luminance values. Classical and Multilinear PCA were performed on image structures, which were dimensionally degraded until mean model performances (i.e., proportions of correct discriminations) matched the mean performance of observers. The posterior probability distributions of the LDA classifiers were then correlated with human error confusions. Among the image structures that were examined, the strongest predictors of human performance involved 2nd-order derivatives of the luminance patterns. Using more than one image structure at a time did not reliably improve model prediction, leading us to choose Laplacian of Gaussian arrays and Multilinear PCA+LDA for further analysis. The model accounted for approximately 33% of the error confusions that were predicted by independent human observers. In other words, the model was about 1/3 as reliable as the test-retest reliability of independent human observations. It appears as though humans may use information analogous to high-order image structures to judge local surface contours, however the exact information guiding our perceptual judgments remains uncertain.

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36.4111 **Knowledge effects on slant estimation are mediated by Conscientiousness** Abigail Robinson[1] (abrobinson01@gmail.com), Jaehyun Oh[1], Christopher Thomson[1], Ruth Talbot[1], Catherine Norris[1], Frank Durgin[1]; [1]Department of Psychology, Swarthmore College

Estimates of (geographical) hill slant are often higher for women than men. We collected estimates of slant for several hills from a cross-section of people from the nearby community and from college students. Prior research has suggested that knowledge about hill slant (e.g., from experience with skiing) has a corrective impact on hill slant estimation but that this could not account for sex differences found (Stigliani et al., 2010). We looked for sex-linked effects on estimation that might be due to personality factors (Agreeableness, Conscientiousness and Emotional Stability) and spatial skills (Mental Rotation) as well as fitness (BMI) and height. Participants were 58 students (27 female, age range 18-22) and 48 non-students (33 female, age range 18-72). Three hills were tested in fixed order (9°, 22.5° and 4.5°). At the first hill a manual slant match (free hand measure), a visual slant match, and a verbal estimate were collected (in that order). Only verbal estimates were collected at the other two hills. Participants subsequently filled out personality surveys, did a mental rotation task, identified background knowledge they might have about hill slant perception/estimation and provided demographic information. All three measures given for the first hill were reliably correlated with one another (manual/visual r=0.50; visual/verbal r=0.54; manual/verbal r=0.33), so we report analyses of the verbal estimates across all three hills. None of the factors we considered could explain the sex differences in slant estimation in our study. We did find strong effects of knowledge concerning slant (which lowered slant estimates), and a reliable trend for slant estimates to become lower (more accurate) with increasing age (possibly an effect of increasing implicit knowledge). The effect of knowledge was mediated by Conscientiousness such that conscientious people were more likely to take their knowledge of slant overestimation into account when estimating slant.

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36.4112 **Interactions between viewing from above and global convexity priors in the interpretation of depth-ambiguous shape-from-contour drawings** Séamas Weech[1] (seamas.weech@queensu.ca), Daniel Gale[1], Nikolaus Troje[1,2,3,4]; [1]Department of Psychology, Queen's University, Kingston, Ontario, Canada, [2]Department of Biology, Queen's University, Kingston, Ontario, Canada, [3]School of Computing, Queen's University, Kingston, Ontario, Canada, [4]Canadian Institute for Advanced Research, Toronto, Ontario, Canada

The 'Viewing from Above' prior (VFA) guides visual perception of ambiguous stimuli in shape-from-shading and shape-from-contour tasks (Reichel & Todd, 1990). Accordingly, the typical Necker cube tends to be reliably perceived from above, particularly for short presentations, although viewing-from-below is equally valid (e.g., Troje, 2010). Initial observations indicated that shape influences the reliability of the VFA: a 'diamond' stimulus (i.e., two attached square-base pyramids) is less likely to be perceived in one consistent orientation. We compared perception of diamond and Necker cube ambiguous line-drawings with four shapes that shared related features: point-up or point-down square-based pyramids and point-up or point-down pyramids attached to a Necker cube. The Necker cube was viewed from above (97%) significantly more often than the diamond (86%). The point-up pyramid was also viewed from above (97%) more often than the point-down pyramid (84%). We also found the point-up pyramid attached to the Necker cube was viewed from above (98%) more often than the same stimulus when inverted (87%). We suggest that a strong VFA prior mediated by a weaker prior for global convexity are generally consistent with the results. The finding contrasts with research that found equal strength for the two priors in shape-from-shading (Langer & Bulthoff, 2001), but supports research on the unequal strength of the two priors in line drawings (Mamassian & Landy, 1998). Specifically, all stimuli tended to be viewed from above; and the point-up and point-down pyramids adhere to a convexity towards the viewer if they are perceived from above and from below, respectively. The same is true for the pyramids attached to Necker cubes. However, the finding that the diamond stimulus is seen less often from above than other stimuli cannot be explained.

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Monday Morning Talks

Attention: Control and mechanisms

Monday, May 18, 8:15 - 9:45 am
Talk Session, Talk Room 1
Moderator: Emma Dowd

41.11, *8:15 am* **Letting go: How the disappearance of a fixation target prompts the brain to shift attention** Louisa Kulke[1] (louisa.kulke.12@ucl.ac.uk), Janette Atkinson[1,2], Oliver Braddick[2]; [1]Dept of Developmental Science, University College London, London, UK, [2]Dept of Experimental Psychology, University of Oxford, Oxford, UK

A peripheral target can either be fixated when the current central target disappears ('non-competition') or while the central target remains visible ('competition') in the Fixation Shift Paradigm, where saccadic latencies can be used as a measure of shifts of attention. Competition, which leads to much slower saccadic latencies in young infants, requires disengagement from the current target, a process which is believed to depend on descending cortical input to oculomotor systems and is diagnostic of cerebral developmental problems (review: Atkinson and Braddick, Dev Med Child Neurol, 2012). We have recorded high density ERPs during the pre-saccadic interval, along with concurrent eye tracking, in both competition and non-competition from 38 normal adults. The adults showed small but significant advantages in saccadic latency for the non-competition condition. Patterns of ERP signals across the scalp, representing the processes of disengagement, attentional shift, and saccade preparation, were compared to investigate the cerebral basis of this advantage. A very early frontoparietal response, contralateral to the target, is seen in both conditions, as is a later, ipsilateral occipitoparietal response. When the contribution of the VEP to central target offset is allowed for, the latency of ERP responses for competition and non-competition is similar. However, both anterior and posterior responses show higher amplitudes in the non-competition than competition condition. These results will be discussed in terms of possible inhibitory connections between frontal, posterior, and subcortical oculomotor systems which may underlie the disengagement process. We are currently testing whether the ERP responses, characteristic of this network, provide developmental signatures of the disengagement process in infants, and potentially may serve as diagnostic signatures of the neural processes which impair fixation shifts in many developmental disorders (e.g. Braddick et al, Nature, 1992; Atkinson et al, Prog. Brain Res., 2011).

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41.12, *8:30 am* **Learning experience shapes attention deployment in the visual field** Tobias Feldmann-Wüstefeld[1] (tobias.fw@gmail.com), Metin Uengoer[1], Anna Schubö[1]; [1]Experimental and Biological Psychology, Philipps-University Marburg

To cope with the huge amount of incoming information, the visual system has to assign priorities to each stimulus in the visual field. Which stimulus is prioritized depends on bottom-up factors that are defined by physical properties inherent of the visual stimuli, e.g., local feature contrast, and top-down factors that are set 'in the observer', e.g., current intentions or goals. Recent results have challenged the classic dichotomy of bottom-up vs. top-down as control mechanisms and have suggested past selection history, e.g. evident in learning experience, as a third source of selection bias that can neither be accounted for by physical stimulus properties nor by goal-driven selection (Awh, Belopolsky, & Theeuwes, 2012). The present study used event-related potentials (N2pc and its subcomponents NT and PD) to examine the relationship between learning experience and selective attention. Participants performed a visual learning task which was combined with a visual search task in the course of the experiment. Results showed that color distractors impaired behavioral performance in the visual search task more when color rather than shape was learned as being predictive in the learning task. ERP results showed that this was due to differential attention deployment: when color was predictive in the learning task, color distractors captured attention also in the search task before they could be actively suppressed. When shape was predictive in learning, color distractors did not capture attention in the search task and suppression was possible earlier in time. These results revealed common underlying mechanisms of visual learning and selective attention and suggest that apart from bottom-up and top-down processing, learning experience changes the way the visual environment is perceived when different stimuli compete for priority.

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41.13, *8:45 am* **Interference control theory: A new perspective on dual-task interference in memorizing and responding to visual targets** Mark Nieuwenstein[1] (m.r.nieuwenstein@rug.nl), Sabine Scholz[1], Nico Broers[1]; [1]University of Groningen

In a recent study, Nieuwenstein and Wyble (JEP:General, 2014) showed that the consolidation of a masked visual target can be disrupted for up to one second by a trailing 2-alternative forced choice task. Aside from demonstrating that working memory consolidation continues long after a mask, the results of Nieuwenstein and Wyble are remarkable in demonstrating retroactive interference (RI) with little to no proactive interference (PI) – the opposite of what is typically found in studies on the attentional blink and psychological refractory period effect. Here, we show that the reversal from PI to RI depends on the probability of T2 presence: When p(T2) is high, we find strong PI with little RI whereas we find strong RI with little PI when p(T2) is low. To explain these findings, we propose that the occurrence of PI and RI reflects the workings of an attentional control mechanism that aims to protect T1 consolidation against interference and that is applied in accordance with the risk of such interference. In this view, a high p(T2) entails a high risk of interference, and this results in the protection of T1 at the expense of a postponement of T2 processing. Conversely, a low p(T2) means a low risk of interference and this entails that T1 is left vulnerable, while T2 can be processed unabated. Consistent with this account, we show that if the risk of interference is increased by embedding the targets in an RSVP stream of distractors, the results again show strong PI with little RI even when p(T2) is low. Aside from offering a new perspective on dual-task interference, this work bears important implications for studies using RSVP, and it also offers an interesting account for why the ability to suppress attentional capture by distractors depends on the likelihood of encountering such distractors.

41.14, *9:00 am* **The temporal dynamics of target selection in real-world scenes** Daniel Kaiser[1] (daniel.kaiser@unitn.it), Nikolaas Oosterhof[1], Marius Peelen[1]; [1]Center for Mind/Brain Sciences, University of Trento

In daily life, humans are constantly required to select behaviorally relevant targets from cluttered and complex environments. In previous neuroimaging studies, the remarkable efficiency of such selection processes has been linked to a selective enhancement of the representation of behaviorally relevant stimulus categories in visual cortex. Although these studies have revealed important insights about the neural basis of real-world search, the temporal unfolding of these effects is still unclear. Here, we recorded MEG activity while participants searched for categorical targets (persons or cars) in real-world scenes. We then tried to recover the presence and location of these two categories within a scene from MEG sensor patterns using multivariate decoding. We found that classifiers trained on patterns evoked by persons and cars in isolation could reliably distinguish between scenes containing persons or cars. Additionally, we were able to decode the location of the behaviorally relevant target category: Classifiers trained on an independent attentional orienting task were able to distinguish whether the target category appeared on the right or on the left side of a scene. Both category and location information could be retrieved already shortly after scene onset, indicating that processing of visual categories in complex scenes is composed of an early boost of category information, accompanied by an attentional orienting towards the relevant target. More generally, our results demonstrate the viability of using MEG to compare representations across different sets of stimuli and tasks to gain insights in the temporal dynamics of visual processing.

41.15, *9:15 am* **Competitive tradeoffs between working memory and attention: An fMRI approach** Emma Dowd[1] (emma.wudowd@duke.edu), Anastasia Kiyonaga[1], Tobias Egner[1]; [1]Department of Psychology & Neuroscience, Center for Cognitive Neuroscience, Duke University

Previous research has highlighted a close relationship between working memory (WM; i.e., the short-term maintenance and manipulation of internal information) and attention (i.e., the selective processing of a limited amount of external information). This reciprocity between WM and attention can be thought of as two sides of the same coin, such that WM (internal) and visual attention (external) could draw from, and thus compete for, a common cognitive resource. To examine the behavioral and neural characteristics of this interaction, we acquired fMRI data during a dual-task paradigm that simultaneously and systematically taxed both internal (WM) and external (visual) attentional load. Participants remembered one or two images (i.e., low vs. high internal load) for a delayed match-to-sample task. During the delay, participants performed a series of visual searches for target items that were either highly distinct from or similar to visual distractors (i.e., low vs. high external load). Behavioral data revealed that the impact of internal load on memory performance was inversely related to the impact of external load on search performance, suggesting that the effective processing of cognitive load in one domain increased susceptibility to load in the other domain. For example, for participants whose search performance was less affected by high external load, memory performance was more impaired by high internal load. Neural activity also revealed robust interactions between the two domains, such that parietal and temporal regions were differentially recruited to manage internal load in the face of low and high external load, respectively. Moreover, individual differences in independent measures of visual WM capacity and visual search efficiency modulated these behavioral and neural tradeoffs between internal and external attention. Collectively, these findings support the idea of WM and visual attention as competitive and interdependent constructs, whose interactions are processed by a network of fronto-temporo-parietal substrates.

41.16, *9:30 am* **Executive attention in adults with and without ADHD – an ERP study** Lilach Shalev[1,2] (lilachsm@tauex.tau.ac.il), Roy Luria[2,3], Keren Saar[1], Irina Nesterovsky[1], Baruch Styr[4], Carmel Mevorach[5], Haleli Balaban[2,3], Orli Azulai[1]; [1]School of Education, Tel-Aviv University, Israel, [2]School of Neuroscience, Tel-Aviv University, Israel, [3]School of Psychological Sciences, Tel-Aviv University, Israel, [4]Maccabi Healthcare Services, Israel, [5]School of Psychology, University of Birmingham, UK

The present study investigated executive attention in adults with ADHD. A typically developed adults group and an ADHD group performed a location-direction Strooplike task, while EEG was recorded. The task induced either a low conflict (location judgment blocks) or a high conflict (direction judgments blocks). The results indicated that the ADHD group showed an overall behavioral impairment. In addition, it was found that participants without ADHD performed the low-conflict task significantly better compared to the high-conflict task. This difference was substantially smaller in participants with ADHD. Moreover, we analyzed the slow potential (SP), an ERP component whose amplitude is sensitive to degree of conflict in such tasks. In the control group the SP amplitude, measured across parietal and occipital electrodes, was more positive in the high conflict- relative to the low conflict-condition. However, in the ADHD group no such sensitivity was found. Importantly, the degree of conflict resolution as indicated by the SP amplitude difference between the high and low conflict conditions, correlated significantly with the severity of ADHD symptoms (r=-.531, p< .005). These findings may pinpoint to the neural mechanism that underlies one of the most frequent difficulties of individuals with ADHD, namely, the suppression of irrelevant information. We suggest that when facing a complex stimulus adults with ADHD are prone to process both the relevant and the irrelevant information and as a result they are less effective in processing complex stimuli not just in the context of neuropsychological tasks but rather in everyday functioning.

Acknowledgement: Ministry of Health, Israel

Perception and Action: Interactions

Monday, May 18, 8:15 - 9:45 am
Talk Session, Talk Room 2
Moderator: Robert Volcic

41.21, *8:15 am* **Learning efficient perceptual sampling** Marko Nardini[1] (m.nardini@ucl.ac.uk), Pete Jones[2], Linnea Landin[3], Mordechai Juni[4], Laurence Maloney[5,6], Tessa Dekker[2]; [1]Department of Psychology, Durham University, UK, [2]Institute of Ophthalmology, University College London, UK, [3]Department of Psychology and Language Sciences, University College London, UK, [4]Department of Psychological and Brain Sciences, University of California, Santa Barbara , [5]Department of Psychology, New York University, [6]Center for Neural Science, New York University

We tested adults and children aged 7-9 and 10-12 years in a stochastic judgment task. Adult observers compensate in part for perceptual uncertainty. However, the manner in which perceptual systems represent and compute with probabilistic estimates remains largely unknown. Developmental studies provide insight into the nature and origins of these capabilities. In our task, subjects could earn a reward by touching an invisible target circle marked by dots (cues) drawn from a Gaussian distribution centred on the target. Subjects could sample up to 20 cues but each cue reduced the possible reward by a fixed amount. Each additional cue improved the reliability of the location estimate by reducing the standard error of the mean. Subjects therefore had to trade off localization accuracy against the cost of additional cues. There were two conditions that differed in the variance of the Gaussian. We computed the optimal sample size that maximized expected reward in each condition: 4 cues (low variance) and 8 cues (high). We assumed that observers aimed for the mean location of each dot cloud; control conditions showed that deviations from this strategy were small across all age groups. Strikingly, across both variance conditions, in both child and adult groups, numbers of cues sampled were indistinguishable from optimal. However, sampling in child groups was more variable trial-to-trial, with a cost to their final rewards as compared with adults. Children's relatively mature abilities to compute with probabilistic estimates here contrast with their much poorer abilities to take uncertainty into account in difficult perceptual and motor tasks (e.g. Nardini et al, PNAS 2010; Dekker et al, VSS 2012). This apparent dissociation suggests that probabilities dependent mainly on external factors (samples of dots, in this task) are computed separately to those dependent mainly on internal noise (sensory uncertainty, in previous tasks).

Acknowledgement: ESRC grant RES-061-25-0523

41.22, *8:30 am* **Increasing eye height makes slopes appear less steep** Bruce Bridgeman[1] (bruceb@ucsc.edu), Ian Cooke[1]; [1]Department of Psychology, University of California, Santa Cruz

Several studies have shown that slopes of hills are greatly overestimated. We have recently demonstrated that the overestimates increase logarithmically as the end point of the domain to be estimated increases – every doubling of the distance to the end point results in a constant increment in perceived slope. A theoretical analysis showed that a critical parameter is the angle v between the observer's line of sight and the slope of the hill, when the observer fixates the far point of the required domain. The theory predicts that increasing observers' eye height above the surface of the hill will reduce the slope overestimates by increasing this angle. Here we test that theory by having observers stand on a 37 cm high box to increase their eye height. Observers estimated an outdoor slope in front of them in degrees, at ranges from 2 to 16 m. Estimates for various ranges defined by traffic cones again followed a logarithmic function (r2 = 0.997), with lower estimates compared to other observers standing directly on the surface of the hill. Apparent slope increased more rapidly with distance than in a group standing on the hill's surface, however, so that at larger distances slope estimates with and without increased eye height converged. As the length of the domain to be judged increases, enhanced eye height has a smaller and smaller effect on the angle v between the line of regard and the hill's surface. A demand characteristic might induce observers to give different estimates for the four distances tested; an analysis of just the first estimate of each observer, however, showed that the distance vs apparent slope function remained logarithmic. We conclude that anticipated effort, perceived danger and other factors play only a minor role if any in slope estimates.

Acknowledgement: Supported by a faculty research grant to Bruce Bridgeman from the University of California, Santa Cruz

41.23, *8:45 am* **Predicting the outcome of an opponent's tennis stroke: Insights from a classification-sequence analysis** Sepehr Jalali[1,2] (sepehr.jalali.1@city.ac.uk), Kielan Yarrow[1], Joshua Solomon[2]; [1]Department of Psychology, City University London , [2]Centre for Applied Vision Science, City University London

Experts are able to predict the outcome of their opponent's next action (e.g. a tennis stroke) based on kinematic cues that are "read" from preparatory body movements. Traditionally, this ability has been investigated by manipulating a video of the opponent, but this can reveal only the information sources that have been anticipated by the experimenter. Here, we instead use classification-image techniques in order to find out how participants discriminate sporting scenarios as they unfold. Videos were taken of three competent tennis players making services and forehand shots, each with two possible directions. The videos were presented to novices and club-level amateur participants for a period from 800ms before to 200ms after racquet-ball contact. Participants stepped off force plates in a tennis-appropriate manner to report shot direction. We established a time limit for responses that was consistent with 90% accuracy in a training phase. Participants then viewed videos through randomly

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placed temporal Gaussian windows ("Bubbles"). The number of windows was varied to ensure ~75% accuracy. A comparison of Bubbles from correct and incorrect trials allowed us to estimate the relative contribution of each cluster of video frames toward a correct response. Two clusters had a significant impact on accuracy. One extended from ~50 ms before ball contact to 100+ ms afterwards. Interestingly, a second cluster suggested that for forehands, information was also accrued from around the time of swing initiation, ~300 ms before ball contact. Clusters were derived based on data from all participants, as an amateur minus novice contrast was not significant. Although still under development, our technique has potential to help players improve in two ways: By showing them 1) from when/where they read information, and 2) their "gives" when making a shot. Ongoing experiments will generate classification images to complement our current classification sequences with spatial information.

Acknowledgement: BBSRC

41.24, *9:00 am* **A dissociation of motion processing for saccades, smooth pursuit, and perception measured for the same target.**

Matteo Lisi[1] (matteo.lisi@parisdescartes.fr), Patrick Cavanagh[1]; [1]Laboratoire Psychologie de la Perception (CNRS UMR 8242), Université Paris Descartes

We compare how three different systems – saccades, pursuit, and perception – determine the direction of the same moving target. Recent studies suggest that this motion information, although it affects all three systems (saccades, Gellman & Carl, 1991; pursuit, Lisberger, 2010; perceived position, De Valois & De Valois, 1991), might be processed differently depending on the purpose of the process (Simoncini, et al., 2012). We take advantage of a perceptual illusion (Tse & Hsieh, 2006) in which motion signals within a moving aperture viewed in the periphery dramatically affect the perceived direction of the aperture itself. We presented moving apertures filled with noise that either drifted orthogonal to the aperture's direction, or varied dynamically with no net motion. The targets appeared in the periphery and moved (12°/s) either toward or away from fixation. Participants were asked to saccade to these targets as soon as they appeared, and then track them with their gaze. Following the trial, participants reported the target direction using a directional arrow. In the trials with internal motion, however, the target disappeared at saccade onset. In these trials, early post-saccadic pursuit (open loop) still occurred so that the effect of the presaccadic illusory direction was seen in the postsaccadic pursuit. We also estimated the direction of target motion taken into account by the saccadic system from the saccade landing errors. Results show that motion signals from the internal drift strongly affect the perceived aperture direction (average direction shift of 25°), and also affect the direction seen in postsaccadic pursuit (average deviation from physical direction of 23°). In contrast, the effect on saccade landing was much smaller (equivalent to about 10° deviation), revealing that the saccade system integrates the internal and external motions of the target differently from the perception and pursuit systems.

Acknowledgement: This work was supported by the French National Research Agency (grant ANR-12-BSH2-0007 to P. Cavanagh)

41.25, *9:15 am* **The visual coupling between neighbors in a virtual crowd**

William Warren[1] (Bill_Warren@brown.edu), Kevin Rio[1]; [1]Dept. of Cognitive, Linguistic, & Psychological Sciences, Brown University

Pedestrians in a crowd use visual information to coordinate walking speed and heading direction with their neighbors. Previously, we characterized the strategies used to control these behaviors in pairs of pedestrians (Rio, Rhea, & Warren, 2014; Dacher & Warren, 2014). Here we investigate how a participant combines the influence of multiple neighbors, providing a bridge from individual behavior to crowd dynamics. In two experiments, a participant (N=10 per experiment) was instructed to "walk together" with a virtual crowd of 12 simulated humans presented within the FOV of a head-mounted display (90˚ H). On each trial, a subset of virtual neighbors changed their walking speed or heading direction mid-way through the trial. We manipulated the number of neighbors in the subset (0, 3, 6, 9, or 12, equivalent to 0%-100% of the crowd), their distance from the participant (1.5m or 3.5m), and the density of the crowd (interpersonal distance of 2.5m or 5.5m). Change in the participant's walking speed and lateral position were measured relative to baseline control trials, when all neighbors maintained a constant speed and direction. The results support three main conclusions: First, neighbor influence is additive. Participant responses increased linearly with the number of neighbors in the subset ($p< .001$), for both speed and heading. Second, neighbor influence is weighted by distance. Responses were significantly weaker when the subset was far than near ($p< .001$), for both speed and heading. Third, the neighborhood structure appears to be metric (fixed radius) rather than topological (N nearest neighbors) (Ballerini et al., 2008). Responses depended on crowd density ($p< .01$), for both speed and heading, contrary to the topological hypothesis. Thus, a pedestrian in a crowd is visually coupled to at least 12 neighbors in the FOV and coupling strength decays rapidly with metric distance, placing strong constraints on models of collective behavior.

Acknowledgement: NIH R01EY10923, NSF BCS-1431406, Link Foundation Fellowship

41.26, *9:30 am* **Velocity of the Human Stadium or "Mexican" La Ola Wave: Systematic Variations Due to Type and Direction**

Michael McBeath[1] (m.m@asu.edu), R. Chandler Krynen[1]; [1]Department of Psychology, Arizona State University

Introduction: The Human Stadium Wave or Mexican La Ola Wave is a common phenomenon at sporting events in which adjacently seated fans successively stand up and sit down to create a ripple which circles around the stadium, typically about half a dozen times. The velocity of the wave can serve as a metric for natural perception-action timing constraints that guide joint group behavior. The velocity is notable because it appears to be quite reliable without any instructions or aid directing it, and because it may systematically vary based on wave type and direction. Methods: The velocity of the wave was measured at several live professional sporting-event stadiums, from multiple internet recordings of college and professional sporting events (both baseball and football games), and in a large Introductory Psychology class inside a 470-seat auditorium. Waves timed included both lateral and vertical directions, and both stand-and-sit and hands-up-only types. Distances were determined using stadium blue prints and seating depth counts. Results: The findings revealed a reliable velocity of the lateral stand-and-sit wave averaging approximately 25 mph (about 40 feet or close to 20 people per second, standard deviation of 2 people per second). The hands-up-only wave was timed to be very close to twice as fast, at 50 mph (about 80 feet or 40 people per second), while the vertical direction was close to half as fast as the lateral direction. Conclusions: The general reliability of the velocity of the wave supports that it likely represents a universal or natural regularity of human perception-action timing and group behavior. The range of speeds for stand-and-sit waves and hands-up-only waves of 20 and 40 people per second support general biomechanical motoric speed, reaction, and coordination limitations near the same 20-40 Hz rates where both auditory and visual repetitions also become difficult to discern.

Face Perception: Mechanisms and models

Monday, May 18, 10:45 - 12:15 pm
Talk Session, Talk Room 1
Moderator: Tim Kietzmann

42.11, *10:45 am* **The deceptively simple N170 hides a complex diagnostic coding mechanism involving visual feature transfer across hemispheres.**

Robin Ince[1] (robin.ince@glasgow.ac.uk), Katarzyna Jaworska[1], Stefano Panzeri[2], Guillaume Rousselet[1], Philippe Schyns[1]; [1]Institute of Neuroscience and Psychology, University of Glasgow, Glasgow UK, [2]Center for Neuroscience and Cognitive Systems @UniTn, Istituto Italiano di Tecnologia, Rovereto, Trentino, Italy

A key to understanding visual cognition is to determine when and how brain responses are sensitive to the specific visual information underlying categorization behavior. We know that the N170 is the first brain response coding such diagnostic information (Schyns et al., Current Biology 2007), as recently shown in Rousselet et al.'s experiment (Journal of Vision 2014). Using Bubbles (Gosselin & Schyns, Vision Research 2001), we found that the eyes are diagnostic for face detection and are coded in latency and amplitude modulations of the N170. Here, with new analyses we show that diagnostic coding of the eyes in the N170 involves cross-hemispheric transfer. We proceed in three steps. First, we show that the eye contralateral to the recording electrode (i.e. Occipito-Temporal Left, or Right, OTL, OTR) modulates the N170 latencies, whereas the ipsilateral eye modulates the later N170 amplitudes. Second, we show that single-trial N170 latencies and amplitudes fully account for all the coding of the eye that can be extracted from the EEG signal, at any time point. Finally, we show an important effect of the temporal ordering of the left and right N170s (on OTL and OTR) on coding of the eyes. Specifically, an earlier N170 on OTL (initially coding the right eye) has a strong effect on the later coding of the right eye on OTR (initially coding the left eye), suggesting causal transfer of the right eye across hemispheres. To summarize, in a face detection task where both eyes are diagnostic, the N170 ERP initially codes the contralateral eye, closely followed by the ipsilateral eye that is transferred from the earlier N170 in the opposite hemisphere. Our results suggest that the deceptively simple N170 ERP hides a complex mechanism of diagnostic visual feature coding involving cross-hemispheric feature transfer.

Acknowledgement: This work was supported by the BBSRC grant BB/J018929/1 and the Leverhulme Trust grant F/00 179/BD.

42.12, *11:00 am* **Representational dynamics of facial viewpoint encoding: Head orientation, viewpoint symmetry, and front-on views** Tim Kietzmann[1] (tkietzma@uos.de), Anna Gert[1], Peter König[1,2]; [1]Institute of Cognitive Science, University of Osnabrück, 49076 Osnabrück, Germany, [2]Dept. of Neurophysiology and Pathophysiology, University Medical Center Hamburg Eppendorf, 20246 Hamburg, Germany

Faces provide a large variety of information, including the identity of the seen person, their emotional state and social cues, such as the direction of gaze. Crucially, these different aspects of face processing require distinct forms/types of viewpoint encoding. Whereas another person's attentional focus is supported by a view-based code, identification requires the opposite: a fully viewpoint-invariant representation. Different cortical areas have been suggested to provide either function. However, little is known about temporal aspects of viewpoint encoding in the human brain. Here, we combine electroencephalography (EEG) measurements with multivariate decoding techniques to resolve the dynamics of face processing with high temporal resolution. Data were recorded while subjects were presented with faces shown from 37 viewpoints. We then used the resulting patterns of visually evoked potentials to compute representational similarity matrices across time, and performed data- and model-driven analyses to reveal changes in the underlying cortical selectivity, while controlling for effects of low-level stimulus properties and eye-movement artifacts. These analyses revealed a distinct sequence of viewpoint encoding. Head orientations were encoded first, potentially driven by low-level stimulus features. Shortly afterwards, at a latency of about 130ms, these were followed by strong effects of viewpoint symmetry, i.e. the joint selectivity for mirror-symmetric viewing angles, which were previously suggested to support subsequent, viewpoint-invariant identity recognition. At a considerably later stage, about 280ms after visual onset, EEG response patterns demonstrate a large degree of viewpoint invariance across almost all viewpoints tested, with the marked exception of front-on faces, the only viewing angle exhibiting direct eye-contact. Taken together, our results indicate that the encoding of facial viewpoints follows a temporal sequence of coding schemes, including invariance to symmetric viewpoints as a separate stage, supporting distinct task requirements at different stages of face processing.

Acknowledgement: ERC-2010-AdG #269716, FP7-ICT-270212

42.13, *11:15 am* **Relative sensitivity to low- vs. high-level visual properties in face-sensitive regions of the human ventral occipito-temporal cortex: evidence from intra-cerebral recordings** Joan Liu-Shuang[1] (joan.liu@uclouvain.be), Jacques Jonas[1,2], Justin Ales[3], Anthony Norcia[4], Louis Maillard[2], Bruno Rossion[1]; [1]University of Louvain, Belgium, [2]Service of Neurology, CHU Nancy, France, [3]University of St-Andrews, UK, [4]Stanford University, USA

Neuroimaging studies have identified a network of regions in the human ventral occipito-temporal cortex (VOTC) sensitive to faces. Using intra-cerebral electrophysiological recordings, we compared the relative responsivity of the different regions to face-structure using a periodic visual stimulation paradigm. Recordings were made in 17 epileptic patients implanted with linear-array depth-electrodes (>1000 contacts in the VOTC). In Experiment 1, we presented sequences of phase-scrambled and intact face stimuli (equalised for low-level image properties) alternating at a fixed frequency of 3Hz (6 images/s) while patients completed an orthogonal task. Significant periodic EEG responses (SSVEPs) reflecting high-level face structure processing were found at 3 Hz, while responses reflecting low-level visual processing (e.g. local contrast change) were recorded at 6 Hz. An index of high-level processing (3Hz/(3Hz+6Hz)) showed a posterior-to-anterior gradient, reflecting increased sensitivity to face structure going from the occipital to the temporo-polar cortex, with a right hemisphere lateralisation. In Experiment 2, we further investigated face structure processing with a sweep VEP paradigm (Ales et al., 2012; 4/17 patients). Stimulation was similar to Experiment 1 except the visibility (phase coherence) of the face image was parametrically varied so that a face gradually emerged over the course of a sequence. The patients performed a face detection task during the trials. Responses at 3Hz, objective markers of face detection, were found in all patients on contacts in the lateral fusiform gyrus and inferior occipital gyrus that overlapped with those defined in Experiment 1. All regions showed non-linear voltage vs coherence functions at 3Hz, with thresholds lying around ≈40% coherence. Sites in the lateral fusiform gyrus had a distinct step-like response profile suggestive of categorical face detection. These findings demonstrate that face-sensitive regions are organised with a posterior-to-anterior gradient of increasingly selective high-level visual processing. These regions appear to detect face structure in a non-linear/categorical manner.

Acknowledgement: ERC Grant facessvep 284025, FNRS Grant FC91608

42.14, *11:30 am* **The topographical representation of the human body in visual cortex** Ghazaleh Kiani[1] (ghazal.kiani18@gmail.com), Sherryse Corrow[1], Jodie Davies-Thompson[2], Jason Barton[1]; [1]Human Vision and Eye Movement Laboratory, Department of Medicine (Neurology), Department of Ophthalmology and Visual Sciences, University of British Columbia, [2]Crossmodal Perception and Plasticity Laboratory, Center for Mind/Brain Sciences, University of Trento

Introduction: Motor and somatosensory cortices have orderly topographic representations of the human body, which are referred to as 'homunculi'. Neuroimaging studies have shown regions in fusiform and occipital cortices that are activated visually by faces and others by bodies, which are adjacent to each other. Objective: We asked whether occipitotemporal regions that respond to visual presentation of parts of the human body show 1) an organized body map, and 2) a similar pattern of magnification for certain body regions. Methods: 10 subjects participated in an fMRI experiment that compared responses during viewing of short video clips of movements of 5 different body-parts (top face-half, bottom face-half, arms, torso and legs) versus their scrambled counterparts. Using a 'winner-takes-all' analysis for all activated voxels, we assigned each voxel a preferred body part designation. We examined the distribution of these voxels on a 2-dimensional flat map. Results: Unlike the case for motor and sensory homunculi, there was significant inter-subject variability in the spatial relationship between areas responding to different body regions, in both occipital and fusiform regions of the right hemisphere. However, the magnification patterns in both regions were similar, showing the largest representation was for the lower face, followed by the torso, upper face, arms, and legs: this pattern bore a strong resemblance to that seen in the motor and sensory cortices. Conclusion: While there are clusters that show preferential visual responses to different body parts, the topographic representation of the visual body is less organized than that for motor and sensory homunculi. Body magnification patterns were similar, though, suggesting that the relatively greater importance of the lower face and mouth region is common to motor, sensory and visual experience.

Acknowledgement: CIHR grant MOP-106511, NIH NRSA grant (SC), Canada Research Chair, Marianne Koerner Chair in Brain Diseases (JB)

42.15, *11:45 am* **Near-perfect prediction of reaction time for face gender judgments based on activity in ventral temporal cortex** Kalanit Grill-Spector[1,2] (kalanit@psych.stanford.edu), Kevin Weiner[1], Nikolaus Kriegeskorte[3], Kendrick Kay[4]; [1]Department of Psychology, Stanford University, [2]Stanford Neurosciences Institute, [3]Cognition and Brain Sciences Unit, Medical Research Council , [4]Department of Psychology, Washington University in St. Louis

We previously demonstrated an fMRI protocol for estimating population receptive fields (pRFs) of individual voxels in face-selective regions of ventral temporal cortex (Kay VSS 2014). Moreover, we demonstrated that pRF properties depend substantially on the attentional task performed by the subject. However, it is unknown how pRF properties might relate to behavior. We conducted a psychophysical experiment in which subjects judged the gender of faces presented at different visual field locations (1 central location + 8 angles x 5 eccentricities up to 12° = 41 locations) while maintaining central fixation. Each trial consisted of an 800-ms cue indicating the location of the upcoming face, a 500-ms gap, and an 800-ms face. As expected, as the eccentricity of the face increased, accuracy levels decreased and reaction times increased. Next, we attempted to predict the reaction times based on the pRFs estimated from the fMRI experiment. For each face location, we computed the predicted BOLD activity in each voxel based on its pRF and averaged activity across voxels in each region of interest (ROI). We then correlated the predicted activity for different face locations against the median reaction time observed for each location. We found near-perfect prediction of reaction time using activity in mFus-faces/FFA-2 (subject 1: $r = -0.96$, noise ceiling = –0.99; subject 2: $r = -0.75$, noise ceiling = –0.82). Furthermore, predictions were best when using (i) pRFs from the same subject (subject specificity), (ii) pRFs in mFus-faces/FFA2 as opposed to pRFs in pFus-faces/FFA1 or IOG-faces/OFA (ROI specificity), and (iii) pRFs estimated while subjects performed a face-related task (task specificity). These results suggest that neural activity in mFus pro-

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vides critical information for face-related judgments and that this information is linearly accumulated over time. Consequently, low activity levels in mFus lead to long integration times and produce long reaction times.

Acknowledgement: NIH 1R01EY02391501A1, McDonnell Center for Systems Neuroscience and Arts & Sciences at Washington University

42.16, *12:00 pm* **The Emergence of Face-Selective Units in a Model that Has Never Seen a Face** Daniel Yamins[1] (yamins@mit.edu), Michael Cohen[1], Ha Hong[1,2], Nancy Kanwisher[1], James DiCarlo[1]; [1]Department of Brain and Cognitive Sciences and McGovern Institute of Brain Research, MIT, [2]Harvard-MIT Division of Health Sciences and Technology, MIT

The existence of face-selective neurons in higher visual cortex is one of most robust findings in visual cognitive neuroscience. It is a matter of ongoing debate whether face selectivity is innately specified via long-term evolutionary pressures, or arises from extensive experience with faces during development. To examine this question, we used deep learning methods (Krizhevsky et al. 2012) to train a hierarchical convolutional neural network for optimal performance on an object recognition task, using a network architecture that has been shown to be highly predictive of neural responses in higher visual cortex (Yamins et al., 2014). Critically, this training involved no exposure to faces, bodies, or animate objects of any kind. We then tested this "face-deprived" network on a standard face-localizer image set (ie. faces, bodies, scene, objects and scrambled objects). Surprisingly, we found a significant fraction of face-selective units (7.2±0.83%, p< 0.01). These units retained a strongly face-selective response profile on an independent set of highly variable testing images. We found significantly smaller fractions of units selective for other categories (bodies, scenes, &c). To simulate the effect of a small amount of ecologically balanced visual experience, we then fit a linear transform of the face-deprived model units to the neural response profiles for a population of neural sites from macaque inferior temporal (IT) cortex, measured on a set of 256 images of which 32 contained faces. We found that the fraction of face-selective units in this simulated IT population when evaluated on the localizer set (28.3±3.3%, p< 0.01) is consistent with independent measurements from IT. Taken together, these results suggest that the observed face-selectivity in higher visual cortex may arise neither from face-specific innate genetic specification or significant face-focused experiential tuning, but rather may largely be the by-product of machinery built for non-face-specific object-recognition tasks.

Acknowledgement: DY: NVIDIA Corporation NK: NIH EY13455

Visual Search: Models

Monday, May 18, 10:45 - 12:15 pm
Talk Session, Talk Room 2
Moderator: Jared Abrams

42.21, *10:45 am* **Visual search in natural scenes: a double-dissociation paradigm for comparing observer models** Jared Abrams[1] (jared@mail.cps.utexas.edu), Wilson Geisler[1]; [1]Center for Perceptual Systems, University of Texas at Austin

Search is a fundamental and ubiquitous visual behavior. Here, we aim to model fixation search under naturalistic conditions and develop a strong test for comparing observer models. Previous work has identified the entropy limit minimization (ELM) observer as an optimal fixation selection model.1 The ELM observer selects fixations that maximally reduce uncertainty about the location of the target. However, this rule is optimal only if the detectability of the target falls off in the same way for every possible fixation (e.g., as in a uniform noise field). Most natural scenes do not satisfy this assumption; they are highly non-stationary. By combining empirical measurements of target detectability with a simple mathematical analysis, we arrive at a generalized ELM rule (nELM) that is optimal for non-stationary backgrounds. Then, we used the nELM rule to generate search time predictions for Gaussian blob targets embedded in hundreds of natural images. We also simulated a maximum a posteriori (MAP) observer, which is a common model in the search literature. To examine which model is more similar to human performance, we developed a double-dissociation search paradigm, selecting pairs of target locations where the nELM and the MAP observer made opposite predictions regarding search speed. By comparing the difference in human search times for each pair with the different model predictions, we can determine which model predictions are more similar to human behavior. Preliminary data from two observers show that human observers behave more like the nELM than the MAP. We conclude that the nELM observer is a useful normative model of fixation search and appears to be a good model of human search in natural scenes. Additionally, the proposed double-dissociation paradigm provides as a strong test for comparing competing models. 1Najemnik, J. & Geisler W.S. (2009) Vis. Res., 49, 1286-1294.

Acknowledgement: NIH R01EY011747

42.22, *11:00 am* **Independent Contributions of Multiple Types of Scene Context on Eye Movement Guidance and Visual Search Performance** Kathryn Koehler[1] (koehler@psych.ucsb.edu), Miguel Eckstein[1]; [1]Department of Psychological and Brain Sciences, University of California, Santa Barbara

We search for objects in environments that provide multiple cues to guide our attention. Contextual information facilitates object recognition and guides eye movement behavior (Biederman, 1972; Loftus & Mackworth, 1978; but see Henderson & Hollingworth, 1999). Current research either does not precisely define different types of contextual information (Greene, 2013) and/or focuses specifically on one type of context (e.g., object co-occurrence: Mack & Eckstein, 2011; scene gist: Torralba et al., 2006). In this work we define three types of contextual information (object co-occurrence, multiple object configuration, and background category) and assess their independent contributions to eye movements and behavioral performance during visual search. Eye-tracked participants (n=160) completed a yes/no task after searching for a target object in 48 realistic, computer rendered scenes that contained all, none, or any combination of each of the three types of contextual information. Retinal eccentricity and local contrast of the target and background was controlled across conditions. The type of contextual information had a significant effect on the detectability of the target ($F = 9.1$, $p < .001$) and on the distance of the closest fixation to the target location ($F = 46.24$, $p < .001$). Object co-occurrence and multiple object configuration contribute to performance effects (each $p < .05$ when compared to the no context condition), whereas background category failed to affect performance in all comparison cases ($p > .05$). Analysis of the sensitivity (d') difference between conditions with individual and combined contextual information failed to reject the hypothesis that the independent contributions of each type of context were additive. Our results suggest that multiple types of contextual information contribute independently to visual search performance and that they may do so in an additive way. This suggests that it will be useful to taxonomize types of scene context and improve the precision of definitions of contextual information in future research.

42.23, *11:15 am* **Linearity in perceptual space** Sripati Arun[1] (sparun@cns.iisc.ernet.in); [1]Centre for Neuroscience, Indian Institute of Science, Bangalore 560012

Our vision is unsurpassed by machines because we use a sophisticated object representation. This representation is unlike the retinal image: on the one hand, two out-of-phase checkerboards, maximally different in image pixels, appear perceptually similar. On the other hand, two faces, similar in their image pixels, appear perceptually distinct. What is then the nature of perceptual space? Are there principles governing its organization? To address these questions, we have been using visual search to characterize similarity relations between objects. Compared to the classical approach of asking subjects to provide subjective dissimilarity ratings, visual search has the advantage that it is a natural, objective task where performance is implicitly related to similarity: the time taken to find a target in visual search depends directly on the similarity between the target and distracters. I will summarize a line of research from our laboratory indicative of a surprising linearity governing perceptual space. In the first study, we found that search time is inversely proportional to the feature difference between the target and distracters. The reciprocal of search time is therefore linear and interestingly, it behaved like a mathematical distance metric. It also has a straightforward interpretation as a saliency signal that drives visual search (Arun, 2012). In a second study, complex searches involving multiple distracters were explained by a linear sum of pair-wise dissimilarities measured from simpler searches involving homogeneous distracters (Vighneshvel & Arun, 2013). In a third study, dissimilarities between objects differing in multiple features were found to combine linearly. Even integral features such as the length and width of a rectangle combined linearly upon including aspect ratio as an additional feature (Pramod & Arun, 2014). In a fourth study, distances between multi-part objects were explained as a linear sum of part dissimilarities (Pramod & Arun, submitted to VSS 2015).

Acknowledgement: Wellcome Trust-DBT India Alliance

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42.24, *11:30 am* **The microgenesis of information acquisition in visual 'popout'** Jonathan Flombaum[1] (flombaum@jhu.edu), Sheng-hua Zhong[2], Bruno Jedynak[3], Huaibin Jiang[4]; [1]Psychological and Brain Sciences, Johns Hopkins University, [2]Computer Science, Shenzhen University, [3]Applied Math and Statistics, Johns Hopkins University, [4]Education Institute, Fujian Normal University

Visual popout refers to searches in which one feature distinguishes a target and time to detection is relatively unaffected by number of nontargets. Rapid detection can make it seem like information about a target is obtained immediately and passively. We sought to investigate the acquisition of target-related information in the earliest moments of a search. In Experiment 1 a color-singleton display was masked after a 16.7-900 ms exposure, and the task was to click the position that the target occupied. We translated average response-distance-error into entropy, an information-theoretic measure of uncertainty. We could thus ask how much increasing exposure reduces uncertainty about a target's position. In the first 200ms, uncertainty declined linearly, then plateauing (reflecting perceptual and motor precision). We fit two continuous time models to the responses of each participant, one characterizing a passive strategy of estimating an item's position successively from received signals, the other, a more active strategy of querying whether a signal is present in successively smaller portions of an image. The active model fit significantly better. In Experiment 2, we scrutinized individual differences in rate of information gain. We replicated the results of Experiment 1, accompanied by color change detection to measure working memory capacity. Rate of information gain was significantly correlated with memory capacity (r=0.55). This suggests that rate of information acquisition may underwrite broad cognitive functioning as WM capacity is known to do. Additional experiments related these results to reaction times in detection search and other forms of popout. Overall, the results suggest a new way to characterize visual search at the algorithmic level. We discuss how this algorithmic theory is consistent with psychological theories such as 'guided search,' and how it can be extended to account for inefficient conjunction search and search asymmetries.

Acknowledgement: JHU Science of Learning Institute Seed Grant, Chinese Ministry of Education Grant 14YJC190010

42.25, *11:45 am* **Foraging in satellite imagery: When is it time to move to the next map?** Krista Ehinger[1,2] (kehinger@mit.edu), Jeremy Wolfe[1,2]; [1]Harvard Medical School , [2]Brigham & Women's Hospital

Optimal foraging theory predicts that foragers should leave a patch when the expected value from staying falls below the expected value from leaving, and this strategy has been observed across various simple foraging tasks (Charnov, 1976; Oaten, 1977; McNamara, 1982). However, it can be difficult to apply foraging models to more complex tasks like search in real-world scenes, where scene context and target features can be used strategically. We investigated quitting times in a map search task that preserves the complexity of scene search but makes it easier to apply standard foraging models. In our online experiments, Amazon Mechanical Turk participants searched for small targets (gas stations) in large satellite images using one of three magnifying interfaces (there were no significant differences between interfaces). Participants were paid based on the number of gas stations they found. We ran two versions of the experiment: in Exp. 1, maps had 0-10 targets and participants completed as many trials as they wished; in Exp. 2, all participants searched the same set of 24 maps containing 1-9 targets. We modeled quitting times with a Bayesian model that incorporates prior beliefs about the number of targets in each map and average search performance, and updates these beliefs as it searches the map. Leaving times were measured in number of search actions (clicks) on the map. Participants had fairly consistent leaving time strategies, quitting the current map when their expected rate fell to 0.019 targets/click (Exp. 1) or 0.015 targets/click (Exp. 2). This is lower than predicted for a rate-maximizing forager, meaning that people searched longer than they should have in each map. There are many possible reasons for this behavior; for example, people may have been trying to maximize total payment or their hourly wage across multiple tasks on the Mechanical Turk website.

42.26, *12:00 pm* **Effects of Object Affordance in a Visual Search Task** Melanie Wulff[1] (mxw127@bham.ac.uk), Alexandra Stainton[1], Pia Rotshtein[1]; [1]School of Psychology, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK

Objects are perceived not only in terms of their visual properties, but also in terms of the potential actions which they can be used for, known as their 'affordances'. A remaining question is whether this action information is processed separately to object identification. The present study aimed to disentangle the coupling between affordance perception and object identification by means of a visual search task. Right-handed participants had to search for either two objects that can form an action pair (e.g., knife and fork) or two colour targets within a search array, whilst the semantic relation of the distracters and the congruency of the target pairs were manipulated. Accuracy was increased when the distracters were semantically related to the target pair and RTs were faster when the targets matched in colour. Surprisingly, participants were more accurate when the active object (i.e., the tool) was on the left side than when it was on the right side (normally the incongruent hand position for right-handed participants). In the action task and to a lesser extent in the colour task, participants chose the active object before the passive object suggesting that the active relative to the passive object has a higher attentional weight. Our data show that effects of object affordance also occur in a multiple search task. The effects of semantic relatedness and side of active object indicate that action retrieval is processed by two separate but interacting routes to action. We propose that functional relations between objects may have strengthened the effects of affordance. Our data further confirm the dual route account from vision-to-action.

Acknowledgement: This research was supported by a grant from the European Union FP 7 CogWatch Project (FP7-ICT-288912).

Monday AM

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Monday Morning Posters

Spatial Vision: Texture and image statistics

Monday, May 18, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

43.3001 Dimensions of Masking Measured by Constrained Natural Scene Sampling

Stephen Sebastian[1] (sebastian@utexas.edu), Jared Abrams[1], Wilson Geisler[1]; [1]Center for Perceptual Systems, University of Texas at Austin

An ultimate goal of vision science is to understand performance under natural conditions. We describe a direct experimental approach for identifying and quantifying the factors that affect detection performance in natural scenes. A large collection of calibrated natural images is divided into millions of background patches that are then sorted into narrow bins along the dimensions of interest. In the present study, each bin represents a particular (narrow range of) mean luminance, contrast, and similarity (phase-independent correlation of the background to the target). Next, detection thresholds are measured parametrically for a sparse subset of bins spanning the entire space. The psychometric function for each bin is measured by randomly sampling background patches from that bin, without replacement. Finally, we analyze the residual variation of the background patches within each bin for other factors that strongly correlate with the measured performance. We find that in the typical natural image amplitude thresholds vary by approximately two orders of magnitude. Further, threshold amplitude is a linear function of mean luminance (Weber's law for luminance), threshold power is a linear function of background contrast power (Weber's law for contrast), and threshold amplitude increases linearly with similarity once above a base level of similarity. We also find that the three dimensions combine systematically, in a fashion consistent with a mixture of separable and additive interactions. Finally, we identified another dimension, "contrast-contrast", that explains some of the residual variance in the thresholds: all else being equal, thresholds tend to be lower with higher variation of contrast within a patch. We argue that the results may form the foundation for a general model of detection in natural scenes. We also argue that this direct experimental approach should be applicable to other natural tasks, if a sufficiently large set of natural stimuli can be obtained.

Acknowledgement: NIH R01EY011747, NIH T32EY021462

43.3002 What is a clear picture? Human sensitivity to noise in naturalistic images.

Jasmine Patel[1,4] (jspatel2@uh.edu), Ramandeep Kaur[2], Bhavin Sheth[3,4]; [1]Department of Biomedical Engineering, University of Houston, [2]Department of Biology, University of Houston, [3]Department of Electrical and Computer Engineering, University of Houston, [4]Center for Neuro-Engineering and Cognitive Science, University of Houston

The visual world is full of noise: from smog to fog to static on a television. Even with noise obscuring our view, we are able to perceive the world and judge visual quality in real-time. How do we judge image quality, and what is it about an image that clues us into its quality? We set out to determine what features of images are utilized to judge quality of an image: we presented images (aerial shots, landscapes and medical images) with noise of varying level added to obscure either global ("diffuse" noise) or local ("sparse" noise) features of an image and naïve observers made a binary choice judgment on better image quality while the diffuse and sparse noisy versions were shown side-by-side. We analyzed each image for the values of various local and global visual features and compared human decisions with classification by a binary tree using these features. Features that aligned with human judgment based on high information gain ratio were determined to be features that observers used to render judgment. The psychophysical task provided data to the classifier: At low noise levels, observers preferred diffuse noise (aerials: 59%, p=0.136; landscapes: 67%, p=0.015; medicals: 73%, p=0.012); at intermediate noise levels, observer preference varied with image type (aerials: 99% diffuse, p< 0.0001; landscapes: 75% sparse, p< 0.0001; medicals: 53% diffuse, p=0.24); at high noise levels, observer preference shifted to sparse noise (aerials: 97%, p< 0.0001; landscapes: 93%, p< 0.0001; medicals: 94%, p< 0.0001). Decision tree analysis of psychophysical data showed clear alignment of local (e.g. local contrast) rather than global (e.g. RMS contrast, spectral power) image features with perceptual decisions across image type and noise level tested. Our results are in stark contrast to the accepted perspective that perceptual processing proceeds from global structuring towards more fine-grained, local analysis.

43.3003 Border ownership assignment in real images

Cornelia Fermuller[2] (fer@cfar.umd.edu), Ching Lik Teo[1], Yiannis Aloimonos[1]; [1]Computer Science Dept, University of Maryland, College Park, [2]UMIACS, University of Maryland, College Park

We explored whether spectral based cues, such as extremal edges, are useful for border ownership classification in real images, and we analyzed how different environments: indoor vs. outdoor affect the prediction. Our algorithmic approach is based on a random forest classifier using spectral and Gestalt-like texture grouping features. The classifier detects in real-time the points in the image, which are likely borders and assigns their border ownership.Training was achieved using annotated images. The spectral cues were obtained by performing a principal component analysis over clusters of edge patches, and then re projecting the input image using the top four principal components (PCs). Global relations were implemented using a novel semi-global Gestalt detector of closure, spiral, radial and hyperbolic patterns. Inference over a 481x321 image takes about 0.1s using commodity hardware in Matlab. The method was evaluated on a data set of outdoor images (BSDS-300) and a data set of indoor images (NYU-DepthV2). Testing over different feature ablations showed that spectral features are better ownership predictors on indoor images while Gestalt features are more useful for outdoor images. The PCs obtained from both datasets further show that the extremal edge cue is more dominant in indoor scenes: it was found as second PC in the indoor images and as third PC in the outdoor images. Combining all features yields 74% and 68% classification accuracy on BSDS-300 and NYU-DepthV2, respectively. Our algorithmic approach confirms the feasibility of computing border ownership using spectral and other information in single images, and it also provides a useful computational tool that can serve as preprocessing step for other geometric scene interpretation processes, such as image segmentation and 3D scene interpretation.

Acknowledgement: nsf INSPIRE grant SMA 1248056, EU Cognitive Systems grant Poeticon++

43.3004 Tilt Aftereffect due to Adaptation to Natural Images

Ron Dekel[1] (Ron.Dekel@weizmann.ac.il), Dov Sagi[1]; [1]Department of Neurobiology/brain research, Weizmann Institute of Science, Rehovot, Israel

Extended exposure to artificial stimuli of limited orientation content is known to result in a shift of perceived orientation away from the mode of the orientation distribution - the tilt aftereffect (TAE). Here we test the generality of this effect using unaltered natural images (N=127) depicting most of their orientation content at a particular orientation (25° clockwise to vertical), selected in a biased half-automatic manner from 10,000,000 images. Nine observers were repeatedly exposed to these images (until response, ~1100 ms, image classification task: animal vs plant), and performed target trials which determined perceived orientation (clockwise vs counter-clockwise of a near-vertical Gabor, duration=30 ms, contrast=0.11, σ=0.25°), randomly interleaved with image trials. Compared to a reference, perceived orientation obtained while being exposed to random natural images, a repeated exposure to images from the biased ensemble produced a steady repulsive TAE of ~1° (p< 0.001). TAE was strongest immediately after image exposure (lag1: 1.44°, ~1.5 sec), minimal on the following trial (lag2: 0.46°, ~3 sec), converging to an intermediate value (0.98°) on later trials. This modulation may reflect repulsive (lag1) and attractive (lag2) short-term TAEs, operating on different timescales. While the larger effect at lag1 clearly resulted from image exposure, it is not ruled out that the reduced effect at lag2 is due to sequential response dependencies. Interestingly, preceding target trials similarly modulated perceived orientation, showing small but significant repulsive TAEs after one trial (p=0.015), and attractive TAEs after two trials (p=0.016). Finally, for comparison, five observers were repeatedly exposed to synthetic adaptors instead of biased images (Gabor, ±25°, duration=1500 ms, contrast=0.27, σ=0.87°), which resulted in a similar repulsive TAE (~1.2°). In conclusion, perceived orientation is modulated by natural images as with synthetic adaptors. Repulsive and attractive TAEs seem to have different timescales.

Acknowledgement: BRF/ISF

43.3005 Evidence for Bound Scene Gist Representations: Statistical Summary Representations across Multiple Dimensions

Melissa Beck[1] (mbeck@lsu.edu), Rebecca Goldstein[1], Katherine Moen[1], Jesse Clifton[1]; [1]Psychology, Louisiana State University

Are statistical summary representations (SSRs) for multiple dimensions processed independently or are they part of a bound scene gist representation? Previous research suggests that multiple SSRs, the means for two sets of circles, can be computed with no cost (Chong & Treisman, 2005). However, there appears to be a cost for encoding averages from multiple dimensions. Emmanouil and Treisman (2008) presented participants with arrays of objects that varied on two dimensions and then either pre-cued or post-cued which average should be reported. Post-cue performance was lower than pre-cue performance, however the cost may have occurred during reporting rather than encoding. If a bound scene gist representation is stored, performance may be impaired when only one dimension is reported. In the current study, participants viewed arrays of 16 lines that varied in length, orientation, or both. Across four blocks of trials, participants were asked to adjust a test line to the (1) average orientation of a group of lines that varied only in orientation, (2) the average length of a group of lines that varied in only length, (3) the average length and orientation of a group of lines that varied in both, or (4) the average length or orientation (determined via a post cue) for a group of lines that varied in both dimensions. Orientation performance supported the bound gist representation hypothesis: Although there was a cost for reporting only orientation when both orientation and location were encoded (post-cue condition), encoding and reporting both was just as accurate as encoding and reporting only orientation. However, for length performance, encoding and reporting both resulted in greater errors than encoding and reporting length alone. These results suggest that all dimensions are not encoded equally; orientation and length may be encoded as a bound unit, while length may also be encoded independently.

43.3006 Statistics of retinal image blur during natural viewing

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Blur is determined by the geometry of the viewed scene, where in the scene the eye is focused, and the size of the pupil. Blur can provide useful information for discriminating distances (Held et al., 2012) and the scale of a scene (Held et al., 2010; Vishwanath & Blaser, 2010). But to make appropriate inferences about scene properties, the visual system needs statistical information about the relationship between blur, scenes, and fixations. We used a mobile eye-tracking and scene-tracking device to investigate this relationship during natural viewing. The device measured fixations and 3D scene layout while participants engaged in everyday activities. We reconstructed the distances to points in each scene from the eye and calculated the point-spread function for all positions in the central 20° of the visual field. The pattern of blur varies from one task to another, but is remarkably consistent between participants. A weighted combination of the patterns across tasks reveals the natural distribution of blur for each position in the visual field. There is a significant vertical gradient of blur, while the horizontal gradient much smaller. The magnitude of likely blurs in different field positions is reasonably consistent with the variation in blur discrimination capability across the visual field. These data reveal the prior distribution of blur as a function of field position and can be used in probabilistic models that infer depth from blur.

43.3007 The posterior part of area LO responds to image statistics, the anterior part to categorical differences.

H.Steven Scholte[1] (h.s.scholte@uva.nl), Ilja Sligte[1], Iris Groen[1], Sennay Ghebreab[2]; [1]Department of Psychology, University of Amsterdam, [2]Department of Informatics, University of Amsterdam

In the past we have shown that a substantial part of the early ERP responses and responses in early visual cortex up to area LO can be well understood on the basis of statistics derived from the distribution of contrasts in an image. One of these statistics, spatial coherency (Groen et al., 2013), describes images on the basis of a range from structured to Gaussian. Images on the structured side typically have a strong figure/ground segmentation often depict man-made scenes, images on the Gaussian side are fractionated and typically depict nature scenes or contain scrambled content. Here we explore to what degree we can understand responses in area LO and ventral cortex using such statistics. We ask the question whether responses are better understood using statistics related to the spatial structure of an image or whether they are better understood on the basis of a categorical contrast of for instance image vs. scrambled image. We show that activity in the posterior part of LO is better explained by the SC statistic, activity in the more anterior part of LO is better explained by the categorical contrast of image vs. scrambled.

43.3008 Cathodal trans-cranial Direct Current Stimulation (tDCS) modifies discrimination thresholds of the slope of the amplitude spectrum.

Bruno Richard[1] (bruno.richard@concordia.ca), Rebecca Birkett[1], Bruce Hansen[2], Aaron Johnson[1]; [1]Department of Psychology, Concordia University, [2]Department of Psychology and Neuroscience Program, Colgate University

When asked to determine perceived contrast in natural scenes, humans rely more heavily on a subset of spatial frequency bands around the peak of the CSF (Haun & Peli, 2013). Interestingly, the bands used by observers shift as a function of the global amplitude spectra of natural images: observers use lower spatial frequencies for natural images with steeper slopes ($\alpha>1$), and higher spatial frequencies for natural images with shallower slopes ($\alpha< 1$). We aimed to explore this effect further by directly manipulating slope discrimination thresholds to both steep and shallow slopes with trans-cranial Direct Current Stimulation (tDCS). tDCS is a neuro-stimulator that modulates the membrane potential of cortical neurons and alters their responses to visually presented stimuli. The effects of tDCS are spatial frequency dependent, and only modulate contrast perception to high spatial frequencies. Thus, if observers rely more heavily on contrast at high spatial frequencies when the amplitude spectrum slope of an image is shallow, cathodal-tDCS (c-tDCS) should decrease discrimination thresholds by increasing contrast sensitivity to high spatial frequencies. Conversely, anodal-tDCS (a-tDCS) should increase discrimination thresholds for shallow slopes. Discrimination thresholds to steeper slopes should remain unaffected by tDCS. Participants completed two stimulation sessions, and began with either a-tDCS or c-tDCS, while a third group received sham both sessions. The c-tDCS first group showed a decrease in discrimination threshold for shallow slopes (α = 0.4, 0.7), and interestingly, also showed an increase in discrimination thresholds for steeper slopes (α = 1, 1.3, 1.6). An increase in contrast sensitivity to high spatial frequencies may benefit slope discrimination for shallow slopes, and furthermore, may also impede slope discrimination for steeper slopes. Our results are concordant with a mechanism, biased in spatial frequency, which encodes contrast in natural scenes in accordance to the relative responses of spatial frequency channels.

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43.3009 An Edgy Image Statistic: Semi-Automated Edge Extraction and Fractal Box-Counting Algorithm Allows for Quantification of Edge Dimension In Natural Scenes

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Edges are significant, ubiquitous features of natural scenes. Basic properties of visual stimuli such as edges should be controlled for in experiments and reported in the literature. Currently, no commonly reported image statistics describe natural scenes' edges. An edge's fractal dimension (Df) could serve as a statistic that quantifies edge roughness in an image across scales. Researchers have often relied on hand tracing to isolate edges in natural scenes for box-counting, a Df measurement technique. For a typical experiment's stimulus set, this would be unfeasibly time consuming. To expedite the process, we developed an algorithm to isolate selected edges of a natural scene for fractal analysis. Our algorithm consists of a three-step manual component (select specific color channels and average their intensity maps, apply an intensity-based threshold, and choose a set of binary objects to retain) followed by a two-step automated component (draw the edges and perform a box-count). We implemented our algorithm in Matlab and applied it to 89 images of clouds. We found that clouds as viewed from the ground have mean Df=1.34 (SD=0.11). We also computed the slope (β) of the radially averaged power spectrum for each image to test for a relationship between Df and β. We found no significant correlation between Df and β ($r(89)=0.145$, $p=0.175$). This implies that an image's textures may be independent from the Df of the textures' borders. This distinction is important because β can be computed with full automation. While computing Df for natural image's objects' edges has been time-intensive, our algorithm allows for quick determination of this critical scene statistic. Df could be used characterize the roughness of edges in visually presented natural scene stimuli. Studying how multi-scale contours affect visual processing would complement the literature on the visual processing of texture.

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43.3010 Opposing effects of summary statistics on peripheral discrimination Corey Ziemba[1] (ziemba@cns.nyu.edu), Eero Simoncelli[1,2,3]; [1]Center for Neural Science, NYU, [2]Howard Hughes Medical Institute, [3]Courant Inst. of Mathematical Sciences

Many have proposed that peripheral vision operates by computing statistical summaries over local portions of the visual field, and that the loss of information associated with this process underlies the phenomenon of "crowding" (Parkes et. al. 2001; Pelli et. al. 2004; Greenwood et. al. 2009; Balas et. al. 2009; Freeman and Simoncelli, 2011). Here, we demonstrate another consequence of this hypothesis: that such statistical representation can either help or hinder visual discrimination performance depending on the observer's task. We created synthetic texture stimuli by matching a set of higher-order statistics measured from digitized photographs (Portilla and Simoncelli, 2001). The parameters include both the marginal statistics and pairwise correlations of the responses of V1-like filters selective for different spatial frequencies, orientations, and spatial positions. Observers were asked to discriminate stimuli presented simultaneously at three degrees eccentricity windowed within circular apertures. When stimuli differed in their statistics, performance increased with increasing patch diameter. This is expected since the parameters of the model converge to different values as the patch size increases. Interestingly, when observers discriminated between different samples matched for the same parameter settings, performance decreased with patch diameter. As the statistics converge to their matching values with increasing patch diameter, subjects were no longer able to utilize the local cues that enable high performance at small patch sizes. These opposing behaviors are analogous to those found for discrimination of auditory textures as a function of temporal window duration (McDermott et al., 2013), and suggest a general processing strategy for sensory systems.

Acknowledgement: HHMI, EY22428

43.3011 Adaptation to texture reveals a local metric underlying perceived size and distance Rumi Hisakata[1,2,3], Shin'ya Nishida[2], Alan Johnston[3]; [1]Japan Society for the Promotion of Science (JSPS), [2]NTT Communication Science Laboratories, Nippon Telegraph and Telephone Corporation, [3]University College London, Division of Psychology and Language Sciences

How the visual system codes metric properties such as size and distance from the information present in the retinal image remains a puzzle. The degree of correlation in the firing of neurons can give some indication of receptive field separation but separation is not coded directly making judging the distance between points by integrating estimates of receptive field separation along a path between them problematic. We need a concept of local spatial scale to resolve this problem. Here we describe a novel and counterintuitive illusion that reveals an internal visual scale against which we determine the spatial properties of objects. In the experiment, observers adapted to dense dot texture and reported on the size of ring that was presented in the same location as the adapting texture as compared to a ring presented in an unadapted field. The perceived size of the ring shrank by approximately 15% after adaptation and the magnitude of the shrinkage depended on the density of texture. Furthermore, we found that this shrinkage not only occurred for geometric figures but also for the perceived distance between two dots. Counterintuitively, the shrinkage coincides with a reduction in apparent density of more sparse dot textures presented in the same adapted location. This new adaptation effect is difficult to explain on a texture or size channel model and shows that the human visual system has a malleable internal metric against which the spatial size or separation of objects is judged and this scale is influenced by adaptation to dense texture. As the underlying scale expands, as revealed though the expanding texture, the apparent size and distance of geometric objects appear compressed. Thus size is coded relative to the metric. This internal metric is an essential first step in processing the geometric properties objects.

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43.3012 Anchoring of "black" in texture discrimination Chien-Chung Chen[1] (c3chen@ntu.edu.tw), Charles Chubb[2]; [1]Department of Psychology, National Taiwan University, [2]Department of Cognitive Sciences, University of California, Irvine

The visual system is biased toward negative luminance contrast. In particular, texture discrimination performance is dominated by a "blackshot" mechanism that is sensitive to the lowest luminances in the image (Chubb et al. 2004, Vision Research). However, it is unclear whether the tuning of this mechanism is absolute (driven by luminance near black) or adaptive (driven by the lowest luminance in the current input). To investigate this issue, we used a task in which the participant strove to classify white noise textures according to whether the histogram on a given trial had higher or lower variance than the uniform histogram. There were five conditions, each of which used 9 luminances: (1) full gamut: stimuli included luminances from black to white; (2) high gamut: stimuli included luminances from dark gray to white; (3) low gamut: stimuli included luminances from black to light gray; (4) uninformative dark: stimuli included luminances from black to white with the proportions of the lowest two luminances fixed at 1/9 on each trial; and (5) uninformative bright: stimuli included luminances from black to white with the proportions of the highest two luminances fixed at 1/9 on each trial. The threshold histogram differences for the full, low and high gamut textures were similar, and the estimated sensitivity functions, scaled by luminance range, were identical, despite the fact that the mean luminance of the high gamut double that of the low gamut. The observer had difficulty in discriminating uninformative dark pattern with a 2-fold increase in modulation threshold. Our results suggest that the tuning of the blackshot mechanism is adaptive, not absolute: the observers' judgments are anchored to the lowest luminance in the image, not to black.

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43.3013 Detection of Orientation-Defined Boundaries is Just as Inefficient as Estimation of Mean Orientation Joshua Solomon[1] (J.A.Solomon@city.ac.uk), Michael Morgan[1,2]; [1]Centre for Applied Vision Sciences, City University London, [2]Max-Planck Institute for Metabolism

When compared with other summary statistics (mean size, size variance, orientation variance), visual estimates of average orientation are inefficient. Observers act as if they use information from no more than two or three items. We hypothesised that observers would attain greater sampling efficiency when their task did not require an explicit representation of mean orientation. To test this hypothesis, we presented two arrays of 32 Gabor patterns each; one left and one right of fixation. Orientations in the target array were sampled from Wrapped Normal distributions having two different means. One distribution defined orientations above the horizontal meridian, the other defined orientations below the meridian. All orientations in the other array were defined by a single Wrapped Normal distribution having the same variance. Contrary to our hypothesis, model fits indicate that observers effectively ignored all but one item from the top and bottom of each array. In fact, we found no change in the threshold difference between the target's two means when all but one item from the top and bottom of each array were removed. We are forced to conclude that the visual system does not compute the average of more than a few orientations, even for texture segmentation.

43.3014 Approximately uniform isodiscrimination contours within a perceptual space of local image statistics Mary Conte[1] (mmconte@med.cornell.edu), Syed Rizvi[1], Jonathan Victor[1]; [1]Brain & Mind Research Institute, Weill Cornell Medical College

Analysis of image statistics is crucial to segmenting a visual scene and characterizing its components. Disentangling the computations used for this analysis is challenging, as image statistics form a high-dimensional domain in which edges, corners, and other local features of natural scenes interact in a complex fashion. We therefore developed a reduced space of synthetic images in which these features can be varied independently. This space consists of binary (black-and-white) images, parameterized by the configurations within 2x2 neighborhoods. Its 10 dimensions capture many of the image statistics that are informative in natural images (Tkačik et al., 2010). Previously (Victor et al., VSS 2013) we showed that at the origin of the space (i.e., for discrimination from randomness), threshold judgments implied a simple combination rule for image statistics: they combined in a quadratic fashion, generating ellipsoidal isodiscrimination contours. Here, we extend this analysis to the periphery of the space and show that the result generalizes. To measure discrimination thresholds, we used a segmentation paradigm. Stimuli consisted of 64x64 arrays of 14-min checks, containing a 16x64 target in one of four locations. Target and background were each defined by structured binary textures, with one chosen at a reference point in the periphery of the space and the other at a parametrically-varied distance from the reference. Thresholds were determined in N=4 subjects from Weibull fits to their psychometric functions. We found that the sizes and shapes of the isodiscrimination contours at peripheral points in the space were similar to the isodiscrimination contours determined, in parallel, at the origin. Thus, over the range tested, perceptual thresholds are determined primarily by the vector difference between image statistics. This simple and approximately Euclidean representation exists in parallel with a highly curved representation (Rizvi et al., VSS 2014) required to account for suprathreshold border saliences.

Acknowledgement: NIH EY07977

43.3015 The texture centroid paradigm: A new method for isolating preattentive visual mechanisms

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What are the basic image attributes sensed by human vision? This fundamental question has proved difficult to answer experimentally. We introduce a novel psychophysical method that provides leverage for addressing this question in the context of visual texture perception. On each trial, the participant sees a brief display comprising a randomly positioned set of circular apertures, each filled with texture. Some apertures contain a "distractor texture" D; others contain "target texture" T. The task of the participant is to mouse-click the centroid of the set of T-apertures, while ignoring the D-apertures. Suppose the participant performs this task using a separable linear computation: (1) computing a set of neural images corresponding to preattentive mechanisms, M_k; (2) combining these images into a weighted average image S (with nonnegative weights w_k); and (3) extracting the centroid of the resulting image. An ideal observer, that aims to minimize the Euclidean distance of the response from the target centroid, should choose the w_k to maximize S_T/S_D, where S_T and S_D are the weighted averages of mechanism responses to textures T and D, respectively. This ratio is maximized by assigning all the weight to the single mechanism M_k for which $M_k(T)/M_k(D)$ is largest. Thus, if a participant performs as well as possible in the centroid task, the resulting behavior reflects use of a single mechanism. We apply this method to white noise textures, varying the distributions of grayscale pixel values characterizing D and T in different conditions. Results implicate (1) a ''blackshot'' mechanism, sharply tuned to the blackest pixels; (2) a ''dark-gray" mechanism with maximal sensitivity for pixels between black and mid-gray, (3) a ''down-ramped'' mechanism whose sensitivity is maximal for black and decreases quasi-linearly with luminance, and (4) a complementary "up-ramped'' mechanism whose sensitivity increases linearly with luminance, with maximum sensitivity to white.

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43.3016 Lower in Contrast, Higher in Numerosity Estimation

Quan Lei[1] (lei.q@husky.neu.edu), Adam Reeves[1]; [1]Department of Psychology, Northeastern University

When equal numbers of gray disks and white disks are intermingled on a dark gray field, there appear to be more gray disks than white ones (Lei & Reeves, 2014). It is yet unclear whether this contrast-dependent illusion occurs only in a discrimination task where subjects have to pay attention to both gray and white disks in order to compare their numerosities. In this study subjects were asked to estimate the absolute numerosity of either gray or white disks intermingled on a dark gray field. In Experiment 1, subjects estimated the numerosity of gray disks (Gray trials) and white disks (White trials) in separate blocks. In each block, the irrelevant (not-to-be-reported) disks had a fixed numerosity of 50 and the relevant (to-be-reported) disks varied in numerosity between 20 and 80, in increments of 10. In Experiment 2, using the same stimuli, Gray trials and White trials were randomized, and subjects did not know which set of disks to estimate until they were given a prompt at the end of each trial. In Experiment 3, Gray trials and White trials were also randomized, but before the disks onset, subjects were cued as to which color to estimate on each trial by presenting either a gray or a white fixation cross. In all three experiments, the estimated numerosity was significantly larger for gray disks than that for white disks, at all numerosity levels. In a control experiment where both gray and white disks were presented alone, no difference in estimated numerosity was found. All these results are consistent with the discrimination data of Lei & Reeves (2014), as if the illusion arises from sensory interactions between intermingled stimuli of different contrasts prior to any cognitively-driven comparisons.

Eye Movements: Cognition and models

Monday, May 18, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

43.3017 The Effects of Task- and Switch-Predictability on Oculomotor Inhibition of Return During Visual Search

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Task-switching methods have long been used to study cognitive control processes but only recently have attempts been made to extend these methods to the study of oculomotor control processes. Nonetheless, preliminary examinations have demonstrated that oculomotor control processes are quite sensitive to changing task contexts, thus establishing the basic utility of task-switching methods for investigating oculomotor control processes. A recent study, for example, reported a general effect of task-switching on the expression of oculomotor inhibition-of-return (O-IOR) such that O-IOR was observed on task-repetition trials whereas facilitation-of-return (FOR) was observed on task-switch trials (Mills et al., VSS, 2014). From the perspective that O-IOR beneficially services search processes by biasing the eyes away from recently inspected locations and toward novel locations (Klein, 1998), the observation of FOR on task-switch trials represents a considerable cost to visual behavior for switching tasks. It would be instructive, therefore, to determine how the oculomotor system mitigates this cost. Behavioral studies of task-switching indicate that switch-costs can be markedly reduced and even eliminated if the schedule of a switch is predictable (Koch, 2005). The main goal of the present study, therefore, was to investigate effects of predictability on O-IOR switch-costs. Participants viewed scenes while either searching for a target 'N' or 'Z', memorizing the scene in preparation for a memory test, or evaluating scene pleasantness. The critical manipulations were Switch-Predictability (whether or not participants knew when a switch would occur) and Task-Predictability (whether or not participants knew on trial n which task to switch to on trial n+1). When participants were prepared for a task switch to search, their initial fixations were more efficient (e.g. less refixations and a greater degree of O-IOR) compared to when the switch-predictability and task-predictability was random.

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43.3018 Effects of task- and switch-predictability on task-switching during scene viewing

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Previous examinations of task-set and visual behavior indicate that viewing task influences saccade- and fixation-relevant parameters such as the rate of change in saccade amplitudes and fixation durations over time (Mills et al., 2011). Such demonstrations invite the possibility that gaze control parameters are task-relevant and potentially affected by task-switching. In support, recent work has demonstrated a general effect of task-switching on sequential dependencies between saccades (Dodd et al., VSS, 2014). Here, we investigate the possibility that gaze control settings may be represented and switched as part of a task-set. Participants viewed scenes while either searching for a target 'N' or 'Z', memorizing the scene in preparation for a memory test, or evaluating scene pleasantness. The critical manipulations were task-predictability (fixed or random task-order) and switch-predictability (fixed or random switch-schedule), yielding four conditions. In the Task-Predictable condition (fixed task-order, random switch-schedule), participants knew what task to switch to but not when to switch. In the Switch-Predictable condition (random task-order, fixed switch-schedule), participants knew on which trial to switch tasks but not which task they would be switching to. In the Both-Predictable condition (fixed task-order, fixed switch-schedule), participants knew what task to switch to and when to switch. Finally, in the Neither-Predictable condition (random task-order, random switch-schedule), participants did not know the task-order or switch-schedule. In each condition, gaze parameters showed stereotypic non-linear change whereby durations increased and amplitudes decreased, with change in both parameters reaching asymptote ~2-4 seconds into viewing. Importantly, in the Switch-Predictable condition there was no effect of task-switching on change in these parameters over time. This is in contrast to the Neither-Predictable and Task-Predictable conditions in which rates of change tended to be shallower on task-switch versus task-repeat trials. Thus, the effect of task-switching on gaze control parameters appears to depend on unpredictable task-switches.

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43.3019 Blinking by Surprise: Eye-Blink Rate and Latency Uncover Stimulus Predictability

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Background: Spontaneous eye-blinking is known to serve an important physiological function, but recent evidence show that it is also linked with cognitive processes. Here we show that the eye-blinks, although rare, are similar to microsaccades in their modulation pattern in response to transient perceptual events, including the temporal dependencies on preceding events, which uncover stimulus predictability. Method: During fixation observers (n=8) viewed and silently counted sequences of 100 randomly-ordered stimuli of two types, presented at 1Hz repetition-rate. These included small patches of contrast (high/low), color (red/blue) and audio-visual stimuli (beep/circle), with an additional go/no-go CPT experiment (n=22 observers, 20min-long, 0.5Hz-rate) on target position. Eye-tracking data were used to compute the average latencies of the blinks (if present) and their rate modulation following stimulus onset. Results: The overall blink-rate varied across observers and conditions (1-80% of trials, 20-60% on-average). Blinking was inhibited around stimulus onset in all conditions, with a pattern generally similar to that observed with microsaccades, including higher-magnitude and shorter-latency for higher contrast. For the audio-visual and CPT experiments, repetition (e.g. sound after a sequence of sounds) decreased the inhibition-rebound latency and magnitude, while change (e.g. sound after a sequence of visual-patches) increased them. The magnitude of these effects changed systematically with the number of preceding items (10-20ms per item, ~100ms total). The contrast experiment showed only a blink-rate increase for high-contrast patches preceded by low-contrast sequences. Conclusion: Eye-blinks, like microsaccades, obey a general pattern of oculomotor inhibition in a lawful and precise manner. This inhibitory pattern depends on stimulus saliency and in some cases on the relation between the current and preceding events, with higher-rate and delayed blinking for “surprise”, which we account for by a simple prediction-error model. Given the sparse and apparently imprecise pattern of blinking, reading the current findings might induce “blinking by surprise”.

43.3020 Characteristic visuomotor influences on eye-movement patterns to faces and other high level stimuli

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Eye-movement patterns are often utilized in studies of visual perception as indices of the specific information extracted to efficiently process a given stimulus during a given task. Our prior work, however, revealed that not only the stimulus and task influence eye-movements, but that visuomotor (start position) factors also robustly and characteristically influence eye-movement patterns to faces (Arizpe, et al, 2012). Here we manipulated lateral starting side and distance from the midline of face and line-symmetrical control (butterfly) stimuli in order to further investigate the nature and generality of such visuomotor influences. First we found that increasing starting distance from midline (4, 8, 12, 16 degrees visual angle) strongly and proportionately increased the distance of the first ordinal fixation from midline. We did not find influences of starting distance on subsequent fixations, however, suggesting that eye-movement plans are not strongly affected by starting distance following an initial orienting fixation. Further, we replicated our prior effect of starting side (left, right) to induce a spatially contralateral tendency of fixations after the first ordinal fixation. However, we also established that these visuomotor influences did not depend upon the predictability of the location of the upcoming stimulus, and were present not only for face stimuli but also for our control stimulus category (butterflies). Finally, for faces, we found a relationship between left starting side (right sided fixation pattern tendency) and increased recognition performance, which likely reflects a cortical right hemisphere (left visual hemifield) advantage for face perception.

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43.3021 Mapping and Correcting the Influence of Gaze Position on Pupil Size Measurements

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Pupil size is correlated with important cognitive variables and is increasingly being used to study cognition. Pupil data can be recorded inexpensively and non-invasively by many commonly used video-based eye tracking cameras, but researchers often underestimate the methodological challenges associated with controlling for confounds that can result in misinterpretation of their pupil data. One serious confound that often is not properly controlled is pupil foreshortening error (PFE)—the foreshortening of the pupil image as the eye rotates away from the camera. Here we report two studies. The first study formally established a strong ratio scale between the “arbitrary” pupil units reported by the EyeLink 1000 eye tracker and known physical units. The second study systematically mapped PFE as a function of gaze position using an artificial eye model and then applied a geometric model correction. Data were collected across 3 experimental layouts of the eye tracking camera and display using 3 spherical artificial eyes with different fixed pupil diameters. The 9 resulting maps showed large PFE that increased as a monotonic function of the oblique angle between the eye-to-camera axis and the eye-to-target axis and was invariant across the 3 different artificial eye pupil diameters. The measured PFE was corrected using a geometric model that expressed the foreshortening of the pupil area as a function of the cosine of the angle between the eye-to-camera axis and the eye-to-target axis. The model reduced the root mean squared error of pupil measurements by 82.5% when the model parameters were pre-set to the physical layout dimensions, and by 97.5% when they were optimized to fit the empirical error surface. Our data and correction procedure provide an unprecedented reduction in PFE while preserving the freedom to study tasks such as reading or visual search that involve free viewing of the display.

Acknowledgement: National Eye Institute

43.3022 Target Detection in Visual Search: Unravelling the Pupillary Response

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Pupillometry, the measurement of pupil size, is a technique used widely in psychological research to infer arousal, cognitive effort and processing load in various observer settings. Specifically, pupil dilation has been linked to increased effort in extended visual search (Porter, Troscianko & Gilchrist, 2007) and with the detection of targets in rapid serial visual presentation (Privetera et al., 2010). Whether pupil dilations elicited by target detection during visual search can be resolved against the backdrop effects of search-induced effort is a question of current interest. We sought to addresses this question with a novel signal-detection-style brief visual search paradigm. Pupil size was recorded as participants searched for a feature-distinct target item in arrays of similar items, responding either ‘target present’ or ‘target absent’ for each trial. Targets were presented briefly at the centre of the screen and participants were asked to maintain central fixation, which minimised eye movements and the pupil-size measurement errors they cause. The factor levels Target (present vs. absent) and Set Size (6 vs. 12) combined in equal parts to make four conditions. Overall, reaction times (RTs) were greater for target-absent trials. Pop-out search effects for target-present trials were evidenced by near-identical RTs for the two set sizes, whereas a marked difference in RTs for target-absent trials suggested that greater effort was required to arrive at the correct response for the larger set sizes. Despite the pop-out search effects on target-present trials and the greater effort required for target-absent searches, pupil dilation was consistently greater when a target was present. These results suggest that pupil dilations resulting from target detection could be reliably separable from the background effects caused effort during visual search.

43.3023 Objects in the peripheral visual field influence gaze location in natural vision

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In everyday behavior there are multiple competing demands for gaze; for instance, walking along a sidewalk requires paying attention to the path while avoiding other pedestrians. Therefore, humans make numerous fixations to satisfy their behavioral goals. One attempt to explore suitable strategies of gaze allocation for natural situations was made by Sprague, Ballard and Robinson (2007), whose computational model predicts human visuo-motor behavior based on intrinsic reward and uncertainty. Their model presupposes that specific visual information is acquired from the currently fixated object only. However, evidence that peripheral objects affect gaze position by drawing it towards the center of gravity of target ensembles (Findlay, 1982; Vishwanath & Kowler, 2003) challenges this premise. Since the influence of peripheral information for natural vision remains largely unexplored, we investigated whether gaze targeting is biased towards peripheral objects in naturalistic tasks. Using a Virtual Reality environment, the fixations of 12 participants were examined while they walked through a virtual room with objects of two different colors that were designated targets or obstacles. The subjects were instructed to either collect targets, to avoid obstacles or to do both tasks simultaneously. For situations in which one of two visible objects was fixated, subjects’ gaze positions were biased more often towards the non-fixated object (72.6%) than away from it (27.4%). Moreover, the gaze position tended to be drawn more frequently towards the neighboring object

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when this neighbor was relevant to the current task than when it was task-irrelevant. These results indicate that information from peripheral objects affect human gaze targeting in natural vision. Furthermore, the effect of the neighbor's task-relevance - and therefore of intrinsic reward - suggests that in a given fixation subjects might gather information from the peripheral visual field to accomplish a current set of goals at once.

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43.3024 Modeling Task Control of Gaze Matthew Tong[1] (mhtong@utexas.edu), Shun Zhang[2], Leif Johnson[2], Dana Ballard[2], Mary Hayhoe[1]; [1]Center for Perceptual Systems, University of Texas at Austin, [2]Department of Computer Science, University of Texas at Austin

Natural behavior involves sequences of gaze changes that serve behavioral goals. A body of evidence suggests that eye-movement targeting is controlled by a priority map that is influenced by the stimulus and a variety of top down factors, including subjective value. However, it is not known how such maps evolve over time to guide attention and gaze from one target to the next. We take the approach of decomposing behavior into a sequence of sub-tasks, where gaze is allocated to gather specific information for a sub-task, such as location of an obstacle to be avoided. We examined behavior in a virtual environment where subjects walk along a path, collect targets, and avoid obstacles. We manipulated relative importance of the tasks using different instructions, and manipulated uncertainty about object location by adding random motion to the objects (Tong & Hayhoe, 2013). We adapted a soft barrier model previously developed by Johnson et al (2014). This model is similar to a random walk, with two parameters that reflect the rate of growth of uncertainty and the priority of a particular sub-task. Different sub-tasks compete for gaze, and a location is likely to be chosen as a gaze target if it important and its location is very uncertain. We used estimates of the priority values that were consistent with subjective values of different sub-tasks recovered from walking behavior using Inverse Reinforcement Learning, and estimated the growth of uncertainty over time. We were able to predict the proportion of time spent on the path, obstacles, and targets in the environment, as well as the effect of added uncertainty about object location. This supports the claim that, in natural behavior, the next target for gaze is determined by both the subjective value of the behavior, and by its information needs.

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43.3025 Visual updating across saccades by working memory integration Leonie Oostwoud Wijdenes[1] (l.wijdenes@ucl.ac.uk), Louise Marshall[1], Paul Bays[1,2]; [1]Sobell Department of Motor Neuroscience and Movement Disorder, Institute of Neurology, University College London, United Kingdom, [2]Institute of Cognitive and Brain Sciences, University of California Berkeley, USA

We explore the visual world through saccadic eye movements, but saccades also present a challenge to visual processing, by shifting externally-stable objects from one retinal location to another. The brain could solve this problem in two ways: by overwriting preceding input and starting afresh with each new fixation, or by storing a representation of presaccadic visual features in memory and updating it with new information from the spatiotopically-matched location. When multiple objects are present in a scene, the planning of eye movements profoundly alters the precision of their working memory representations, transferring memory resources from fixation toward the saccadic target. Here we show that enacting a saccade updates not only the precision of representations but also their contents. When multiple item colours are shifted imperceptibly during a saccade, the perceived colours are found to fall between pre- and post-saccadic values, with the weight given to each input varying continuously with item location, and fixed relative to saccade parameters. Increasing sensory uncertainty, by adding colour noise, biases updating towards the more reliable input, consistent with an optimal integration of pre-saccadic working memory with a post-saccadic update signal. We recover this update signal and show it to be tightly-focused on the vicinity of the saccade target. These results reveal how the nervous system accumulates detailed visual information from multiple views of the same object or scene.

Acknowledgement: Wellcome Trust

43.3026 Reward associations slow the release of visual fixation Jane Raymond[1] (j.raymond@bham.ac.uk), Sandra Murphy[1]; [1]School of Psychology, University of Birmingham

When rapid orienting to brief visual targets is reliably rewarded, associations between targets (cues) and orienting responses become established via learning processes. An important question is whether such learning is limited to the specific stimulus-response associations acquired during learning or is more abstract, allowing modulation of other oculomotor behaviours not specifically reinforced during learning. To investigate, we briefly (250 ms) presented three different Japanese letters (hiragana) in pairs and differentially reinforced choice; different items led to a monetary win, loss, or nothing. Half of participants (n = 24) were asked to choose the optimal hiragana; others actively rejected the non-optimal item, thus learning different cue-response associations but the same cue-value associations. After learning, each hiragana served as a fixation stimulus in a simple saccadic reaction time (SRT) task requiring speeded saccades to a left or right peripheral (4 deg) dot target (no rewards provided). Fixation stimuli either remained visible for 200 ms after the target appeared (overlap condition) or offset 200 ms prior to the target's appearance (gap condition). SRTs are typically slower in the overlap versus gap conditions because fixation stimuli activate inhibitory 'fixation neurons' in the superior colliculus that prevent reflexive saccades during fixation. If learning builds cue-value associations (not just cue-response associations) and thus makes items more attractive, then SRTs should be slower in the overlap condition when the fixation stimulus is win (versus loss or zero) associated regardless of the task used during learning. Indeed, SRTs for both groups were significantly slowed (by 27 ms) with win versus zero (or loss) fixation stimuli in the overlap condition; no value effects in the gap condition were found, ruling out a strategic account. These results show that fixation neurons can be modulated by prior value-learning, and that cue-value associations can influence oculomotor behaviours not specifically reinforced during learning.

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43.3027 Motor preparation and attentional benefits: dependencies on the number of possible saccade targets Michael Puntiroli[1] (michael.puntiroli@unige.ch), Dirk Kerzel[1], Sabine Born[1,2]; [1]Faculté de Psychologie et des Sciences de l'Education, Université de Genève, Switzerland, [2]Laboratoire Psychologie de la Perception, Université Paris Descartes, France

Growing evidence suggests movements are prepared through widespread and complex modulation in multiple brain centers, where inhibitory components assure execution is not triggered prematurely (Cohen, Sherman, Zinger, Perlmutter & Prut, 2010). It has been suggested that preparing an eye movement towards few possible targets, compared to many, results in longer latencies because of the activation of these inhibitory components (Lawrence, John, Abrams & Snyder, 2008). In contrast, Belopolsky & Theeuwes (2009) suggest that attending to a location that has a high probability of being a saccade target, because of only few available options, results in the activation of the oculomotor system and facilitation. Our goal was to clarify this discrepancy and to measure attention at object locations when saccade target alternatives were few or many. While the total number of presented stimuli was kept constant (twelve circles), the saccade target could be at only two possible circle locations in the few alternatives condition, while the many alternatives condition featured six options. We employed a dual-task paradigm, primarily requiring the rapid execution of saccades to the only circle that became the target colour. The secondary task was to discriminate an asymmetric cross flashed at one of the circles. Our results show that slower saccade initiation is found when the possible saccade targets are two, indeed suggesting inhibitory motor components may be at play. However, the discrimination scores show that perception at the saccade target and the (never fixated) alternative saccade target were both facilitated compared to an attended control location. This suggests motor suppression may not necessarily affect perception. Recently Dhawan, Deubel & Jonikaitis (2013) showed that inhibition of saccades led to perceptual suppression, while in our study perception appeared unaffected. We put forward attention-based interpretations focusing on attentional window size and fuzzy loci leading to more stimulus-driven eye movements.

43.3028 Trans-saccadic prediction error re-calibrates perceived size in the peripheral visual field Matteo Valsecchi[1] (matteo.valsecchi@gmail.com), Karl Gegenfurtner[1]; [1]Department of Psychology, Justus-Liebig-University Giessen

Our visual world appears uniform despite the fact that the properties of our visual system change dramatically between foveal and peripheral vision. This might be explained by the fact that our visual system is able to predict the changes in sensory inputs associated with our eye movements and use potential prediction errors in order to maintain perceptual calibration. In a series of experiments we investigated whether the repeated exposure to a trans-saccadic change in the size of the object being foveated can lead to a change in its perceived size when viewed peripherally. In each trial, observers first compared the size of a centrally presented approximately circular stimulus (radius 1.65°) with a similar stimulus presented at the

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same time 20° in the peripheral visual field. The size of the peripheral stimulus varied between trials following an adaptive staircase. After the size judgment, the observers looked directly to the peripheral stimulus and performed a difficult shape discrimination. After 100 trials in which each observer´s baseline peripheral size PSE was established, a gaze-contingent change in the peripheral stimulus was introduced when the observers saccaded towards it (10% radius increase/decrease in separate groups, N=8+8). Over the following 400 trials the PSE decreased by around 8% in the decrease group, whereas it remained relatively constant in the increase group. Most observers did not notice the trans-saccadic change. In further experiments we found that the change in perceived size persisted when the observers were no longer required to saccade to the peripheral stimulus. If the trans-saccadic manipulation of the stimulus size was only experienced in one visual hemifield during training, its effect generalized to the opposite hemifield with similar gain. The results suggest that our impression of uniformity between central and peripheral vision is due to a constant and relatively quick process of sensori-motor re-calibration.

43.3029 Selective scanpath repetition supports memory-guided visual search

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Introduction: Visual stimulus repetition has been shown to improve processing efficiency and performance on recognition memory tasks. According to scanpath theory, memory-based repetition effects are mediated by repetition of the pattern of fixations or "scanpath" elicited during stimulus encoding at subsequent retrieval. However, it remains unclear how scanpath repetition supports efficiency gains on goal-directed tasks. Methods: The present study used eye-movement monitoring to test the predictions of scanpath theory against a memory-based visual search task. Younger and older subjects were instructed to find a changing target within a flickering naturalistic scene. Eye-movement search efficiency measures were compared across novel (V1) and repeated (V2) image viewings. A modified string-edit similarity measure was used to compare V1 and V2 scanpaths. Results: Younger adults searched more efficiently than older adults, indexed by both search time and number of fixations. An increase in search efficiency was observed for repeated images relative to novel images. This effect did not differ by age. Time-binned scanpath similarity analysis revealed repetition of initial and final V1 fixations at V2, with older adults repeating more initial V1 fixations than young adults. Consistent with previous findings, early scanpath similarity correlated negatively with search time at test. However, similarity of V2 fixations to middle V1 fixations predicted poor search performance in young adults. Conclusion: We conclude that scanpath compression mediates increased search efficiency by selectively recapitulating encoding fixations that provide goal-relevant input. Subtle age differences in early scanpath repetition were additionally detected using these measures. Results support and extend theories of eye-movement-based repetition effects to account for efficiency gains on visual search as a function of goal-relevance and memory.

Acknowledgement: NSERC

43.3030 What can we learn from eye tracking data on 20,000 images?

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Since traditional gaze tracking requires specific hardware, gathering image saliency data is expensive, tedious, and slow. Therefore, existing saliency prediction datasets are orders-of-magnitude smaller than typical datasets for other computer vision recognition tasks. The small size of these datasets limits the potential for training data-hungry saliency prediction algorithms, and may lead to over-fitting in benchmark evaluation. To address this deficiency, we introduce a webcam-based gaze tracking system that supports large-scale, crowd-sourced eye tracking deployed on Amazon Mechanical Turk. By a combination of careful algorithm and gaming protocol design, our system obtains eye-tracking data for saliency prediction with the same accuracy as in-lab webcam-based eye tracking systems, with relatively low cost and little effort on the part of the researchers. Using this tool, we construct the iSUN database with gaze data collected from 227 participants for 20,000 natural images – to our knowledge the largest eye tracking dataset available to date. This large data pool enables us to address the central bias of Internet photos, by choosing a subset of data to produce a uniform sampling as a benchmark. It also enables us to design a simple yet powerful data-driven label transfer algorithm from the nearest neighbor image for saliency prediction. Empirical results show that this simple algorithm can produce good results that are visually close to ground truth, although the current version of the algorithm does not outperform state-of-the-art saliency models. This is because data collection on the iSUN database is still ongoing, so many of the nearest-neighbor images have fixations from only 1 or 2 observers, which does not give a complete, accurate ground-truth saliency map for that image. We will open-source our tool and provide a web server where researchers can upload their own images to get gaze-tracking results from AMTurk.

43.3031 Eye movement correlates of behavioral performance in a simulated guard duty task

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Eye movement patterns, including the pupillary response, have been shown to correlate with cognitive states such as mental workload or time-on-task fatigue. Likewise, these signals have been shown to directly correlate with behavior in both simple and complex tasks. In this study we explored the link between eye movement patterns and performance in a simulated guard duty task. Here, subjects viewed a sequence of photographs of individuals along with their corresponding identification card (ID) to determine the validity of each ID. The number of IDs awaiting verification randomly fluctuated during the task and was visually represented to the subject in the form of a dynamic queue to vary task load. Behavioral performance, EEG, gaze position and pupil diameter were measured continuously throughout the duration of the task. Using an established saccade detection algorithm, we were able to generate a number of features from the eye movement data. Through regression analysis, we found that both the length of the queue and reaction time were significantly correlated with eye movement features, including pupil diameter, saccade and blink frequency. In a similar fashion, we used Independent Component Analysis (ICA), combined with linear regression, to identify the EEG features most predictive of behavioral performance. Interestingly, a number of the most predictive EEG features were also eye movement related. In line with previous studies, our results demonstrate that a significant amount of task-relevant information can be extracted from patterns of eye movements.

43.3032 Eye movements to tool images are predicted by frequency of physical experience with the tool

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Images of manipulable objects, such as tools, attract attention. There has been recent suggestion that it is the 'graspable' handle rather than the functional end of action-relevant images that drives attentional capture. Further, the attentional advantage of tools over non-manipulable objects is thought to be attributable to the automatic recruitment of motor-related brain networks, perhaps as a result of previous physical experience with the object. Here we studied observers' eye-movements to tool images to determine what part of a tool is prioritized, and whether or not gaze patterns are influenced by the frequency of usage of the object. Observers viewed life-sized high-resolution color photographs of a variety of tools for 2 sec each, during which time they completed a speeded classification task. Eye-movements were recorded during the length of the stimulus presentation period. After the experiment subjects rated how frequently they used each item in everyday life –on a scale from daily to yearly. Surprisingly, eye-movements were overwhelmingly biased towards the functional end, rather than the handle of tools: initial fixations were directed to the functional end, and across the whole trial mean fixation duration was longer and the number of fixations greater within the tool's functional end than the handle. Subsequent regression analyses revealed that the more frequently a tool was used, the more prolonged was the first fixation within the functional end of the tool, and the fewer fixations were made during stimulus presentation. Taken together, these data suggest that it is the functional end of a tool (which specifies the type of action that a tool affords) rather than the handle (which is relevant for grasping and action execution) that attracts eye movements and attention. Critically, we show for the first time a strong predictive relationship between exploratory eye-movements and previous physical experience with manipulable objects.

43.3033 iMap 4: An Open Source Toolbox for the Statistical Fixation Mapping of Eye Movement data with Linear Mixed Modeling

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A major challenge in modern eye movement research is to statistically map where observers are looking at, as well as isolating statistical significant differences between groups and conditions. Compared to signals of contemporary neuroscience measures, such as M/EEG and fMRI, eye movement data are sparse with much larger variations across trials and participants. As a result, the implementation of a conventional Hierarchical Linear Model approach on two-dimensional fixation distributions often returns unstable estimations and underpowered results, leaving this statistical problem unresolved. Here, we tackled this issue by using the statistical framework implemented in diverse state-of-the-art neuroimaging data processing toolboxes: Statistical Parametric Mapping (SPM), Fieldtrip and LIMO EEG. We first estimated the mean individual fixation maps per condition by using trimmean to account for the sparseness and the high variations of fixation data. We then applied a univariate, pixel-wise linear mixed model (LMM) on the smoothed fixation data with each subject as a random effect, which offers the flexibility to code for multiple between- and within-subject comparisons. After this step, our approach allows to perform all the possible linear contrasts for the fixed effects (main effects, interactions, etc.). Importantly, we also introduced a novel spatial cluster test based on bootstrapping to assess the statistical significance of the linear contrasts. Finally, we validated this approach by using both experimental and computer simulation data with a Monte Carlo approach. iMap 4 is a freely available MATLAB open source toolbox for the statistical fixation mapping of eye movement data, with a user-friendly interface providing straightforward, easy to interpret statistical graphical outputs and matching the standards in robust statistical neuroimaging methods. iMap 4 represents a major step in the processing of eye movement fixation data, paving the way to a routine use of robust data-driven analyses in this important field of vision sciences.

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Development: Typical develoment and aging

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Poster Session, Banyan Breezeway

43.3034 Three-month-old infants' sensitivity to horizontal information within faces

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Horizontal information is crucial to face processing in adults (Goffaux & Dakin, 2010). Yet the ontogeny of this preferential type of processing remains unknown. To clarify this issue, we tested 2 groups of 16 3-month-old infants in a preferential looking paradigm with upright (Group 1) or inverted (Group 2) stimuli. Each infant was exposed to 4 x 2 (left/right position of the face counterbalanced) 15-second trial consisting in the simultaneous side-by-side presentation of a full-front female face and of a full-front car, either unfiltered (UNF) or filtered in order to selectively reveal horizontal (H), vertical (V), or both orientation bands (HV) (Figure 1). As previously suggested, 3-month-old infants looked longer at upright and richer stimuli (UNF and HV) than to inverted and poorer stimuli (H and V). At upright orientation, there was also a significant interaction between the stimulus category (face/car) and the filter type (UNF, H, V, HV) revealing that, at this early age, infants looked longer at the face than at the car stimulus when horizontal information was preserved and when it was combined to vertical information (H and HV). At inverted orientation, the same interaction did not reach significance. These results suggest that horizontal information drives face processing during infancy, as it does at adulthood, and emphasize the predominant role of this band of information in the refinement of the face processing system with age.

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43.3035 Visual exploration and discrimination of emotional facial expressions in 3-, 7- and 12-month-old infants

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(* These authors contributed equally to the research) The first year of life is critical in the development of the abilities to process facial expressions. Numerous studies have investigated discrimination and categorization of distinct facial expressions of emotion. However, infants' visual exploratory strategies of these facial expressions and their developmental paths remain unclear. The perfection of eye movement tracking systems makes now the detailed analysis of facial exploration of faces feasible, and hence facilitates the identification of the features in facial expressions which infants focus on. In this study, oculometric parameters of 3- (n=36), 7- (n=66) and 12-month-old infants (n=59) were collected while facial expressions were displayed to them. Infants were consecutively exposed to 6 x 2 (randomized direct/averted gaze) 6-second trials consisting in the presentation of a full-front female or male avatar face expressing anger, disgust, fear, joy, sadness or neutrality. Results indicate a significant main effect of age on visual exploration: while 3-month-olds spent most of their time exploring eyes and external traits, 7- and 12-month-olds explored significantly less the external traits and focused more on mouth and nose. Further, the avatars' facial expressions had no effect on 3-month-olds' visual exploration; as compared to the 7- and 12-month-olds who differentially explored distinctive facial features depending on the facially-displayed emotion. In conclusion, our data suggest that, along the first year, infants' visual exploration gradually develops to focus on relevant internal features, with differentiated attention to critical facial features depending on the emotion displayed.

43.3036 Cues For Accommodation and Vergence in Infancy and Early Childhood

T. Rowan Candy[1] (rcandy@indiana.edu), Erin Babinsky[2], Tawna Roberts[3], Vivian Manh[4], Eric Seemiller[1], Yifei Wu[1], Don Lyon[1]; [1]Optometry & Vision Science, Indiana University, [2]Universitat Pompeu Fabra, [3]Optometry, University of Houston, [4]Ophthalmology, University of Washington

Purpose: Focused binocular fixation on a target relies on a combination of accommodation and vergence oculomotor responses. These require recalibration during early development, as a result of changes in refractive error and increases in inter-pupillary distance (IPD). This study tracked the roles of blur and disparity cues in these motor responses during this period. Methods: 103 infants were followed from 3 months until 3 years of age. Their accommodation and vergence responses to a movie with naturalistic spatial amplitude spectra were recorded simultaneously using eccentric photorefraction and Purkinje image tracking (PowerRefractor, MCS). The target was moved repeatedly between 90 and 33cm and recordings were made in i) full cue binocular conditions (Bn), ii) the absence of disparity cues while occluding one eye with an IR filter (Oc), and iii) a reduced blur cue condition (Bl) (the image was covered with a lowpass spatial filter and masked with a Difference of Gaussian). Results: Changes in vergence and accommodation between the two viewing distances were computed for each condition. The ratio of vergence to accommodation was compared across the three conditions. Relative to the full cue Bn baseline, the ratio in the absence of disparity (Oc) was reduced at all ages ($F = 0.22$, $p=0.80$), suggesting that accommodative convergence is consistently low in early childhood. In contrast, the ratio in the Bl condition was lower in infancy and childhood than in adults ($F=4.78$, $p=0.02$), suggesting convergence accommodation is higher during early development. Conclusions: The results suggest that vergence driven by cues other than disparity remains low in early childhood, while accommodation driven by cues other than blur is increased. This relationship is theoretically beneficial during the developmental period when accommodative demand is typically high due to hyperopia and vergence demand is low due to the narrow IPD.

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43.3037 Evolutionary-based threat modulates perception of looming visual stimuli in human infants

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Research with both human and non-human primates suggests that the visual system exhibits specialized processing of evolutionary-based threats. Adult humans (Ohman & Mineka, 2001) and monkeys (Shibasaki & Kawai, 2009) detect images of snakes and spiders faster than neutral images during visual search. Moreover, human infants orient more quickly to a threatening compared to a non-threatening image, when presented with two images simultaneously (e.g., a snake and a flower). Taken together, these results suggest a perceptual bias for threat that exists prior to the development of overt fear and that may be innate in human development (LoBue

& DeLoache, 2009). Yet differential orientating in infants and visual search paradigms typically used with adult humans and nonhuman primates are heavily dependent on contrast images; there are also influences of stimulus familiarity and strategic processes (Frischen, Eastwood, & Smilek, 2008), raising questions about the mechanisms underlying the perceptual basis of sensitivity to evolutionarily-based threats. The current study extends existing research by examining infants' defensive blinking in a visual looming paradigm. We tested 60 6- to 12- month-old infants. Infants were presented with images of snakes, spiders, rabbits, and butterflies. Each image loomed towards them, one at a time, at six velocities, creating different time-to-contacts (TTCs). As in previous studies (Kayed & van der Meer, 2000), analyses revealed that infants' blinks scaled according to TTC. We also found that defensive blinking was modulated by the threat value of stimuli. Infants blinked sooner to snakes and spiders compared to rabbits and butterflies at all TTCs (ps < .05). Critically, this effect cannot be accounted for by familiarity, as infants looked longer overall to the non-threatening than threatening animals ($p < .05$). That infants' defensive blinks were modulated by the threat value of the animal provides evidence for specialized spatiotemporal perceptual processing of evolutionary-based threat.

43.3038 **Oculomotor response to radial optic flow in infancy** Elizabeth Nawrot[1] (nawrot@mnstate.edu), Mark Nawrot[2]; [1]Department of Psychology, Minnesota State University Moorhead, [2]Center for Visual and Cognitive Neuroscience, Department of Psychology, North Dakota State University

Research with infants has illustrated the development of adult-like smooth pursuit gain by five months-of-age and links this to the development of sensitivity to depth from motion parallax. Ocular following response eye movements to radial optic flow stimuli may also be an indicator of sensitivity to changes in depth. An expanding flow field elicits convergent eye movements while a contracting one elicits divergent eye movements. This response suggests the visual system is interpreting the radial flow as a change in depth. We measured the oculomotor response to radial optic flow in infants across the age range where smooth pursuit gain is developing. Vergence eye movements were elicited from 56 infants 8-20 weeks-of-age. The stimulus comprised a radial optic flow pattern that expanded or contracted across eight 400 msec trials. The order of the four expanding and four contracting trials was randomized and eye position was monitored with a Tobii X120 eye-tracker. We defined the threshold for a vergence eye movement as velocity greater than 0.3 deg/sec. The majority of infants produced vergence eye movements in response to the expanding and contracting trials with about half producing either a convergence or divergence response appropriate to the stimuli. Approximately one-quarter produced both convergence and divergence responses. However, there was no relationship between age and the presence/absence of the vergence response or its velocity. We did find a significant positive correlation between age and smooth pursuit gain in a subset of these infants as expected. It may be that the vergence response is already developing at the youngest age. Similar to research on infants' reactions to looming stimuli, these results suggest that sensitivity to depth from radial optic flow may develop very early.

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43.3039 **Infant-specific gaze patterns to the focus of a radial optic flow** Nobu Shirai[1] (nobu.shirai@gmail.com), Tomoko Imura[2]; [1]Department of Psychology, Faculty of Humanities, Niigata University, [2]Department of Information Systems, Niigata University of International and Information Studies

The focus of a radial optic flow serves as a cue for perceiving direction of locomotion (e.g. Gibson, 1950). Niemann et al. (1999) reported that when naive adult observers passively viewed a radial flow, they tended to gaze around the focus of the radial flow. We examined whether the similar gaze behavior is observed in young infants (4-6 months, N = 20) in the present study. In each experimental trial (duration = 10 second), we presented either an expansion or a contraction flow (35.3 degree x 26.4 degree) composed of 500 moving dots on a computer screen as a visual stimulus. The focus of a radial flow horizontally moved back and forth (temporal frequency = 0.2 Hz) between the right and left side of the screen (distance = 18.4 degree). Infants' gaze behaviors were recorded by an eye tracker (Tobii X120) during each trial, and a circular area of interest (subtended 9.2 degree) was set at around the focus of a radial flow. Two mean flow-speed conditions (5.8 degree/s and 11.6 degree/s) were adopted, thus there were four experimental conditions (expansion/contraciton vs. low/high speeds). Two trials were done for each experimental condition, so that each infant took part in a total of 8 trials. The result showed that the infants looked significantly longer around the focus of a contraction than that of an expansion. No significant effect of flow speed was observed. Additionally, our pilot study indicated naive adults looked significantly longer at the focus of an expansion than that of a contraction. These results suggest that gaze behaviors to radial optic flows are substantially different between adults and infants aged around 5 months, while similarly aged infants have fundamental abilities to detect the focus of a radial flow (e.g. Gilmore et al., 2004).

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43.3040 **Early development of Apparent Motion processing mechanisms** Francesca Pei[1,2] (fpei@stanford.edu), Anthony Norcia[1]; [1]Department of Psychology, Stanford University, [2]Autism Center at Packard Children's Hospital, Stanford

Direction selectivity is present in V1 of animal models near birth. Direction selective mechanisms in V1 have small receptive fields and they are thus unlikely to be able to support the processing of long-range apparent motion, which can be seen over distances that are much larger than the size of V1 receptive fields. Long-range apparent motion is thus likely to rely on extra-striate areas and these higher areas appear to be poorly developed in early infancy based on data from other motion-based marker tasks (Gilmore et al., 2007; Rosander et al., 2007; Hou et al., 2009). In order to asses the developmental status of long-range motion mechanisms, we measured Visual Evoked Potentials in 12 adults and 21 infants between 4 and 7 moths of age. Participants were presented arrays of grating patches displayed at different spatial displacements and temporal offsets so as to produce a vivid percept of "apparent" motion (tests) or the percept of flashing of simultaneous patches (controls). Two spatial separations of paired-flash targets were used; 0.25 wavelengths (short-range) or 3 wavelengths (long-range). To test for sensitivity to motion vs temporal change, we compared the linear prediction from two sequential flash responses (linear prediction for motion) with the actual response of the test condition and the linear prediction and actual response for two simultaneous flashes (control) both for long and short range separations. The magnitude of the additivity failure represents the strength of non-linear spatiotemporal interactions in the motion and flash conditions. These interactions were comparably strong for infants and adults at both separations for the flashing conditions, but were selectively reduced for the long-range motion condition. We can conclude that the mechanisms supporting long-range motion differentially immature at 4-7 months.

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43.3041 **Do infants have requirements for perceiving shadows?** Kazuki Sato[1,2] (a12.rrx5@g.chuo-u.ac.jp), So Kanazawa[3], Masami Yamaguchi[1]; [1]Department of Psychology, Chuo University, [2]Japan Society for the Promotion of Science, [3]Department of Psychology, Japan Women's University

The contrast polarity of shadows is a crucial factor for shadow perception. Cavanagh and Leclerc (1989) indicated two requirements for perceiving shadows: (i) shadows should be darker than non-shadow areas and (ii) the contrast polarity along borders of shadows should be consistent. We investigated whether the perception of shadows in 5- to 8-month-olds had satisfied these requirements. Previous studies showed that around 7-month-olds could perceive depth from attached and cast shadows (Granrud & Yonas, 1985; Yonas & Granrud, 2006). Hence, we hypothesized that the 7-month-olds can perceive shadows, meanwhile this perception has the same requirements as adults. We carried out two experiments to test this hypothesis. In Experiment 1, we tested whether infants could discriminate attached-shadow figures and cast-shadow figures which had a consistent contrast polarity firstly, and then tested the figures which had a reversed contrast polarity of shadow areas. The results showed that only 7- to 8-month-olds could discriminate attached- and cast-shadow figures not when the contrast polarity of shadow areas was reversed, but when the shadows were darker than background. In Experiment 2, we tested whether infants could detect the congruence between the shape of an object and its cast-shadow which had a consistent contrast polarity firstly, and then tested the figures which had an inconsistent contrast polarity by added white outlines to the shadow areas. The results showed that 7- to 8-month-olds could detect the incongruence between the shape of an object and its cast-shadow shape only when the contrast polarity along borders of shadows was consistent. In conclusion, we found that 7- to 8-month-olds possibly have two requirements for the perception of shadows as the same as adults.

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Monday AM

43.3042 **Visual Attention Differences in Caesarean versus Vaginally Delivered Infants** Audrey Wong Kee You[1] (audwky@yorku.ca), Scott Adler[1,2]; [1]York University, [2]Centre for Vision Research

Little is known about the role that the birth experience plays in brain and cognitive development. Recent research suggests that birth experience influences development of the somatosensory cortex, an area involved in spatial attention to sensory information. Whether there are attentional differences between infants who have different birth experiences as occurs for caesarean versus vaginal delivery, however, has never been investigated. This study explored whether differences in spatial attention occur in infants born by caesarean section versus vaginally. Three-month-old infants performed either a spatial cued task in which we measured the latency of their stimulus-driven reactive saccadic eye movements or a visual expectation task in which we measured both their level of cognitively-driven anticipatory and latency of stimulus-driven reactive saccades. The results show that caesarean delivered infants' stimulus-driven, reflexive attention is slowed relative to vaginally delivered infants', whereas their cognitively-driven, voluntary attention is unaffected. Thus, type of birth experience influences one form of infants' attention, and possibly any cognitive process that relies on spatial attention. This study also reveals that birth experience likely influences the initial state of brain functioning and, consequently, must be considered in our understanding of brain development.

43.3043 **The effects of aging on perception and cognition** Albulena Shaqiri[1] (albulena.shaqiri@epfl.ch), Aaron Clarke[1], Marina Kunchulia[2,3], Daniela Herzig[4], Karin Pilz[5], Michael Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, [2]Laboratory of Vision Physiology, Beritashvili Center of Experimental Biomedicine, Tbilisi, Georgia, [3]Institute of Cognitive Neurosciences, Agricultural University of Georgia, Tbilisi, Georgia , [4]Clienia, Psychiatric and Psychotherapy Clinic, Sirnach, Switzerland, [5]School of Psychology, University of Aberdeen, Scotland, UK

The developed world is aging faster than ever before. Even in the absence of neurodegenerative disease, aging affects all kinds of human functions including perception and cognition. In most perceptual studies, one paradigm is tested and it is usually found that older participants perform worse than younger participants. Implicitly, these results are taken as evidence that there is one aging factor for each individual determining his/her overall performance levels. Here, we show that visual and cognitive functions age differently. We tested 131 older participants (mean age 70 years old) and 108 younger participants (mean age 22 years old) in 14 perceptual tests (including motion perception, contrast and orientation sensitivity, biological motion perception) and in 4 cognitive tasks (MoCA, WCST, verbal fluency and digit span). Young participants performed better than older participants in almost all of the tests. However, within the older participants group, age did not predict performance, i.e., a participant could have good results in biological motion perception but poor results in orientation discrimination. It seems that there is not a single "aging" factor but many.

Acknowledgement: Velux Foundation

43.3044 **Global and local biases and biological motion processing in healthy ageing.** Hannah Agnew[1] (hannah.agnew@abdn.ac.uk), Louise Phillips[1], Karin Pilz[1]; [1]University of Aberdeen, School of Psychology

The ability to perceive biological motion has been shown to deteriorate with age and it has been shown previously that older adults rely more on the form than the local motion information when processing point-light walkers (Pilz et al., 2010, Vision Research). Recently, it has been suggested that biological motion processing in ageing is related to a form-based global processing bias (Insch et al., 2012, Psychology and Aging). Here, we investigated the relationship between older adults' advantage for form information when processing point-light actions and an age-related form-based global processing bias. In a first task, we asked older and younger adults to sequentially match three different point-light actions; normal actions that contained local motion and global form information, scrambled actions that contained primarily local motion information, and random-position actions that contained primarily global form information. In accordance with previous results, we found that both age groups performed best for normal actions, then random-positioned actions and performed worse for scrambled actions. In a second task, we investigated form-based global processing biases using the Navon task. Both age groups exhibited a global processing bias as they displayed faster RT's for global stimuli in comparison to local stimuli. Interestingly, older adults were found to be more accurate than younger adults in their responses to the Navon stimuli. However, the global processing bias in the Navon task did not correlate with the advantage of form information when processing point-light actions in both age groups. These results indicate that the advantage for form information when processing point-light actions and the form-based global processing bias in the Navon task do not rely on the same underlying processes, and suggest that there is no systematic relationship between the two types of visual task.

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43.3045 **Value-based modulation of saccadic control across adult lifespan** Jutta Billino[1] (jutta.billino@psychol.uni-giessen.de), Elena Hitzel[1], Sabine Margolf-Hackl[1], Karl Gegenfurtner[1]; [1]Department of Psychology, Justus-Liebig-University Giessen

There is a strong interest in understanding sensorimotor changes during ageing, and several studies have explored age effects on oculomotor control of saccades. Results from cognitive learning paradigms have suggested attenuated effects of value as well as increased sensitivity to negative outcomes in older subjects. We were interested in whether similar effects can be observed in saccadic regulation. We investigated prosaccades and antisaccades in 20 young subjects (M=28.2 years, range 22-38 years) and 28 senior subjects (M=67.0 years, range 60-80). Both saccadic tasks were presented randomly interleaved and a central cue indicated the specific task before each trial. We implemented three different value conditions. A neutral condition was used as a baseline from which we derived a latency criterion for each individual subject. Based on this criterion, subjects could either win money in a reward condition or lose money in a punishment condition. Corroborating previous findings, we found a profound increase with age for saccadic latencies in the neutral condition for prosaccades as well as for antisaccades. However, both age groups did not differ in the latency reduction we observed in the reward and punishment conditions. Young and senior subjects showed equivalent regulation of saccadic reaction times by expected value. Our results did not support differential efficiency of reward or punishment. They provide evidence that value-based modulation of saccadic control is preserved across adult lifespan.

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43.3046 **Characterizing Motion Parallax Depth Thresholds in Older Adults** Jessica Holmin[1] (jessica.holmin@my.ndsu.edu), Mark Nawrot[1]; [1]Center for Visual and Cognitive Neuroscience, North Dakota State University

Successful navigation in the world requires effective visuospatial processing. Unfortunately, older adults have many visuospatial deficits, which can have severe real-world consequences. One visuospatial process, depth from motion parallax (MP), has been largely unexplored in older adults. Unambiguous depth from MP requires intact retinal image motion processing and an extra-retinal pursuit eye movement signal. Both the motion and eye movement systems are affected by age. Given these deficits, it follows logically that sensitivity to MP may be affected in older adults, but no one has investigated this possibility. The current study characterizes depth from MP in older adults and explores whether age-related changes in the motion and pursuit systems affect depth perception from motion parallax. Stationary younger (18-35 years) and older (60-75 years) observers performed depth-phase judgments on random-dot motion parallax stimuli. The stimuli translated laterally at one of three velocities (2.3, 10.1, and 25 deg/sec), generating the necessary pursuit signal. Dots within the stimuli translated laterally (0.013-0.92 deg/sec), generating constituent retinal image motion. The MP depth threshold at each pursuit velocity was quantified using the motion/pursuit ratio, which takes into account image motion, pursuit signal, and viewing distance. In addition, observers performed an analogous motion perception threshold task to assess age-related changes in motion perception. Age-related changes in the pursuit system were assessed with a step-ramp pursuit task at the three velocities used in the motion parallax task. Older adults have higher motion parallax thresholds at all pursuit velocities, as well as higher motion thresholds and lower pursuit gain, especially at higher velocities. We conclude that the threshold limit for unambiguous depth from MP is affected by age. Decreased sensitivity to depth from MP is tied to age-related deficits in motion perception and pursuit eye movements, both of which are necessary for unambiguous depth from MP.

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 See page 3 for Abstract Numbering System

Temporal Processing

Monday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4001 Similarity of Low-Pass Filtered and Pixelated Images at Different Time Scales

Takeshi Suzuki[2] (dutsuki@src.ricoh.co.jp), Yannik Schelske[1], Tandra Ghose[3]; [1]Department of Computer Science, University of Kaiserslautern, Germany, [2]Ricoh Institute of Technology, Japan, [3]Department of Psychology, University of Kaiserslautern, Germany

In digital image editing, users perform editing operations on rasterized images. Depending on the resolution of their screen, these rasterized images appear to be pixelated, that is, individual pixels of the image are perceived as discrete units, thereby changing its spatial frequency spectrum. Changes in spatial frequency spectra on perception are usually investigated by low-/high-pass filtering. We studied to what degree are low-pass filtered images perceptually similar to pixelized images, in explicit (Experiment-1) and implicit (Experiment-2) tasks. For every base-image, we created one pixelized version (pixel-size corresponded to 1 deg of visual angle) and six levels of low-pass filtered images. For Experiment-1, 12 participants chose from six low-pass filtered images with increasing levels of blur, the one that appeared most similar to the pixelized version of the same image. The trials were not timed and 100 images from four categories (landscape with/without water, macro with human/non-human focal object) were used. For (long, unconstrained) inspection durations tested in Experiment-1, participants chose the least blurry image as most similar to the pixelized version. In Experiment-2, with 2IFC-task, 14 participants discriminated between low-pass filtered (three-levels) and pixelized versions of the same image, for three time-intervals (40ms, 70ms, 100ms). Discrimination performance was average over interval durations at 82.42% for the pixelized and the original base-image. It plateaued at about 70% for medium low-pass filtered and pixelated version. Accuracy increased with prolonged interval durations. For (short) inspection durations tested in Experiment-2, the pixelized image was perceptually most similar to the versions with greater blur. We conclude that results from studies of low-pass filtered images can be generalized to pixelized version for durations less than 100ms but not for the longer inspection durations that are usually used in digital photo-editing processes. Thus new studies with pixelized-images are required to study the perceptual process of digital photo-editing.

Acknowledgement: Marie Curie grant (CIG#293901) from the European Union awarded to Tandra Ghose

43.4002 Neuro-encryption: concealing perceptual targets in observer-dependent, experimentally controlled alpha phase patterns

Sasskia Bruers[1] (bruers@cerco.ups-tlse.fr), Rufin VanRullen[1]; [1]Centre de Recherche Cerveau et Cognition, Université de Toulouse UPS, CNRS-UMR 5549, Toulouse, France

Recent evidence suggests that visual perception is a rhythmic process: target detection undergoes periodic fluctuations at frequencies from 7 to 15Hz, and these rapid changes can be linked to the phase of ongoing brain oscillations. In turn, these oscillations are modulated by visual stimulation: for example, the impulse response function during a stream of random (white-noise) luminance changes includes a strong oscillatory component at ~10Hz akin to a perceptual echo. The phase, amplitude and duration of this 'echo function' are observer-specific. Thus, the same white-noise sequence produces markedly different but predictable patterns of oscillatory responses in different observers. We combined these observations to establish the feasibility of a 'neuro-encryption' system. We first recorded the EEG impulse response ('echo') function of each individual observer (N=9). In a separate session without EEG, we embedded threshold-intensity targets in streams of white-noise luminance fluctuations; all subjects viewed the same sequences with the same targets. For each observer, we used the previously-recorded echo function to estimate (by convolution with the white noise sequence) the oscillatory brain response around each target. We then compared oscillatory phase for detected and undetected targets, and found a significant opposition between them: around a certain phase the targets were more likely (by ~10%) to be detected than at the opposite phase. Importantly, this performance difference persisted when considering only trials for which two subjects had opposite phase estimates: the observer around the 'good' phase performed better (paired t-test, $p< 0.001$) than the one at the 'bad' phase, for the same target embedded in the same random sequence. In sum, for a given subject we can predict target detection in any random sequence, without concurrently recording brain signals. This augurs the possibility of creating stimulus sequences in which only one subject can perceive a target message, a form of 'neuro-encryption'.

Acknowledgement: We would like to acknowledge the support of the ERC Consolidator Grant P-CYCLES (614244).

43.4003 Decoding the temporal structure of perception and reflection

Scott Guerin[1] (scott.guerin@yale.edu), Stefan Uddenberg[1], Marcia Johnson[1], Chun Chun[1]; [1]Department of Psychology, Yale University

Perception has a clear temporal structure: each stimulus is preceded and followed by other stimuli. However, we may think about recently encountered stimuli in a temporal order that deviates from the perceptual input. How does the brain generate and maintain distinct representations of temporal structure associated with perception and reflection? In this experiment, we constructed a task that dissociates the temporal structure of perception and reflection. Participants viewed one face and one scene (2 s each) in one of two sequences: Face-Scene or Scene-Face. Following perception, participants were cued to direct their internal attention towards one then the other of the just-seen stimuli (refreshing, Johnson et al., 2005). Participants were instructed to imagine the picture as vividly as possible and answer a question about it (Male/Female or Indoor/Outdoor). Each refresh period lasted 2 s. On half the trials, participants refreshed the pictures in the same order they were perceived. On the other half of trials, participants refreshed the pictures in the reverse order. We applied multi-voxel pattern analysis to decode the temporal structure of perception and reflection. Based on an initial analysis of 12 participants, and consistent with our previous findings, we were able to decode the temporal structure of perception above chance in occipital, ventral temporal, and parietal cortices (all $p < .001$), with a trend in prefrontal cortex ($p = .06$). Critically, we were also able to decode the temporal structure of reflection in occipital, ventral temporal, parietal (all $p < .01$), and prefrontal cortices ($p < .05$). Consistent with previous studies indicating that perception and reflection share overlapping visual representations, our results indicate that perception and reflection share common neural machinery for the representation of temporal structure.

43.4004 Changes in temporal integration mitigate the disruptive effects of transcranial magnetic stimulation over visual cortex in humans

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Transcranial magnetic stimulation (TMS) has become a popular method for studying the functional properties, connectivity and chronometry of brain regions associated with visual encoding. However comparatively little is known about the precise mechanisms by which TMS influences on-going visual processing, though studies suggest it may suppress the processing of the signals associated with a task and/or induce increased levels of internal noise. To investigate this issue single-pulse TMS was applied over left-hemisphere V1 in eight observers during a forced-choice, orientation-identification task (horizontal vs. vertical) using a Gabor target (2 c/deg, centred 6 deg in the right visual field). Stimulus contrast was set to each observer's threshold, corresponding to 79% correct performance, measured in the absence of TMS. When TMS was applied over V1 performance decreased in all observers (~ 10% on average) compared to accuracy levels obtained during stimulation over a control site (Cz). Unexpectedly we found accuracy levels improved during V1 stimulation across a block of 200 trials in most (5/8) subjects, but remained stable during control site stimulation. Furthermore, no recovery was found when a brief, external, visual noise mask was used instead of a TMS pulse. These results show that the magnitude of TMS disruption can dissipate with repeated stimulation. To explore the potential mechanism underlying this recovery phenomenon we also measured the critical flicker fusion threshold (CFFT), using an LED driven by a square-wave temporal waveform of variable frequency, both prior to and following the same TMS protocol. For observers that previously exhibited TMS recovery, occipital simulation extended temporal integration periods by an average of 12% (by 3-8 ms). This suggests that the visual system can dynamically adapt to increased internal noise levels, by increasing the temporal interval over which visual stimuli are integrated, thus minimising the deleterious effects of TMS-induced cortical activity on sensory judgments.

43.4005 Time compression in an unadapted region after adaptation to a moving surround

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After adaptation to a rapidly moving grating, a drifting grating placed at the adapted region appears to last shorter than its actual duration ("adaptation-based time compression", Johnston et al 2006). This effect occurs retinotopically (Bruno et al 2010), though there might be some spatiotopic component as well (Burr et al 2007). The spatial tuning of this effect has been reported to have a narrow spatial window (Ayhan et al 2009), such that the effect of adaptation never transfers to unadapted locations in its vicinity. However, previous testing methods of spatial interactions should be revised so as to maximize potential effects of adaptation by overwhelming a test stimulus with a large enough adaptor completely surrounding the test region. To this end, we used a concentric configuration: centered at 8° eccentricity, a rapidly moving (10 Hz) sinusoidal adapting grating that alternated its direction every second occupied the annular region (outer diam 11.4°, inner 7.6°) for 32-s initial and 8-s top-up adaptation periods, each followed by a drifting (10 Hz) sinusoidal grating (diam 5.7°) presented as the test stimulus only within the central region for 0.6 s. In the opposite (left) hemifield, we also presented a reference stimulus, which was also a sinusoidal grating with the same parameters as the test except that the motion direction was opposite and that the duration was variable (0.3–0.9 s). Observers had to judge which stimulus lasted longer. Even though the test stimulus was located at a region with no former adaptation, we found a robust time compression (~10%), which was sometimes as strong as the effect obtained with retinotopic adaptation. Our results indicate some involvement of higher-order motion processing mechanisms that can deal with spatial interactions over a considerable space constant, although our findings do not necessarily refute the hypothesis of the magnocellular pathway's contribution.

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43.4006 **Perception of transient pattern at the transition between high-speed flickering stimuli** Yutaka Nakajima[1] (nakajima@hi.is.uec.ac.jp), Yutaka Sakaguchi[1]; [1]Laboratory for Human Informatics, Graduate School of Information Systems, The University of Electro-Communications

We found that a novel phenomenon on the high-speed (400 Hz) flickering stimuli that if the counterphase-flickering pattern (e.g. square-wave grating) is immediately switched to another flickering pattern, a luminance-averaged pattern around the time of transition can be stably perceived. The purpose of this study is to investigate the temporal property of this phenomenon. In the experiment, stimuli were presented at the center of the screen within a square region (2 x 2 deg) surrounded by a pseudo gray background (a 1-pixel checkerboard). Stimuli consisted of two rectangular flickering patterns: Uniform squares of black and white (FU) and counterphase-flickering horizontal/vertical square-wave gratings (FG). Flicker frequency was 400 Hz (i.e., frame duration was 1.25 ms), implemented by a high-speed DLP projector (LightCommander, TI Inc.). The stimuli were presented in order of FU, FG and FU without ISI. The duration of FU was fixed at 200 ms while that of FG was randomly selected from 9 durations (2.5 – 200 ms). Participants (n = 5) were asked to discriminate the orientation of the grating by 2-AFC in one experimental session, and to answer the perceived number of the gratings by 3-AFC (zero, one, or two) in the other session. The orientation discrimination performance was improved with longer FG duration, and average percent correct reached 75% around 10 ms. As for the perceived grating number, participants perceived no grating when FG duration was shorter than 10 ms, one grating with FG duration between 10 and 100 ms, and two gratings with FG duration longer than 100 ms. It suggests that the abrupt switch between 400-Hz flickering stimuli can be detected with a stable perception of a oriented pattern so long as two transitions do not occur within 10 ms and the pattern can be perceived at each transition with FG duration over 100 ms.

43.4007 **Continuous flash suppression effectiveness depends on mask temporal frequency** Weina Zhu[1,2] (zhuweina_xm@sina.com), Jan Drewes[2], David Melcher[2]; [1]School of Information Science, Yunnan University, China, [2]Center for Mind/Brain Sciences (CIMeC), University of Trento, Italy

A variant of binocular rivalry called Continuous Flash Suppression (CFS) (Tsuchiya & Koch, 2005) has become a popular tool for investigating visual processing outside of conscious awareness (Yang, Brascamp, Kang, & Blake, 2014). In a CFS paradigm, a series of different Mondrian patterns is flashed to one eye at a steady rate, suppressing awareness of the image presented to the other eye (Tsuchiya, Koch, Gilroy, & Blake, 2006). In most studies using CFS the temporal frequency for the mask images is set to 10 (Tsuchiya & Koch, 2005; Tsuchiya et al., 2006) or 20 (Jiang et al., 2009) Hz. To date, little is known about the precise relationship between masking effectiveness and temporal masking frequency. Given the role of temporal factors in many theories of visual awareness, such as phase coupling of neural oscillations across brain regions or re-entrant processing, we investigated the suppression effectiveness of a wide range of masking frequencies (0-32Hz). In a breakthrough CFS paradigm, participants reported whether an image (a face or house) was presented on each trial while Mondrian-like textures were presented as masks. In condition 1, trials with all different frequencies occurred in random order while in condition 2, trials with the same masking frequency were grouped in blocks. We found that the response times differed dramatically between temporal masking frequencies, with mask effectiveness following a log-normal curve peaking around 6Hz in both conditions. The static mask (0 Hz: traditional binocular rivalry) yielded similar breakthrough times as higher frequencies of CFS. In practical terms, these results show that, the 10 Hz/20 Hz frequencies used in most CFS studies may not be optimally effective. More generally, these findings support the idea that temporal factors play a critical role in perceptual awareness.

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43.4008 **Individual differences in the perception of time** Simon Cropper[1] (scropper@unimelb.edu.au), Alan Johnston[2], Christopher Groot[1]; [1]Melbourne School of Psychological Sciences, University of Melbourne, [2]Cognitive, Perceptual and Brain Sciences, University College London

The ability of subjects to identify and reproduce brief temporal intervals is influenced by many factors; stimulus-, task- or subject-based. The current study examines the role the individual's personality has upon their perception of short durations, and their metacognition of that percept. Undergraduate subjects (n=120) completed the OLIFE schizotypal personality questionnaire prior to performing a modified temporal-bisection task. In the task, subjects responded to two identical instantiations of a 4deg diameter sinusoidal grating, presented 4deg above fixation for 1.5secs in a rectangular temporal-envelope. They initiated presentation with a button-press, and released the button when they considered the stimulus to be half-way through (750msecs). Subjects were then asked to indicate their 'most accurate estimate' of the two intervals and given feedback for the latter half of the trials. The stimuli were either static or drifted, blocked into 100 stimulus pairs. From a group perspective there was a significant order effect whereby the first interval appeared to be shorter (and closer to veridical) than the second, although this effect reduced to insignificance when stimuli were drifted. Subjects had insight into their own performance, indicated by a reduced variance for the 'best estimate' compared to the 'worst' of the two; this difference increased with feedback. In terms of personality, the positive-psychotic subscales of the OLIFE were correlated with a reduced confidence in performance, but no actual performance difference, and a reduced ability to use feedback. Negative subscales only correlated with an increased ability to use the drift to improve performance. These data are explained in terms of an increased level of noise with increasing positive schizotypy having an effect upon precision rather than accuracy in the decision process. In a greater context, these data are also consistent with a fully-dimensional view of psychosis.

43.4009 **Metacognition of time perception** Brendan Keane[1] (b.keane1@uq.edu.au), Kielan Yarrow[2], Derek Arnold[1]; [1]Perception Lab, School of Psychology, The University of Queensland, [2]Department of Psychology, City University London

It has been demonstrated that people have insight into the accuracy of their own decision-making processes. This is evident from correlations between decisional confidence and objective task performance, and is often described as a form of metacognition, as it requires that the brain has formed an accurate reportable estimate of the precision with which it has encoded information. Metacognitive insight has been demonstrated for judgments concerning diverse visual properties, including orientation (de Gardelle & Mamassian, 2014), contrast discrimination (Fleming, Weil, Nagy, Dolan, & Rees, 2010), and direction (Ratcliff & Starns, 2013). Here we report that the human brain also forms reportable estimates of the precision with which it has encoded temporal relationships. We examined metacognitive insight into precision during a subjective timing task (audio-visual temporal order judgments), and into accuracy during an objective timing task (a three alternative audio-visual odd-one-out task varying audio-visual temporal offset). In both tasks we found that people expressed levels of confidence that were well correlated with performance. This cannot be attributed to low confidence on trials wherein people simply missed the stimulus presentation, or suffered a lapse in concentration, as participants were required to indicate when this happened, and such trials were repeated. Our data indicate that the human brain accurately estimates the precision with which it has encoded audio-visual timing relationships on a trial-by-trial basis.

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43.4010 **Affective distortions of temporal duration and resolution judgments** Kevin Roberts[1] (kevin.roberts@psych.ubc.ca), Rebecca Todd[1]; [1]Department of Psychology, University of British Columbia

The emotional relevance, or affective salience, of a stimulus is known to influence subjective time estimation. Paradigms typically used to measure such salience-driven distortions require the participant to judge stimulus duration. Yet these paradigms neglect to measure the temporal resolution of the moment-to-moment experience, and whether viewing affectively salient stimuli modulates visual sampling rate is not known. In two experiments we employed neutral, negative, and positive (approach-motivating) dessert images. First, to confirm previous findings we used these stimuli in a temporal bisection paradigm to assess affective distortion of stimulus duration judgment. Participants learned two standard durations, "short" (400 ms) and "long" (1600 ms). Subsequently, stimuli were presented for seven durations (400 to 1600 ms at 200 ms intervals) and were categorized by the participant as either "short" or "long". Stimulus durations for negative stimuli were judged as longer than for the other two stimulus types. Second, we used a novel experimental paradigm to test affective distortion of moment-to-moment subjective temporal perceptual experience. We hypothesized that negatively valenced salient stimuli would increase visual sampling rate relative to neutral stimuli, leading to greater acuity in detecting changes between frames. In this task, participants viewed a "standard" stimulus fading to black over a 2000 ms period at 48 frames per second, immediately followed by a "target" stimulus fading to black over a 2000 ms period at 24, 48, or 72 frames per second. Participants then rated the smoothness of the target stimulus fade, as compared to the standard, where judgments of the target as less smooth suggest more ease in distinguishing frames and thus increased visual sampling rate. Negative stimuli were judged as fading less smoothly than other stimulus categories. These results suggest that negatively valenced stimuli increase temporal sampling rate, indicating a possible mechanism underlying influence of affective salience on perceived duration.

43.4011 **Context-dependent neural modulations in the perception of duration, revealed by fMRI** Yuki Murai[1] (ymurai@fechner.c.u-tokyo.ac.jp), Yuko Yotsumoto[1]; [1]Department of Life Sciences, The University of Tokyo

Recent neuroimaging studies have revealed that two distinct brain networks are recruited in the perception of sub-second and supra-second durations. The aim of this study is to examine how intermediate duration between sub- and supra-second, that is, around one second duration, is processed in our brain. We hypothesized that durations around one second can be processed either by the sub-second system or by the supra-second system in a context-dependent matter; when the one-second stimuli are presented in the context of sub-second processing, the one-second stimuli would be processed by the sub-second system, and when they are presented in the context of supra-second processing, then, they would be processed by the supra-second system. To test our hypothesis, we measured neural correlates during the perception of duration by using functional magnetic resonance imaging (fMRI). Seventeen subjects were asked to reproduce durations of the visually presented stimuli by pressing a button. The stimulus duration was either sub-second, one-second, or supra-second. In half of the scans, trials of the one-second duration were intermixed with the trials of the sub-second durations, and in another half of the scans, trials of the one-second duration were intermixed with the trials of the supra-second durations. Firstly, we replicated previous studies by showing the separate neural networks recruited for the sub- and supra-second perceptions; visual cortex, premotor, SMA, and cerebellum for the sub-second perception, and insula and basal ganglia for the supra-second perception. Secondly, when one-second stimulus was presented with the sub-second stimulus, the visual cortex and cerebellum exhibited greater activations compared to when the stimulus was presented with the supra-second stimulus. The present results suggest that the durations around one-second could be processed either by the sub- and the supra- second system, and the visual cortex plays a part in such context-dependent modulations.

Color and Light: Surfaces, textures, and materials

Monday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4013 **Coupled computations of depth, material, and illumination** Barton Anderson[1] (barta@psych.usyd.edu.au), Phillip Marlow[1]; [1]School of Psychology, University of Sydney

There is currently extensive debate about how the visual system derives the material properties of surfaces. The majority of work has attempted to solve this problem by identifying features in the unprocessed images that provide diagnostic information about the material composition of surfaces. However, we previously showed that it is possible to induce transformations in perceived material properties by manipulating the bounding contours that border otherwise identical luminance gradients. Here, we show that manipulating either the motion parallax or stereoscopic depth of sparse dots can cause dramatic changes in the perceived material properties of surfaces containing identical image gradients. In one class of displays, we constructed a series of vertically modulated luminance gradients (which appear as a set of horizontal bands). An array of sparse dots was superimposed on the gradients, and their binocular disparity or velocity was varied in a manner consistent with one of two 3D surface geometries. When the surface geometry was consistent with a luminance gradient on a slowly curved surface illuminated along the viewing direction, the surface appeared strongly metallic; but when the surface geometry was consistent with a rapidly curving surface with grazing illumination, the surface appeared dull and matte. We also show that these results can be extended to doubly curved surfaces. Our results reveal that the visual system exploits internalized physical constraints that relate 3D surface geometry to the rate of change of luminance to compute the material properties of surfaces.

Acknowledgement: ARC

43.4014 **Brain processing of gloss information with 2D and 3D depth cues** Hua-Chun Sun[1] (hxs195@bham.ac.uk), Massimiliano Di Luca[1], Roland Fleming[2], Alexander Muryy[3], Hiroshi Ban[4], Andrew Welchman[5]; [1]School of Psychology, University of Birmingham, UK, [2]Department of Psychology, Justus-Liebig-Universität Gießen, Germany, [3]School of Psychology, University of Southampton, UK, [4]Center for Information and Neural Networks, National Institute of Information and Communications Technology, Osaka, Japan, [5]Department of Psychology, University of Cambridge, UK

Surface gloss information conveyed by image cues (i.e., highlights) has been shown to be processed in ventral and dorsal areas. In this study we used fMRI to distinguish the brain areas that selectively process 2D and 3D cues about surface gloss. We performed one experiment using 2D images of random objects with glossy surfaces where diffuse highlights could be presented rotated by 45 degree to make the object look matte. We also performed a second experiment with binocular cues where the specular reflections of the environmental on random shapes could have disparities coincident with the surface so to appear painted and thus making the object look matte. The same twelve participants took part in the two experiments where fMRI activations were measured over the whole brain with an Echo-Planar Imaging sequence (32 slices, TR 2000 ms, TE 35 ms, voxel size 2.5 × 2.5 × 3 mm). We performed Multi-Voxel Pattern Analysis to test whether a classifier trained to discriminate glossy vs. matte objects with 2D cues can still discriminate with 3D cues, and vice versa. We found transfer effects from 2D to 3D cues in early (V1, V2) and dorsal visual areas (V3d, V3A/B, V7, IPS). This transfer suggests the presence of circuits processing gloss independently of the type of cues in dorsal areas only. We did not find transfer from training with 3D cues to 2D cues, suggesting that stereoscopic information related to gloss has a pattern of activation that is additional to the representation of gloss.

43.4015 **Appearance of 'gold' affects glossiness and metallicity of a surface** Tomohisa Matsumoto[1] (matsumoto@u.ip.titech.ac.jp), Kazuho Fukuda[2], Keiji Uchikawa[1]; [1]Department of Information Processing, Tokyo Institute of Technology, Japan, [2]Department of Information Design, Kogakuin University, Japan

It is known that glossiness of a surface is affected by various factors, i.e., illumination, shape, image statistics, highlight of a surface. However, it has not been fully studied whether glossiness is affected by chromaticity of a surface. Metallicity, on the other hand, is one of material perceptions similar to glossiness, but we do not know yet what determining factors, including chromaticity, to perceive metallicity. Matsumoto et al. showed that gold

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is perceived on a glossy surface of certain chromaticities, and that metallicity closely related to goldenness (Matsumoto et al., APCV 2011, VSS 2014). In the present study, we investigated effects of chromaticity on goldenness, glossiness and metallicity of a surface to clarify relationships between color appearance, glossiness and metallicity. We used metallic and non-metallic spheres with 3D-CG as test stimuli with 36 chromaticities. All pixels of a stimulus had the same chromaticity. Luminance of each pixel in metallic and non-metallic stimuli was morphed to make test stimuli with 5 different levels of contrast gloss. The observer performed magnitude estimation of goldenness, glossiness and metallicity of the stimulus. It was found that the stimuli with chromaticities that yield strong appearance of 'gold' tend to have higher glossiness and metallicity than those with other chromaticities when the stimuli were of medium contrast gloss. Such effects of chromaticity on perceived glossiness and metallicity were not observed for the stimuli of high contrast gloss. These results suggest that gold appearance per se might enhance glossiness and metallicity of a surface.

Acknowledgement: KAKENHI-22135004

43.4016 Estimating discrimination ellipsoids for skin images

Tushar Chauhan[1] (Tushar.Chauhan@liverpool.ac.uk), Kaida Xiao[1], Julian Yates[2], Sophie Wuerger[1]; [1]School of Psychology, University of Liverpool, [2]School of Dentistry, University of Manchester

The aim of this study was to estimate discrimination thresholds in 3-D colour space for images of skin patches from two ethnicities - Caucasian and Asian; with the observer fully immersed in three different illumination conditions - dark, daylight and cool-white-fluorescent. In the illuminated conditions, the patches were presented in an 'object mode' wherein the screen was covered by grey cardboard and only the stimulus was visible. Thresholds were measured using a 4-AFC paradigm. The stimuli were generated by adding a 3-D test colour vector to the original skin patch. The test vector was in one of 14 pre-selected directions in CIELAB colour space, and its length was controlled by the QUEST adaptive procedure. The final length of the vector in each direction was the estimated threshold. An ellipsoid was fitted to the 14 data points in the 3-D CIE UCS (u′v′Y) space. For each observer, this fit was done for each illumination condition and patch type separately (six fits per observer). The lengths of the three axes and the orientation of each ellipsoid were calculated. Here we report data for 5 observers. Our main findings are: (1) Discrimination ellipsoids for D65 (daylight) and TL84 (cool white fluorescent) are similar in size and orientation (2) One of the axes of the ellipsoids is always parallel to the luminance axis (3) In the u′-v′ plane the projected ellipses are oriented at an angle i.e. neither of the axes is parallel to the u′ or v′ axes (4) Variability of the thresholds was larger in the dark condition. Our preliminary results (five observers) suggest that tolerance limits for skin colour changes are very similar for daylight and fluorescent office light. Discrimination along the luminance axis (Y) seems to be independent of discrimination in the chromaticity plane (u′v′).

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43.4017 Exploring the perceptual similarity structure of dynamic textures

Yaniv Morgenstern[1] (yaniv.morgenstern@gmail.com), Shinho Cho[1], Daniel Kersten[1]; [1]Department of Psychology, University of Minnesota

Most previous work on material perception has focused on their optical properties, such as matte and specular reflectance. However, material categories and attributes may also be recognized from their motion flows, such as the contrasting dynamic textures produced by water and honey. We used a multi-arrangement form of multidimensional scaling (MDS; Kriegeskorte and Mur, 2012) to investigate the perceptual dimensions with which human observers compare dynamic textures. Observers used the drag and drop operations of the computer's mouse to arrange 97 dynamic textures (viewed as animated icons on a computer screen) according to their similarity. The dynamic textures were looped three-second movies windowed with either a small (radius = 38 pixels) or a large (radius = 225 pixels) circular aperture to control the level of spatial context. In the low spatial context condition (small apertures), the subjective reports and the MDS of the similarity arrangements were consistent with categorizations based on color and motion. In the high spatial context condition (large apertures), nine out of eleven human observers clustered the textures into semantic categories, including natural and artificial, liquid viscosity, wind, and hair/pili movement. The MDS of the average similarity arrangements for these nine observers showed that semantic categories were clustered along a primary attribute continuum from highly penetrable (e.g., water, honey), to less penetrable (e.g., hairs, cloth, fire), to impenetrable (e.g., cement, wood, metal). These findings suggest that larger spatial context reduces ambiguity resulting in similarity arrangements based on physically meaningful dimensions.

43.4018 Can the classifier trained to separate surface texture from specular shading infer geometric consistency of specular highlight?

Hideki Tamura[1] (tamura13@vpac.cs.tut.ac.jp), Shigeki Nakauchi[1]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology

Separating the surface texture (changes in albedo) from surface shading is a fundamental task for the visual system (Kim et al., 2014). We investigated whether this task is possible only from the image statistics. Images of randomly generated "bumpy" surfaces with/without specular reflections were rendered as gloss/matte surfaces. Half of the images in each category were modified so as to have surface texture (pigmentation) by multiplicatively changing the intensities with binary noise patterns. These images of four categories (matte, gloss, textured-matte and textured-gloss; 1,800 images for each category) were normalized to have the same mean and variance of pixel intensity, and then 744 of PS statistics (Portilla & Simoncelli, 2000) were calculated for them. Next, we developed a statistical model to classify the images into four categories using their PS statistics by canonical discriminant analysis (CDA). It turned out that the trained classifier is able to clearly categorize the generated images, and the first two canonical coordinates correspond to gloss/matte and uniform/textured axes, respectively. With the trained classifier, we examined the hypothesis: computations for evaluating the geometric consistency of highlights on glossy surfaces are common with those for separation of changes in albedo from surface shading. Diffused matte components and specular highlight components were separated from original glossy surface images, and as the test images the matte surfaces were textured with the separated highlight components in the same manner as in the training "textured" image generation with various multiplicative factors (1.2 to 5.0). This pigmentation was applied to consistent and inconsistent locations (original highlight components were horizontally flipped) of surfaces (3,600 in total). The trained classifier was able to differentiate consistent/inconsistent categories, except when the highlight-shaped texture regions have very high or very low local contrasts, suggesting that inference of geometric consistency of specular highlights is partially done by albedo-shading computations.

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43.4019 Perception of a thick transparent object is affected by object and background motions but not dependent on the motion speed

Shohei Ueda[1], Yusuke Tani[2], Takehiro Nagai[3], Kowa Koida[4], Shigeki Nakauchi[2], Michiteru Kitazaki[2]; [1]Graduate School of Engineering, Toyohashi University of Technology, [2]Department of Computer Science and Engineering, Toyohashi University of Technology, [3]Graduate school of Science and Engineering, Yamagata University, [4]Electronics-Inspired Interdisciplinary Research Institute, Toyohashi University of Technology

While a thick transparent object such as glass ball is in front of a textured background, the texture is perceived as distorted through the object. This distortion field is a cue for judging refractive index of transparent objects (Fleming, Jäkel, & Maloney, 2011). We aimed to investigate effects of the dynamic distortion field on judging the refractive index of transparent objects. A test and a matching stimulus were presented adjacently on a CRT monitor, and subjects were asked to adjust the refractive index of the matching stimulus to make its material identical to the test stimulus. In Experiment 1, the test stimulus was randomly chosen from stimuli of five refractive indices (1.3-1.7), and either rotated around the vertical axis or remained stationary. The matching stimulus was always stationary and subjects could change its refractive index. We found that the perceived refractive index was higher with the moving object than the static object. In Experiment 2, the background texture of the test stimulus moved horizontally back and forth instead of object motion, and we found that the background motion also increased the perceived refractive index. We varied the background-motion speed (38 to 300% of Experiment 2) in Experiment 3. We confirmed the overestimation effect of the moving background, and we found that the degree of the overestimation was independent of the motion speed. In conclusions, the dynamic distortion field caused by object- or background-motion raised the perceived refractive index, but its motion speed did not matter. Thus the results cannot be explained by overestimation of distortion field by its dynamic change. Rather the dynamic distortion field may make the perceived rigidity of the object more than the static distortion field, and induce the overestimation of refractive index since the rigid materials generally have higher refractive index than the non-rigid materials.

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43.4020 **MatMix 1.0, a novel material probe for quantitatively measuring visual perception of materials** Fan Zhang[1] (f.zhang-2@tudelft.nl), Huib de Ridder[1], Sylvia Pont[1]; [1]Perceptual Intelligence Lab, Industrial Design Engineering, Delft University of Technology

Recently Pont et al. (2012) showed that the appearance of objects consisting of any materials can be described as linear superpositions of objects of different canonical materials. In this study, we successfully implemented this method in a novel material probe (MatMix 1.0) to quantitatively measure visually perceived material qualities. The probe and stimuli were optical mixtures of four basis photos of a 3D object finished with four canonical types of materials (matte, velvety, specular, glittery). The probe images were taken under office lighting. A mixing desk type of interface was used in three matching experiments to quantify material perception. A stimulus image and the probe were shown together in the interface. Below the probe there were four sliders, representing the four materials, to control the probe appearance. In experiment 1, stimuli were lighted and viewed in the same way as the probe, whereas the 3D object was photographed from a different angle for experiment 2, and photographed under three canonical types of lighting (brilliant, diffuse, spot) for experiment 3. In each trial, observers were asked to match the material of the object in the probe with the material of the object in the stimulus. Experiment 1 showed surprisingly good results, indicating that participants handled the interface well. In experiment 2, the performance only slightly decreased and showed that observers truly matched perceived material qualities (not images). In addition, interactions between matte, velvety and specular components were found, while glittery was found to be relatively independent from all others. Experiment 3 confirmed the findings of the previous experiments, and showed that canonical lightings systematically affect material perception. Thus, MatMix 1.0 promisingly forms a robust and intuitive method to quantify visual material qualities. Results show that viewing and lighting conditions systematically influence material perception, suggesting that material consistency is not absolute.

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Binocular Vision: Stereopsis and depth

Monday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4021 **Gaze Dependent Vergence Adaptation** Muriel Dysli[1,2] (muriel.dysli@insel.ch), Mathias Abegg[1]; [1]Ophthalmology, Inselspital, University of Bern, Switzerland, [2]Graduate School for Cellular and Biomedical Sciences, University of Bern, Switzerland

Purpose: The innervational pattern of extraocular muscles that maintain ocular alignment vary with gaze direction, age, and orbital anatomy. A muscle paresis, for example, may cause a misalignment, which is characterized by a gaze dependent deviation of the ocular alignment. Clinically this is termed incomitant strabismus. In this study we aimed at investigating the physiological mechanisms that enable orthophoria, i.e. good ocular alignment, in all directions of gaze. For this purpose we explored the physiological response to vergence stimuli and assessed their directional specificity. Methods: Vergence stimuli of gaze dependent magnitude were used to model image disparity of an incomitant, 'paretic', strabismus. We measured consecutive horizontal vergence responses that were elicited after subjects shifted their gaze from a gaze position without image disparity into a field of view with increased image disparity. Results: We found that repetitive saccades into a field of view with increased image disparity led to a rapid decrease of the phoria level, i.e. the magnitude of ocular misalignment in optically dissociated eyes decreased over time. The decrease was more pronounced in the gaze direction with increased disparity and to a lesser extent in the other gaze directions. Moreover, we confirmed a rapid increase of the vergence velocity over time. The gaze dependent modulation of phoria was found in both, smooth pursuit and saccadic eye movements. Conclusion: Thus an acute gaze dependent change of image disparity, such as may be encountered in new onset paretic strabismus, leads to an increased velocity of the vergence response and an increase of the phoria level with a gaze specific and a gaze independent component. This early adaptive response enables an increased efficacy of binocular vision and an orthophorisation in all directions of gaze in a case of a new onset incomitance.

43.4022 **Stereoacuity improves after short-term binocular pattern mismatch** Bart Farell[1] (bfarell@syr.edu), Cherlyn Ng[1]; [1]Institute for Sensory Research, Syracuse University

Monocular deprivation can chronically suppress vision in the deprived eye, if it is applied for sufficient duration early in life. However, it can have a transient effect in the opposite direction if applied briefly (a few hours) to normal adults. This short-term monocular deprivation appears to increase the gain for the deprived eye relative to the undeprived eye, affecting binocular vision by shifting the interocular balance. An interocular gain difference produced by patching a single eye might be expected to lower stereoacuity in normal observers, since raising contrast in just one eye reduces stereoacuity (the 'contrast paradox'). We hypothesized that alternately depriving each eye in turn might benefit stereoacuity by increasing post-deprivation gain in both eyes and dampening interocular suppression. We switched a translucent patch between the eyes of visually normal adult observers hourly for 6 hours. The unpatched eye viewed the natural visual environment. Compared to pre-patch performance, post-patch grating stereoacuity, measured during 20 minutes following patch removal, improved by 20% to 33%. In a second experiment, we alternately covered the left and right eyes of two observers with cylinder lenses to determine the existence of orientation-specific gain. Each eye was 'patched' with the lens for 45 or 60 minute periods, giving a total through-the-lens viewing of 4 to 6 hours. Unexpectedly, post-patching stereoacuity improved for test gratings with the same orientation as seen through the lens and worsened for orthogonal gratings. This result cannot be explained by monocular orientation adaptation. It implies that the interocular balance has a channel structure that is modulated not specifically by monocular deprivation but rather by interocular pattern mismatch. The post-patching enhancement evident in both experiments indicates that interocular suppression may limit stereoacuity under natural viewing conditions.

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43.4023 **Modulating ocular dominance in the adult in real time.** Robert Hess[1] (robert.hess@mcgill.ca), Jiawei Zhou[1], Alexandre Reynaud[1]; [1]McGill Vision Research, Dept Ophthalmology, McGill University, Montreal, Canada

Using a dichoptic spatial phase combination paradigm that assesses the relative contribution that each eye makes to the binocular percept (ocular dominance), we have shown previously that 2.5 hours of patching, be it opaque or translucent, can result in a short-term enhancement of the patched eye's contribution to binocularity. This suggests that it is differential pattern deprivation, rather than the differential luminance deprivation that is driving this ocular dominance change. Here we ask what aspects of the pattern stimulation are important for ocular dominance. Observers dichoptically viewed movies of 2-3 hrs duration in which the spatial information in one eye's view had been altered (pattern deprivation). We measured each eye's contribution to the binocular percept before and after movie viewing using the dichoptic spatial phase task. Scrambling the spatial phases in one eye's view had no effect on ocular dominance, suggesting features constructed from phase-aligned components are unimportant in this regard. At the level at which these changes in dominance occurs only the Fourier amplitude spectrum is important. To verify this we show that graded changes to the magnitude of the amplitude spectrum result in graded changes in ocular dominance. To ascertain whether different parts of the amplitude spectrum are more important than others, we compared highpass with lowpass filtering and show that only the latter affects dominance. Finally, the ocular dominance change is not orientationally-dependent, suggesting the underlying mechanism is isotropic. Short-term changes in ocular dominance in adults can be obtained by altering the contrast of isotropic, high spatial frequency components seen by one eye.

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43.4024 **Comparison of monocular and stereo sources of motion information about time-to-contact of slow and fast objects** Aaron Fath[1] (ajfath@indiana.edu), Mats Lind[2], Geoffrey Bingham[1]; [1]Department of Psychological and Brain Sciences, Indiana University, [2]Department of Information Technology, Uppsala University

Stereomotion perception relies on two primary sources of information: interocular velocity differences (IOVD) and changes in disparity over time (CDOT). IOVD results from comparison of two monocular flow fields (MFF). Binocular disparity results from comparison of two monocular image structures and CDOT characterizes how this disparity evolves. CDOT-based stereomotion perception has been theorized to be a slower process than IOVD-based perception. If so, CDOT should be an inferior source of information for fast-moving objects. If CDOT is inferior for fast objects, is there a spatiotemporal domain in which CDOT is superior? Ten participants were each presented with three types of displays that depicted two squares approaching from different distances in depth at different

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constant velocities yielding different times-to-contact (TTC). Squares disappeared during approach and participants specified which square would have contacted them first. One display type was dynamic random-dot stereograms that isolated CDOT by rerandomizing points each frame (CDOT-only). Another was evolving (i.e., without rerandomization) random-dot configurations (MFF+IOVD). Corresponding points were not used, as they are in stereograms, so disparity did not specify approach. The third was evolving random-dot stereograms, so motion was defined by MFF, IOVD, and CDOT (COMBINED). For all three displays, in half of the trials, the two squares moved at speeds ranging 26–32 cm/s. In the other half, speeds ranged 73–127 cm/s. For fast stimuli, performance as measured by proportion correct was comparable for MFF+IOVD and COMBINED trials, but CDOT-only trials were significantly worse. Performance with slow stimuli was comparable for CDOT-only and COMBINED trials, but MFF+IOVD trials were significantly worse. Optimal performance levels were similar for both speed conditions. To yield invariant performance levels across speeds, the visual system appears to use primarily CDOT to perceive motion of slower objects, but MFF and IOVD for faster objects.

43.4025 **The alignment of functional selectivity in V1 following ocular misalignment** Veronica Choi[1] (v.choi88@gmail.com), Benjamin Scholl[1], Nicholas Priebe[1]; [1]Center for Perceptual Systems,Department of Neuroscience, College of Natural Sciences, University of Texas, Austin

Disruption in the visual field before the critical period can change how the neurons in the primary visual cortex integrate binocular inputs. Strabismus (ocular misalignment) during development leads to cortical neurons that are almost exclusively monocular when measured by spike rate.The traditional interpretation for this phenomenon is an underlying reduction, or even elimination, of the synaptic input to the cortical neuron from the non-preferred eye via activity-dependent competition. Since this interpretation has relied almost exclusively on recording of suprathreshold activity (spiking), which is indirectly related to synaptic input, we measured subthreshold membrane potential responses to assess the changes in functional selectivity following ocular misalignment. Following surgically-induced strabismus in cats before the critical period (p12) we used whole-cell recordings in vivo to measure the activities of the cortical neurons in adult animals. We compared each neurons preference for orientation, spatial frequency, and contrast sensitivity for both the right and left eyes. We find a surprising match between these selectivity of the neurons for the right and left eyes at the level of membrane potential. Right and left eye inputs in strabismus animals share orientation preference, spatial frequency preference, and contrast sensitivity despite the increased degree of monocularity in these neurons. While we do uncover some variance in selectivity between the right and left eye inputs, this degree of variances matches that found in normal animals. These direct measurements of input selectivity following strabismus reveal that despite the lack of correlation between the images that the left and right eyes provide, the underlying selectivity of the neurons is maintained.

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43.4026 **Decision-related activity in V2 for a fine disparity discrimination task** Stéphane Clery[1] (stephane.clery@cin.uni-tuebingen.de), Bruce Cumming[2], Hendrikje Nienborg[1]; [1]Centre for Integrative Neuroscience, University of Tübingen, [2]Laboratory of Sensorimotor Research, NEI, NIH

The stereoscopic depth of a target can be evaluated relative to the fixation plane (absolute disparity) or relative to a background (relative disparity). Fine disparity discrimination is thought to rely on relative disparity judgments (Prince et al., 2000). V2 neurons are the first in the visual processing hierarchy to show selectivity for relative disparity (Thomas et al., 2002), and have previously been found to have decision-related activity for coarse disparity discrimination tasks (Nienborg and Cumming, 2006, 2009). Here, we asked whether V2 neurons also show decision-related activity in a fine disparity discrimination task. We recorded extracellular single unit activity while two macaques performed fine disparity discrimination. The stimuli were random dot stereograms with a disparity defined central disk and a surrounding annulus. The animals had to discriminate whether the disk was protruding or receding relative to the surrounding annulus. The neurons discriminated the stimuli reliably although neuronal discrimination performance compared to that of the animals was lower on average (mean neurometric to psychometric threshold ratios: 2.61). These results suggest a perceptual role of V2 neurons for fine disparity discrimination. The V2 units also had decision-related activity, quantified as choice probabilities (mean=0.57, significantly different from 0.5 chance level, $p< 0.01$, $n=63$). Interestingly, neuronal selectivity for relative disparity was not correlated with decision-related activity ($r=0.014$, $p=0.93$). In a subset of units ($n=28$) we measured decision-related activity for the coarse and fine disparity discrimination task and found a significant correlation ($r=0.4$, $p< 0.05$). Choice probabilities have been shown to depend on the structure of interneuronal correlations (Shadlen et al. 1996, Gu et al. 2008). This could explain that choice probabilities in the fine task were independent of their selectivity for this task. The correlation of the choice probabilities between tasks suggests a surprisingly stable structure of interneuronal correlations between the two tasks.

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43.4027 **Disparity defined depth of a dynamic random noise patch within a static random dot field is easier to see than that of a normal random dot stereogram** Masahiro Ishii[1] (m.ishii@scu.ac.jp), Akiko Yasuoka[1]; [1]School of Design, Sapporo City University

Depth in a random dot stereogram is harder to perceive than that in a normal stereogram. Depth, however, is much easier to perceive when an outline is placed around the disparate region. This research uses a hybrid random dot stereogram in which a patch of dynamic random noise is set within a static field of random dots to test; the patch is binocularly correlated and binocular disparity is assigned to it. The normal (static) and the dynamic random dot stereogram are used to compare with the hybrid stereogram. Disparity thresholds to perceive depth are measured. Differences between them are as follows: a subjective contour, which is not luminance defined but is monocularly perceptible, appears around a dynamic patch; a dynamic patch, which has spatiotemporal changes, may stimulate the target detectors with not only disparity but motion; a dynamic random dot stereogram stimulates entirely with motion; a particular set of disparity detectors may be fatigued by a static stimulus. Experiments by the method of constant stimuli were conducted to measure disparity threshold. In each trial, a stereogram containing a central square in depth was presented. The refresh rate of dynamic change was 10 fps. Each dot was white on a black background. The results indicated our subjects could perceive smaller depth in the hybrid stereogram than that in the normal and the dynamic stereogram. Another experiment was conducted using a partially colored stereogram in which the central dots were green and the rest dots were white. The result indicated smaller depth could not be seen although the target could be seen monocularly. We noticed subjective contours in the hybrid (dynamic-static) stereogram appeared clearer than that in the partially colored stereogram. The visibility of subjective contours and/or motion stimulation might help people to see depth better.

Acknowledgement: CREST, JST

43.4028 **Apparent depth of a patch of dynamic random noise within a static field of random dots** Akiko Yasuoka[1] (a.yasuoka@scu.ac.jp), Shinichi Kita[2], Masahiro Ishii[1]; [1]School of Design, Sapporo City University, [2]Department of Psychology, Kobe University

A patch with one texture appears as a distinct perceptual entity within a background region with contrasting texture if their features differ adequately (texture segregation). If there is no pictorial depth cue such as size, the patch, which is a small closed region, may stand out. Incidentally, if two fields of random dots that are identical except for a slight shift in a region are presented in rapid alternation, the region appears as an entity reciprocating above the background (RDK). With these phenomena, a number of studies have attempted to reveal several types of perception such as texture, subjective contour, or motion. While Klymenko et al. (1989) reported that a flickering region appeared as a background when the temporal frequency was high, most studies have not focused on depth perception. This study investigates apparent depth of a patch of dynamic random noise within a static field of random dots. Dynamic random noise involves spatiotemporal changes and stimulates motion detectors. In this regard, it differs from flickering stimuli. An experiment was conducted to determine the appearance. The disparate region was depicted with dynamically changed random dots (2.5, 5, or 10 fps) and the remaining region was depicted with static random dots. Each dot was white on a black background. The disparate region subtended 3.7x3.7 deg. We asked subjects to judge apparent depth of the patch. The results indicated that the disparate region tended to appear through an aperture if the refresh rate of dynamic random noise was 10 fps. Another experiment was conducted to estimate the perceived depth using a depth nulling technique. Binocular disparity was used to null the perceived depth. We found the perceived depth was about 0.5-1.0 arcmin of binocular disparity.

Acknowledgement: CREST, JST

 See page 3 for Abstract Numbering System

43.4029 Vertical size disparity pooling across attended color and contrast

Benjamin Backus[1,2] (bbackus@sunyopt.edu), Baptiste Caziot[1,2]; [1]Graduate Center for Vision Research, SUNY College of Optometry, [2]SUNY Eye Institute

Modifying the interocular vertical size ratio (VSR) to be different from unity causes a frontal surface to appear slanted. This "induced effect" normally functions to correct the stereo slants of surfaces located to the side of straight ahead. VSR is pooled regionally within the visual field (Kaneko & Howard, 1997; Adams, Frisby & Buckley, 1996; Porrill et al, 1999), but details about VSR measurement remain unknown. Duke and Howard (2005, 2012) reported a refinement of pooling: VSR had separate effects within different transparent surfaces that were separated in depth by horizontal disparity. Duke and Howard interpreted their result as showing that VSR measurement occurs separately within horizontal-disparity defined surfaces. An intriguing and more general alternative, however, is that individual display elements (e.g. dots) in one surface were simply selected by attention through parallel processing, with VSR being computed across the attended (and therefore salient) display elements. If so, top-down attention to spatial locations would be acting remarkably early, and with great precision. To test this idea we constructed mixed-VSR displays in which two populations of dots had different colors (black/white, green/red, or black/dark gray) that carried different VSR signals. Observers were instructed to attend to one or the other color within blocks of 40 trials, and to indicate which side of the display appeared near. Attended colors had greater subjective salience. However, although color itself had a significant effect on sign-of-slant judgments, attended color did not. Thus, higher luminance contrast, but not attention to color, increased the contribution of a dot during the measurement of VSR. Thus, Duke and Howard's interpretation still stands: VSR measurement occurs separately within surfaces separated by horizontal disparity.

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43.4030 Invariance of processing latency across signal types and strengths

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Residual Latencies (RL) are non-decisional components of response time (Luce, 1986) that can in turn be decomposed into processing and motor latencies (respectively pre- and post-decisions). Thus, when motor response is similar across different tasks, differences in RL can be attributed to differences in processing latency. Previously (Caziot et al., 2014, OSA), we used RL analysis to show that processing times for luminance and stereo signals were nearly identical. Here we extend this result to different levels of luminance contrast and slant from stereo. Observers were asked to distinguish between a dark and a bright disk (contrast task), or sign of slant in a sparse RDS (slant task). Each task had two levels of difficulty (low/high contrast, small/large slant). Observers were asked to answer before a deadline that varied block by block from 200ms to 500ms. We then fitted exponential Speed-Accuracy Tradeoff Functions (SATFs) to the data. The response time at which performance (fraction correct) deviated from chance was the RL. Increased difficulty lowered the slope of the SATFs, as expected for a lower signal-to-noise ratio. We also found that RL was slightly increased for low contrast compared to high contrast. However RL were similar for the two slant conditions, and comparable to the RL in the high contrast condition. The increase in RL at low contrast can be explained by low-level physiological properties of the visual system (i.e. prior to V1). We conclude that (1) in accordance with our prior findings, stereo is not processed more slowly than luminance, including now for slant perception; (2) increased signal strength increases the slope of the SATF and (3) processing latency for tasks that are difficult due to noise during later processing stages (e.g. stereo slant) is, in general, probably not affected by the strength of the signal.

43.4031 Assessment of depth magnitude from binocular disparity

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While binocular disparity is well known for providing high-resolution discrimination thresholds, it also plays an important role in defining the separation of features or objects in depth. This suprathreshold performance has been assessed using a variety of techniques, most of which involve visual and/or haptic transformations. Ideally, if these techniques accurately assess depth percepts, they would be interchangeable, and equally affected by factors such as experience. To test this prediction we compared the accuracy of three depth estimation methods (haptic sensor, digital caliper, and a virtual ruler) using a simple line stimulus, with groups of experienced and naïve observers. Participants were asked to estimate the amount of depth between two vertical bars using each estimation technique. We found no consistent difference between measurements regardless of the method used. However, while experienced observers' estimates followed geometric predictions, naïve observers consistently under-estimated small, and over-estimated large disparities. One explanation for this difference is that naïve observers are more sensitive to the cue conflict between stereopsis and perspective foreshortening. To test this hypothesis, a second group of naïve observers were assessed using the original and a perspective-corrected configuration. Our results showed a significant effect of removing cue conflict at the largest test disparity only. Closer examination showed that the data were bi-modal. Removal of the conflict eliminated the estimation errors for half of the observers; the remaining observers were unaffected by the manipulation. We conclude that the three techniques evaluated are equally accurate for the configuration used here. A more important consideration is the amount of experience with such procedures. While some observers readily discount conflicting depth cues, others do not and these individuals may require additional training. Failure to take experience into account will result in high inter-observer variability and distorted depth estimates.

43.4032 The impact of binocular disparity on visual short-term memory

Sarah Zohar[1] (sar.zohar@gmail.com), Laurie Wilcox[1]; [1]Psychology, Centre for Vision Research, York University

Although visual short-term memory (VSTM) has been studied extensively, the majority of this literature has focused on the impact of 2-D stimulus properties. Studies of the effects of binocular disparity on VSTM have drawn conflicting conclusions due to design and stimulus differences. To reassess the impact of stereopsis on VSTM we used a novel paradigm in which oriented brackets were presented on two disparity-defined planes simultaneously. A concurrent letter recall task prevented observers from cognitively rehearsing a verbal descriptor of the brackets. On each trial, observers viewed a set of four randomly selected letters, followed by a field of brackets containing two of four possible orientations (left, right, up, down). Observers were asked to remember the set of letters, and the bracket orientations. In the test phase, another set of letters appeared and observers indicated if they were the same or different from the first. A field of brackets then appeared and observers indicated if the orientations were the same or different from the original. We computed d' for four conditions: zero disparity full-density, zero disparity half-density, two disparity-defined planes with non-uniformly distributed brackets and two disparity-defined planes with uniformly distributed brackets (each plane contained one orientation). We found no difference between 2-D and 3-D conditions, however there was a large effect of element distribution in the 3-D conditions. In a follow up experiment we varied binocular disparity to determine whether this result was specific to a particular depth offset. There was a clear interaction between disparity and element distribution in the 3-D conditions. We conclude that there is no overall benefit to VSTM of displacing stimuli on different depth planes. Instead it appears that VSTM is influenced by the perceptual organization of the elements, which can be influenced by their 3-D placement.

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43.4033 On the consequences of perceptual organization via good continuation in depth

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We have previously reported that mid-level configural effects – specifically, perceived closure – play a significant role in processing the binocular disparity of line segments (Deas & Wilcox, 2014). Here we demonstrate that the Gestalt cue of good continuity has a stereoscopic counterpart ('good continuation in depth') that operates when the relative disparity of neighbouring features varies smoothly. This disparity-based grouping cue negatively influences perceived depth (Experiment 1) but in similar stimuli enhances detectability (Experiment 2). In our first study we assessed the effect of good stereoscopic continuation on perceived depth magnitude using a touch-sensitive sensor. First, the relative separation in depth between two isolated dots was compared to estimates made when intermediate elements were added to form a continuous disparity gradient. We found that the perceived separation in depth between end dots systematically declined as intervening dots were added. Importantly, veridical depth was restored when the disparity of the intermediate dots was jittered. In Experiment 2, the same dot configurations were used in a visual search paradigm to evaluate if disparity-based grouping has a positive impact on search time. Observers searched for a target, defined by good stereoscopic continuation, among distractors which contained depth jitter, or vice versa. By modulating the disparity profile of the target relative to the distractors, we found that detection was dramatically more efficient when the target path contained a continuous disparity gradient. Our results demonstrate the operation of a disparity-based grouping cue that corresponds to the Gestalt principle of good continuity in depth. We posit that this disparity-based grouping may be partly responsible for the well-documented underestimation of perceived slant.

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Perceptual Organization: Grouping

Monday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4034 Percept-Concept Consistency Facilitates Memory

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We investigated how the perceptual organization of text affects memory for information presented in visual displays. It is well known that identical equally-spaced elements form a single perceptual unit, whereas unequally-spaced elements can elicit the percept of separate groups (grouping by proximity; Wertheimer, 1923). By analogy, placing text in a single paragraph groups all sentences into a perceptual unit, whereas adding blank lines between sentences causes them to form separate groups. When sentences that describe different concepts are spatially separated, the perceptual organization is consistent with the conceptual structure (percept-concept consistency). Does percept-concept consistency facilitate memory? Participants viewed a short excerpt about 'chemo-fog' (chemotherapy-related cognitive impairment). They were told they would see the excerpt for 30-sec and would then be asked to describe what they learned. The content of the excerpt included three sections: (1) definition of chemo-fog, (2) description of symptoms, and (3) call to provide more support for cancer survivors. There were three between-subject conditions: paragraph (all text presented as a single paragraph), bullet-list (text was spaced into three parts, reflecting the conceptual structure of the content with separate bullets for each symptom), and graphic-list (identical to bullet-list except bullet points were replaced by symbols representing each symptom). The words were identical across conditions. There was no difference in memory for the definition of chemo-fog (section 1), but participants remembered more symptoms (section 2) and were more likely to describe the call for support (section 3) in the bullet-list and graphic-list conditions than in the paragraph condition (there was no difference between bullet-list and graphic-list conditions). Therefore, percept-concept consistency facilitates memory. Further, participants' aesthetic preference for the visual displays mirrored the memory results, except participants preferred the graphic-list displays to the bullet-list display. The results support a link between ease of processing (fluency) and aesthetic preference.

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43.4035 The Salience of Lower-Order Features in Highly Self-Similar Wallpaper Groups

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Symmetric visual patterns arise frequently in natural images and human cultural artifacts. All 2-D symmetric patterns that tile the plane represent one of 17 "wallpapers" -- combinations of the fundamental symmetries of rotation, translation, glide reflection and reflection. Most research on human perception has focused on two-fold reflection. Here we examine how human observers classify patterns with varying combinations of the fundamental symmetries. Clarke et al. (2011) found that five of the seventeen wallpaper groups (P1, P3M1, P31M, P6, and P6M) had a high degree of self-similarity. We presented adult participants (n=11) with twenty spatial-frequency-normalized exemplars from each of the five highly self-similar wallpaper groups. Each exemplar was generated from a seed region containing random grayscale noise, which was then replicated, rotated, reflected, and translated according to the pattern of regularity reflected in each wallpaper group. Observers were instructed to sort the exemplars into as many subsets as they wished based on any criteria they saw appropriate. We used the Jaccard index to measure the degree to which observers sorted exemplars from the wallpaper patterns into consistent categories. Observers found consistent patterns of self-similarity between the wallpaper groups, $p < .001$. P1 exemplars were judged to be more self-similar than than the other groups, $p < .001$, and P6M exemplars were judged to be more self-similar than P6, $p < .001$. The findings suggest that mirror and translational symmetry influence unconstrained observer judgments about pattern regularity. Visual inspection of the subsets generated by observers suggested that the presence of salient secondary features (i.e. emergent global geometric structures such as striations, grid patterns, and characteristic shapes) influences the detection of self-similarity in wallpaper patterns. The results contribute to an emerging understanding of how group theory may shed light on human and machine pattern detection.

Acknowledgement: NSF 1248076

43.4036 Similarity grouping as feature-based attention

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Perception organizes spatially distinct areas of our world into groups, according to a set of well-studied cues, including connection, common region, proximity, and the Gestalt similarity cues of color, luminance, and shape. One counterintuitive recent proposal (Huang & Pashler, 2007; Levinthal & Franconeri, 2011) is that similarity grouping is 'just' feature selection - seeing a red, bright, or square group is just global selection of those features. This account makes the striking prediction that similarity grouping must be serial, such that other groups (green, dark, circles) cannot be constructed in the same instant. Past support - from serial grouping in display symmetry judgments and visual search tasks - has been subject to alternative interpretations. Here we provide the most direct evidence yet for this account, by demonstrating a striking lack of influence of similarity grouping in a task that is immune to these alternatives - when people rapidly estimate numerosity of a set of objects, grouping them reduces estimates. We replicate this effect (N=16) for connection (M=-27% reduction, p=0.001), common region (M=-17%, p=0.013), and proximity (M=-9%, p=0.033). But no significant reduction appears for color (M=2%), luminance (M=-5%), or shape (M=3%) grouping of element displays, despite a phenomenally strong grouping percept in these displays. The illusion of simultaneous grouping of similarity groups may be like the illusion that light in our fridge is always on - groups are always present when we select a feature, just like the light is always on when we open the fridge. But with a true test of simultaneity, similarity grouping can be shown to be serial.

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43.4037 The change of reading/writing habit induces the directional change in drawings, but not in photos.

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It has been known that reading/writing direction habits affect aesthetic preferences regarding picture direction. For example, people who read and write rightward aesthetically prefer pictures depicted facing to the right more than pictures depicted facing to the left, and vice versa. Accordingly, it has been suggested that a psychological assimilation occurs between the direction of reading/writing habits and the preferred direction of a picture's configuration. However, such claims are primarily based on the results of cross-cultural studies comparing countries or cultures that do not have the same reading/writing directions. If so, does the directional change of reading/writing habits within a culture induce changes in the picture display? Korea is a good place to ask this question because it underwent gradual changes in reading/writing direction habits, from leftward to rightward, during the 20th century. Thus, reviewing the pictures that were depicted during that time may provide insight into how reading/writing direction habits influenced the preference of picture direction. In this study, we randomly collected 3,920 hand drawings and 17,477 photos published in Chosun Ilbo, the oldest newspaper in Korea from 1927-2013, and we counted the direction of pictures: leftward or rightward. The regression analysis shows that the direction of the drawings showed a clear shift from the left to the right, but the direction of photos showed no change. The result indicates that a change in reading/writing direction habits induce a change in drawing habits to the same direction, but its effect differs depending on the picture type. For the difference, we argue that reading/writing habit may share a physical constraint more with drawing actions than with taking photo actions.

43.4038 Driving a rotating Necker Cube: context position matters

Marouane Ouhnana[1] (marouane.ouhnana@mail.mcgill.ca), Frederick Kingdom[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University

Aim. Previously we reported that the relative rotation speeds of an ambiguous Necker cube and the context figure that triggered its reversals was not important for the strength of correlation between the two objects' reversals. Here we examine whether their relative positions are important. Method. The context figure was an unambiguous skeleton cube that rotated at the same speed as the ambiguous Necker cube. The two figures were presented on either side of a fixation cross at 2.86 degrees of eccen-

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tricity, along the horizontal (0,180 deg), vertical (90, 270 deg) and diagonal (45, 135, 225, 315 deg) axes that connected the figures. Observers indicated via button press the direction of rotation of the Necker cube during each 32s trial. The data was subject to a type of reverse correlation analysis to establish the correlation between the motion reversals of the context and Necker cube. Results. Strongest contextual influences were observed when the context figure was directly below the Necker cube. Conclusion. These results are consistent with the idea that perceived frictional relationships are important for the perception of rotating reversible figures.

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43.4040 **How Do Multiple Inducers Group in Perceptual Completion Stimuli - Psychophysics and Modeling** Gal Nir[1] (nga@post.bgu.ac.il), Ohad Ben Shahar[2]; [1]The department of Brain and Cognitive Science, Ben Gurion University of the Negev, [2]The department of Computer Science, Ben Gurion University of the Negev

Visual completion, the perceptual process of completing visual information missing due to occlusion, is a fundamental organizational process that facilitates much of higher level vision. The general problem of contour completion is typically divided into the grouping problem and the shape interpolation problem. The latter deals with the ability of the visual system to complete the gaps in occluded objects and by that to facilitate recognition and other higher level visual tasks. The grouping problem, on the other hand, deals with the process that pairs specific inducers (the points in the visual stimulus where the occluder meets the occluded object) between which completion occurs. While previous computational work has addressed mostly the shape problem, perceptual work has addressed both issues. Even so, perceptual studies on the grouping problem have been restricted to the conditions by under which a given pair of inducers is indeed grouped to induce a completed contour, rather than to studying how inducers are grouped in multi-inducer scenarios. Here we investigate the grouping problem in stimuli with two pairs of inducers, exploring psychophysically the stimuli features that lead to the selection of a specific grouping decision from the set of all possible groupings. We employ a dot localization paradigm (Guttman and Kellman, 2004) and report grouping results based on the independent parameters of the geometric properties of the shape, including inducer distance, orientation difference, curvature, etc... Using these findings we developed a model that quantifies inducer grouping during visual completion in a way that extends the popular relatability theory (Kellman and Shipley, 1991) and readily allows the future incorporation of top-down factors like familiarity and attention.

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43.4041 **Decreases in Variance are Detected Better than Inceases in Variance** Drew Walker[1] (dehoffma@ucsd.edu), Timothy Lew[1]; [1]University of California, San Diego

Although many investigations of visual summary representations (“ensemble statistics”) have focused on how people compute the central tendency of stimuli such as average set size (e.g. Ariely, 2001), orientation (e.g. Parks, et al., 2001), or facial emotion (e.g. Haberman & Whitney, 2009), less attention has been given to representations of set heterogeneity. People rapidly extract set variance (Michael, et al., 2013), and the variance of a set affects how ensembles are averged (Corbett et al., 2012; Fouriezos et al., 2008; Im & Halberda, 2013). We investigated the ability to detect changes in the variance of circle sizes across sets, using a staircase algorithm. On each trial subjects (n = 23) were presented first with a pedestal display of circles followed by a test display, and had to judge if the variance of the circle sizes (the logarithm of the circle diameter) of the test display was the same as the pedestal set, or if it had changed (the mean was held constant). In one block of 200 trials the changed test variance increased compared to the pedestal variance, while in the other block of 200 trials the changed test variance decreased compared to the pedestal (block order was counterbalanced). We found that people could detect smaller differences between the pedestal and test variance when the variance had decreased, compared to equivalent changes when the variance increased.

43.4042 **Non-specific Perceptual Organization Deficits After Traumatic Brain Injury.** Thiago Costa[1,2] (e.thiagocosta@gmail.com), Ana Zaninotto[2], Gláucia Benute[2], Mara Lúcia[2], Wellingson Paiva[3], Johan Wagemans[4], Lee de-Wit[4], Paulo Boggio[1]; [1]Social and Cognitive Neuroscience Laboratory and Developmental Disorders Program, Mackenzie Presbyterian University, São Paulo, Brazil. , [2]Division of Psychology, Hospital das Clínicas, University of São Paulo Medical School, São Paulo, Brazil, [3]Division of Neurosurgery, University of São Paulo Medical School, São Paulo, Brazil, [4]Department of Experimental Psychology, University of Leuven, Belgium

Traumatic Brain Injury (TBI) is a prevalent condition and there is limited visual perception research of this population. Here, we investigated perceptual organization changes in 15 closed head TBI outpatients (and age-matched controls) with diffuse axonal injury only (a fundamental clinical manifestation of TBI) and no other known comorbidities. Patients had normal or corrected visual acuity and differed in the time since the lesion (between 4 and 9 months). Perceptual organization was measured with the Leuven Perceptual Organization Screening Test (L-POST), a coherent motion task (CM) and the Leuven Embedded Figures Test (L-EFT). These tests were chosen to screen for deficits in different aspects of perceptual organization (L-POST), to evaluate local and global processing (L-EFT) and grouping in a dynamic set of stimuli (CM). TBI was significantly impaired compared to controls in all measures for both reaction time and accuracy, except for CM thresholds (p=0.23). Repeated measures ANOVA showed that the TBI group was similarly affected in all aspects of the L-EFT (open vs. closed figures, different number of continued elements shared by figure and ground). TBI was also similarly affected in all perceptual factors of the L-POST (perceptual grouping, figure-ground segmentation, parts in wholes, and shape discrimination). No significant correlations were found between scores and time since lesion, except for CM (r_s=-0.65), which might explain the lack of group-level differences in CM. The only scores significantly correlated to IQ were L-EFT reaction times (r_s=-0.58) and parts in wholes L-POST factor (r_s=0.62). These findings demonstrate that perceptual organization is diffusely affected in TBI and this effect has no substantial correlations with IQ. As many of the neuropsychological tests used to measure different cognitive functions involve some level of visual discrimination and perceptual organization demands, these results must be taken into account in the general neuropsychological evaluation of TBI patients.

Acknowledgement: FAPESP, CNPq

43.4043 **Individual differences in autistic traits predict visual binding abilities** Sol Sun[1,2] (sol.sun@mail.utoronto.ca), Ryan Stevenson[1], Naomi Hazlett[1], Morgan Barense[1,3], Jonathan Cant[2], Susanne Ferber[1,3]; [1]Department of Psychology, University of Toronto, [2]Department of Psychology, University of Toronto Scarborough, [3]Rotman Research Institute at Baycrest

A core symptom of autism spectrum disorder (ASD) is a deficit in binding sensory inputs into a unified representation. Past research suggests that these impairments extend from lower-level perceptual grouping to higher-level holistic face perception. Given that visuo-spatial attention plays a critical role in binding, we hypothesized that normally-distributed autistic traits in the healthy population would predict the degree to which attentional scope could be modified to influence holistic face perception. We directed participants to adopt either a global or local attentional scope using a Navon task. Participants viewed pairs of Navon letters (big letters composed of small letters) and made same/different judgments based on attention to the big (global scope) or small (local scope) letter. The effects of this manipulation were measured on the composite face task, a well-established measure of holistic face perception. Autistic traits and sensory processing styles were measured using the Autism Quotient (AQ) and Sensory Profile (SP), respectively. In the Navon task, we observed a global interference effect, that is, greater susceptibility to interference from global information, relative to local. Furthermore, individuals with higher SP scores showed weaker global interference effects. ASD has been associated with both abnormal sensory processing styles, as well as weaker global interference effects. Consistent with this idea, we found an interaction in that SP was more strongly associated with global interference in individuals with higher AQ scores. In the composite face task, we found that the attention-to-detail subscale of the AQ predicted differences in susceptibility to the composite face illusion between global and local conditions. Specifically, individuals high in autistic traits were less capable of adopting a global attentional setting, which led to weaker

holistic face perception. These results shed light on how autistic traits and sensory processing styles converge to influence visual binding abilities.

Acknowledgement: Natural Science and Engineering Research Council of Canada (NSERC), Canadian Institutes of Health Research (CIHR)

43.4044 **Evidence for global perceptual averaging in individuals with Autism Spectrum Disorder** Jennifer Corbett[1] (jennifer.e.corbett@gmail.com), David Melcher[1]; [1]Center for Mind/Brain Sciences (CIMeC), University of Trento

Studies of visual perception in individuals with Autism Spectrum Disorder (ASD) report enhanced local processing, and either impaired or suppressed global processing. In contrast, we report evidence of global size averaging despite poor accuracy at recalling sizes of individual objects, as well as a persistent contextual influence of adaptation to mean size on the perceived size of single objects across groups of ASD and control observers. In Experiment 1, participants viewed a set of heterogeneously sized circles followed by two test circles and judged which test circle represented the mean size (mean task), or was a member (member task) of the set. Despite their noted hypersensitivity to local detail, the ASD group showed the same patterns of high accuracy in the mean task and chance accuracy in the member task as the control group, in-line with Ariely's (2001) proposal that observers can extract average properties of sets without retaining information about individual items. In Experiment 2, participants adapted to two patches of heterogeneously sized dots with large and small mean sizes, then judged which of two subsequently presented test dots was larger. Contrary to the notion that individuals with ASD are better at suppressing global context, both groups perceived the sizes of the physically identical test dots as an inverse function of the preceding adapting patches. This negative aftereffect of mean size adaptation across observers supports the proposal that mean size is encoded as a fundamental visual attribute (Corbett, et al., 2012). Taken together, results suggest that individuals with ASD show normal sensitivity to such contextual regularities in the surrounding environment. Our findings not only provide further evidence for the fundamental nature of perceptual averaging in vision, but also raise questions for theories that predict superior local visual processing and impaired or suppressed global visual processing in individuals with ASD.

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Multisensory Perception: Visuo-auditory interactions 2

Monday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4045 **An elephant never forgets the sound of a hammer: Task difficulty and multimodal search.** Bonnie Angelone[1] (angelone@rowan.edu), Alyssa Lompado[1]; [1]Rowan University, Psychology Department

How is attention divided in the human brain? What qualities of a task promote attentional division, and is there a point at which division hinders performance? Thus far, research has just examined limited situations in which multimodal stimuli are used. Tasks utilizing the pairing of visual and auditory stimuli have shown that the addition of auditory information does not inhibit performance (Kobus et al., 1986). Some research suggests that certain types of sound can enhance performance (Chen & Spence, 2011). Also, there was facilitation of visual search performance as auditory information that was unrelated to the task was added (Ngo & Spence, 2012). There may be other situations in which performance differs depending on task demands. To further investigate this, our studies consisted of a visual search task of six Snodgrass objects (Snodgrass & Vanderwart, 1980) paired simultaneously with an auditory stimulus that was either congruent or incongruent with the visual target. In three experiments, task difficulty was manipulated by varying the search category on each trial and the clarity of the image. Participants searched for visual objects that were either from the category "ANIMAL" or "HOUSEHOLD ITEM." As an assessment of accuracy they indicated where the target was on the screen. Generally, in all experiments, the pairing of an incongruent target and sound did not significantly impact reaction time and accuracy performance when the target category was more concrete, i.e. "ANIMAL." However, visual target and sound incongruency only impacted performance when the target type was not as well defined semantically, i.e. "HOUSEHOLD ITEM". This result was sustained even when the difficulty of the visual task was enhanced by degrading the screen with an overlay of "snow". Our results support that deficits in performance are more reliant on the semantic components of a task and the level of task difficulty.

43.4046 **Age-Related Differences in the Flash-Induced Beep Illusion** Denton DeLoss[1] (ddelo001@student.ucr.edu), George Andersen[1]; [1]University of California, Riverside

Previous research has found age-related differences in the sound-induced flash illusion. However, only a single study with younger adults has examined the effects of flashes on the perceived number of beeps (Andersen, Tiippana, & Sams, 2004). The current study examined this reversal of the illusion at multiple visual and auditory intensities in older and younger individuals. Twelve younger (M=22, SD=2.2) and twelve older (M=76, SD=7.1) individuals participated in the study. On the first day, 70%, 82% and 94% detection thresholds for a single visual flash and for a single auditory beep were determined with QUEST using a two-interval forced choice procedure. On the second day, participants were presented 1-2 beeps (3.5 kHz sine wave tones), paired with 0-2 flashes of a uniform white disc, 5° visual angle below fixation, presented on a grey background. Beeps were presented at the three threshold intensities, and were paired with 0-2 visual flashes that were also presented at the three threshold intensity levels. Participants reported the number of beeps perceived on each trial while ignoring the flashes. Results indicate that the illusion, while small, was consistently present and significant at all intensity levels. Older adults showed a greater effect of the illusion for both fusion (two beeps perceived as one when paired with one flash) and fission trials (one beep perceived as two when paired with two flashes). The effects of beep and flash intensity were found to be nearly equal for the age groups for fusion trials. However, the effects of intensity for older and younger participants was found to significantly differ for fission trials. The importance of these findings to aging, multisensory integration, and the sound-induced flash illusion will be presented.

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43.4047 **A mid-level sound-shape correspondence: Bouba/Kiki and radial frequency patterns** Pi-Chun Huang[1] (pichun_huang@mail.ncku.edu.tw), Yi-Chuan Chen[2], Charles Spence[2]; [1]Department of Psychology, National Cheng Kung University, Tainan, Taiwan, [2]Department of Experimental Psychology, Oxford University, Oxford, UK

One of the most well-established sound-shape correspondences is that the majority of people pair the word "Bouba" with rounded patterns while matching "Kiki" with angular patterns. To date, this correspondence has primarily been demonstrated using arbitrary visual patterns, and hence very little is known regarding the precise visual characteristics underlying this correspondence. In the present study, we examined the crossmodal mapping between bouba/kiki and radial frequency patterns in order to systematically manipulate the visual features of a pattern. A radial frequency pattern, a closed-contour with sinusoidal modulation along its radius, is widely used in shape perception studies and considered as mid-level visual processing. Three dimensions of the radial frequency patterns were manipulated: shape frequency, shape amplitude, and spikiness (by increasing the number of harmonics of triangular waveforms added on the top of rounded contour). In each trial, the participants (N = 74) viewed a radial frequency pattern on the screen and judged that either "bouba" or "kiki" (presented auditorily) provided a better match. The results demonstrate that all three factors modulated the sound-shape correspondence interactively. When the shape frequency increased from 3 to 11 cycles/360 degrees, the associated sound shifted from "bouba" to "kiki". In the intermediated shape frequency ranging between 5 and 7 cycles/360 degrees, the associated sound shifted from "bouba" to "kiki" either when the shape amplitude or the spikiness was increased. These results suggest that shape frequency dominated over the shape amplitude and spikiness in determining the sound-shape correspondence that was observed, implying that visual global/local processing may underpin this particular sound-shape correspondence. We suggest that radial frequency patterns thus provide an intriguing visual stimulus set with which to systematically investigate the crossmodal correspondence between bouba/kiki and rounded/angular shapes. Furthermore, a possible hierarchy of crossmodal correspondences including early-level features, mid-level patterns, and high-level object can be established.

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43.4048 The correspondence between neutral voice and face is mediated by common perceptual properties Shoko Kanaya[1] (s.kanaya@aist.go.jp), Yoshiyuki Ueda[2], Hideyuki Tochiya[3], Kazuhiko Yokosawa[3]; [1]National Institute of Advanced Industrial Science and Technology (AIST), [2]Kyoto University, [3]The University of Tokyo

We can infer a voice of an unfamiliar person from his/her face. One hypothesis attributes this to common information conveyed by voices and faces. However, the nature of this critical information remains unclear (Mavica & Barenholz, 2013). Some recent reports have shown that auditory and visual stimuli, which do not have any direct relations (e.g. music – color, timbre – visual texture), nonetheless appeared to be related based on certain perceptual and emotional properties (Palmer et al, 2013; Peterson et al., 2014). The present study examined whether supra-modal information, such as perceptual and emotional properties and personality traits can mediate such inferential links between voice and face. In this experiment, voices conveyed neutrally spoken sentences and faces were neutral visual pictures of male/female faces. To investigate indirect relationships between voice and face, models of pictures were different people than the speakers. In the first task, one voice was presented simultaneously with multiple faces, and participants had to select the first, second and third faces that corresponded to the presented voice. In a second, then a third task, the voice and face were independently presented along with 18 pairs of bipolar adjectives. Using an eight point scale, participants rated the likelihood of a voice or face matching a given pole. Adjectives described perceptual properties (e.g. smooth - rough), emotional properties (e.g. happy - sad), and personality traits (e.g. passive - dominant). For each adjective pair, a weighted average of ratings of faces selected as corresponding to each voice was calculated. Results showed that weighted averages were strongly correlated with ratings for the voice itself, especially for certain perceptual adjectives (e.g. r = .74, glossy – matte). This suggests that the correspondence between neutral voices and faces are mediated mainly by perceptual properties.

43.4049 Acquiring multiple cross-modal correspondences Erika Kumakura[1] (kumakura@l.u-tokyo.ac.jp), Kazuhiko Yokosawa[1]; [1]The University of Tokyo

Cross-modal correspondences are tendencies to match co-occurring features across sensory modalities that stem from statistical relations of co-occurring features in daily experience (Spence, 2011). Previous studies have demonstrated that a novel one-to-one correspondence between different sensory features can be acquired through perceptual learning (Ernst, 2007; Michel & Jacobs, 2007). However, it is not certain whether a generalized representation of cross-modal correspondence can be formed merely from co-occurrence of multiple features. Also unknown is whether perceptual learning of correspondences can happen in noisy environments. This study investigated whether subjects can form a generalized representation from correspondences among specific multiple features (Exp.1); it also considered whether other co-occurring features, which are randomly selected (i.e. accessory features), affect perceptual learning (Exp.2). Subjects had to judge whether the contrast of a presented Gabor patch was "High" or "Low" while listening to a pure tone. During this task, the specific pair of visual orientation and auditory loudness co-occurred with either high or low contrast (i.e. Exemplars). In Exp.2, as accessory features, pitch features co-occurred and were randomly selected with other features. We analyzed subjects' judgments to the medium contrast which co-occurred with all pairs of orientation and loudness. We predicted that if subjects can learn statistical relationships of multiple features and generalize these, then their judgments of the medium contrast should be modulated according to the co-occurred pair of orientation and loudness. In Exp.1, subjects' judgments of the medium contrast revealed a partial modulation to "High" when the co-occurring pair of orientation and loudness appeared with high contrast, but not vice versa. Exp. 2, involving pitch manipulation, resulted in more extensive learning than in Exp 1. These results suggest that multiple feature correspondence can be generalized through perceptual learning, within limits; it also suggests that accessory features may facilitate this learning.

43.4050 Relations among Visual Texture, Musical Features, and Emotion Thomas Langlois[1] (thomas.langlois@berkeley.edu), Joshua Peterson[2], Stephen Palmer[3]; [1]Department of Psychology, University of California, Berkeley

Previous research indicates that systematic music-to-color cross-modal associations in non-synesthetes are mediated by emotion (e.g., Palmer et al., 2013; Langlois et al., under review; Whiteford et al., VSS-2013). The present research asks whether specific musical features mediate cross-modal associations from music-to-texture by using single-line melodies that vary along highly controlled musical dimensions: register (low/high), mode (major/minor), note-rate (slow/medium/fast), and timbre (piano-sound/cello-sound). We also investigated whether these associations are mediated by emotional and/or geometric factors. First, 46 non-synesthetic participants picked the 3 most-consistent (and later 3 least-consistent) textures for each of 32 variations on a synthesized melody from a 4x7 array of black-and-white textures. Next, they rated each melody, and later each texture along 5 emotional dimensions (Happy/Sad, Angry/Not Angry, Agitated/Calm, Weak/Strong, Harmonious/Disharmonious), and a series of geometric dimensions (e.g., Simple/Complex, Sharp/Smooth, Granular/Fibrous, Curved/Straight, Separate/Connected). For each dimension, we computed Music-Texture-Associations (MTAs) as a weighted average of the ratings of the 3 textures chosen as going best/worst with each melody. Results indicated that cross-modal melody-to-texture associations were emotionally mediated, because the correlation between the emotional ratings of the music and the emotional MTAs of the chosen textures were so high (Angry/Not-Angry=.79, Calm/Agitated=.91, Active/Passive=.76, Harmonious/Disharmonious=.64). Unlike music-to-color associations, the Happy/Sad correlation (r=.31). was not significant. Melodies-to-texture associations were also mediated by shared geometric features (e.g., Sharp/Smooth=.96, .Curved/Straight=.92, Simple/Complex=.89, Granular/Fibrous=.80). Crucially, the cross-modal melody-to-texture associations corresponded to specific musical features. k-means clustering analyses revealed strong timbre and note-rate effects: cello melodies were paired with straight/sharp/fibrous textures, and piano melodies with curved/smooth/granular textures. Different textures were also chosen for different note-rates, with more granular/separate textures being chosen with slow note-rate melodies, and more fibrous/connected textures being chosen with faster note-rate melodies. These clusters show that the note-rate and timbre of a melody can be inferred reliably from visual texture correspondences alone.

Acknowledgement: NSF

43.4051 Dissociation of Perception and Action in Audiovisual Multisensory Integration Lynnette Leone[1] (lynnette.leone@ndsu.edu), Mark McCourt[1]; [1]Center for Visual and Cognitive Neuroscience, Department of Psychology, North Dakota State University

Early reports of audiovisual (AV) multisensory integration (MI) indicated that unisensory stimuli must evoke simultaneous physiological responses to produce decreases in reaction time (RT). The "temporal rule" states that MI depends on the temporal proximity of unisensory stimuli, the neural responses to which must fall within a temporal window of integration. Ecological validity demands that MI occur only for simultaneous events (which may give rise to non-simultaneous neural activations), and spurious neural response simultaneities unrelated to veridical multisensory occurrences must be rejected. Two experiments investigated the question of simultaneity in AV MI. Experiment 1 used an RT/race model paradigm to measure AV MI as a function of stimulus onset asynchrony (SOA: ±200 ms, 50 ms intervals) under fully dark-adapted conditions for visual (V) stimuli that were either rod- (scotopic 525 nm flashes; 511 ms mean RT) or cone-isolating (photopic 630 nm flashes; 356 ms mean RT). Auditory (A) stimulus (1000 Hz tone) intensity was constant. Despite the 155 ms slower mean RT to the scotopic versus photopic stimulus, facilitative AV MI in both conditions occurred exclusively at a 0 ms SOA. Thus, facilitative MI demands both physical and physiological simultaneity. Experiment 2 investigated the accuracy of simultaneity and temporal order judgments with these same stimuli. Facilitation of RT was not reflected in accurate judgments of AV stimulus simultaneity or temporal order (difference in average PSS = 74.79 ms and 40.08 ms, respectively). We consider the mechanisms by which the nervous system may take account of variations in neuronal response latency arising from changes in stimulus intensity to selectively integrate only those physiological simultaneities that arise from physical simultaneities. We discuss the possibility that this integration is predominantly for the purpose of taking action, that vision for perception may be more susceptible to temporal discrepancies.

Acknowledgement: NIH P20 GM103505

43.4052 Emotion mediation in audio-visual correspondences among natural sounds, texture, and art Joshua Peterson[1] (jpeterson@berkeley.edu), Stephen Palmer[2]; [1]University of California, Berkeley, [2]University of California, Berkeley

Previous research shows that music-to-color associations are mediated by emotion (Palmer et al., 2013), even for low-level musical stimuli, including two-note intervals and instrumental timbres (Griscom & Palmer, VSS-2012). To test the generality of such emotional effects beyond music and color, we first examined crossmodal relationships between natural sounds (e.g. zippers, flames, radio static) and line-based visual textures. For each

Monday AM

sound, participants chose the three most-consistent and three least-consistent among 28 black-and-white textures. Subjects later rated each sound and texture individually on 5 emotional (e.g. happy/sad, angry/not-angry) and 8 non-emotional dimensions (e.g. sharp/smooth, simple/complex). For each dimension, we computed an index of sound-to-texture associations (STAs) as a weighted average of the ratings of the 6 textures chosen as going best/worst with each sound. We found medium correlations between ratings of the sounds and the STAs of the textures chosen to go best/worst with them for some non-emotional dimensions (e.g. simple/complex=+.57, slanted/not-slanted=+.59), but no emotional dimensions. Because previous emotion mediation effects involved highly emotional stimuli, such as music, we hypothesized that an emotional visual stimulus, such as abstract art, might result in emotion mediation with the same natural sounds. Using the same design, a sound-to-artwork association task produced medium correlations between sound ratings and the sound-to-artwork association indices of the artwork chosen to go best/worst with them for both emotional (e.g. angry/not-angry=+.62) and non-emotional dimensions (e.g. simple/complex=+.60). We also tested for synergistic effects using two modalities that both contained highly emotional content: the same 28 abstract-art pieces and 34 widely-varying musical selections from heavy-metal to Hindustani-sitar. Strong correlations emerged between music ratings and the music-to-artwork association indices of the artwork chosen as going best/worst with them for both emotional (e.g. calm/agitated=+.88) and non-emotional dimensions (e.g. active/passive=+.87). The results suggest that emotion-mediated crossmodal matches are context dependent, depending on the modalities involved.

43.4053 **The impact of auditory task demands on visual search: Evidence from behavior and fixation-related brain potentials**

Anthony Ries[1] (anthony.ries@us.army.mil), Jon Touryan[1], Barry Ahrens[2], Patrick Connolly[2]; [1]U.S. Army Research Laboratory, Human Research and Engineering Directorate, Translational Neuroscience Branch - Aberdeen Proving Ground, MD , [2]Teledyne Scientific Company - Durham, NC

Eye-fixations elicit a neural response commonly referred to as the lambda potential that is similar to the visually-evoked P1 event-related potential (ERP) component. An outstanding question is whether the lambda potential is influenced by concurrent auditory task demands. To address this question we obtained simultaneous eye-movement and electroencephalographic (EEG) measures during a guided visual search task while parametrically modulating working memory load using an auditory N-back task. Eye fixations were guided across a grid of letters consisting of 'L's (non-targets) at random orientations. Participants were instructed to make a button press when they fixated on the infrequent target letter 'T'. Participants performed the guided fixation task alone, while ignoring binaurally presented digits, or while using the auditory information in a 0, 1, or 2-back task. Our results show that reaction time increased and accuracy decreased in both the visual search task and auditory N-back task as a function of working memory load. Moreover, we found evidence that the amplitude of the fixation-related potentials were affected by auditory working memory demands. These results suggest that active engagement in an auditory task can influence early stages of visual processing and negatively affect visual search performance. The data provide support for a link between cross-modal processing resources.

43.4054 **Influence of vision on auditory spatial perception in sighted people.** Alessia Tonelli[1] (alessia.tonelli@iit.it), Luca Brayda[1], Monica Gori[1]; [1]Robotics, Brain and Cognitive Sciences Department , Italian Institute of Technology

Recent evidence, in early blinds individuals, supports the idea that the visual modality might be fundamental to calibrate the complex auditory space perception (Gori et al. 2014). Here we examined in blindfolded sighted participants whether the observation of the room, in which they are immersed, improve complex auditory accuracy. We asked two groups of blindfolded sighted participants to perform two tasks which require different skills: auditory spatial bisection and spatial discrimination. The first group performed the tasks in an anechoic chamber, the first time without the possibility to see the room; the second time, after the room was visually inspected. The second group followed the same procedure, but the tasks were performed in a normal room. The accuracy of responses in both tasks in the anechoic chamber was the same before and after seeing the room. Interestingly, the second group had an improvement of bisection accuracy, but not in the discrimination accuracy, after seeing the normal room. These evidence suggests that the visual system aids the auditory system to exploit spatial knowledge of the room when localizing complex sounds.

43.4055 **Inter-individual response differences predict multisensory response enhancement** Maarten van der Smagt[1] (M.J.vanderSmagt@uu.nl), Nathan van der Stoep[1]; [1]Experimental Psychology, Helmholtz Institute, Utrecht University

Research on multisensory integration often makes use of stochastic ('race-') models to distinguish performance enhancement in Reaction Times (RTs) due to multisensory integration from enhancement due to statistical facilitation. Only when performance on a multisensory task supersedes that of the race-model it is attributed to multisensory 'integration'. Previously (VSS 2014) we have shown that the subjective cross-modal correspondence (i.e. a subjective intensity match) influences the degree to which race-model violations occur. Here we investigate how the resulting inter-individual RT-difference to unimodal auditory and visual stimuli affects multisensory integration. Observers first matched the loudness of a 100ms white noise burst to the brightness of a 0.86° light disc (6.25 cd/m2) presented for 100ms on a darker (4.95 cd/m2) background, using a staircase procedure. In a subsequent speeded detection experiment, the observers were instructed to press a key as soon as an audiovisual, auditory only or visual only target was presented to the left or right from fixation. The subjectively matched loudness as well as +5dB and -5dB loudness values were used as auditory stimuli. Catch trials without stimulation were also included. We calculated for each subject, and each auditory condition, the unimodal RT-difference between detecting a visual or auditory stimulus. In addition we calculated the Multisensory Response Enhancement (MRE), and whether the race-model predictions were violated (RMV). We correlated MRE and average RMV with unimodal RT-differences across observers. Interestingly, the results show a significant, negative, correlation between MRE magnitude and unimodal RT-difference, but no correlation between MRE and individual RT's, nor any correlation between RMV and the unimodal RT-difference. These results are in line with the model proposed by Otto, Dassy and Mammasian (Journal of Neuroscience, 33, 7463-7474, 2013) and indicate that unimodal stimuli that yield similar RTs in an individual lead to the largest Multisensory Response Enhancement.

Multisensory Perception: Visuo-haptic and visuo-vestibular interactions

Monday, May 18, 8:30 am - 12:30 pm

Poster Session, Pavilion

43.4056 **V6 is active during antero-posterior but not in lateral galvanic vestibular stimulation.** Felipe Aedo-Jury[1,2] (felipe.aedo-jury@cerco.ups-tlse.fr), Simona Celebrini[1,2], Benoit Cottereau[1,2], Maxime Rosito[1,2], Alexandra Séverac-Cauquil[1,2]; [1]Université de Toulouse, Centre de Recherche Cerveau et Cognition, Toulouse, France, [2]Centre National de la Recherche Scientifique, Toulouse Cedex, France

Vestibular and visual signals are crucial to navigate. Therefore, it is important to identify the areas devoted to integrate both signals. A recent work has identified 2 cortical areas activated during lateral galvanic vestibular stimulation (GVS): the human medial superior temporal cortex and the cingulate sulcus visual area (CSV) (Smith AT et al, 2012). V6 has been identified to be active during optic flow stimulation but not during lateral GVS (Cardin V & Smith AT, 2011). Here, We investigated the cortical networks processing antero-posterior visuo-vestibular information using fMRI. Particularly whether V6 is involved in antero-posterior vestibular stimulation. GVS evokes antero-posterior or lateral sway according to the stimulation configuration (Séverac-Cauquil A et al, 1998). We randomly applied 1mA, 2-s, GVS in four configurations (front, back, left, right) on 13 subjects while recording their BOLD activity in the scanner. Our results show that BOLD activity for antero-posterior contrasted to lateral stimulation increased significantly in superior dorsal area (SDA) and inferior temporal cortex (ITC). A posteriori region of interest analysis using functional localizers and retinotopic mapping to identify CSV and V6 (Smith AT et al, 2012) showed significantly larger BOLD activation in V6 during antero-posterior compared to lateral stimulation and baseline whereas CSV showed a significant BOLD increase for both axes compared with baseline, but no difference between both conditions. Based on these results, we hypothesize that visual cortical areas V6, SDA and ITC are specific for anterior-posterior direction, while other visual areas, CSV, VIP and MST respond equally to vestibular input in both axes. We concluded that different visual areas are possibly devoted to integrate information coming from different direction of self-motion.

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See page 3 for Abstract Numbering System

43.4057 **The development and organization of visuohaptic modality-biased signals in the LOC** R. Joanne Jao[1,2] (rjjao@indiana.edu), Karin James[1,2,3], Thomas James[1,2,3]; [1]Cognitive Science Program, Indiana University, Bloomington, [2]Department of Psychological and Brain Sciences, Indiana University, Bloomington, [3]Program in Neuroscience, Indiana University, Bloomington

Areas of the putative visual cortex are involved in combining multisensory information about object shape. In particular, the lateral occipital complex (LOC) is a known region involved in visuohaptic object recognition. Relative to adult research, there have been few studies investigating the development of crossmodal perception of visual and haptic information, and fewer still exploring the neural substrates of this ability. In the present study, BOLD fMRI was measured in children aged 7 to 8.5 years and in adults during intramodal (visual-to-visual, haptic-to-haptic) and crossmodal (visual-to-haptic, haptic-to-visual) delayed match-to-sample recognition tasks. In both children and adults, results indicated that the ventral occipitotemporal cortex followed a medial to lateral organization in which there was a visual to haptic bias in the mapping of sensory modalities used to process shape information. These areas were adjacent to (and on either side of) an overlapping bimodal region within the LOC (corresponding to LOtv). Additionally, results showed a crossmodal enhancement effect in which crossmodal matching produced greater activation than intramodal matching in the overlapping bimodal LOC region (LOtv), but not in the medial visual-preferring or lateral haptic-preferring areas of the LOC, suggesting that this bimodal region was sensitive to sensory changes. Finally, although children and adults did not differ qualitatively in the overall patterns of neural activity, children produced more widespread, but lower intensity, activation than adults. This suggests that fundamental neural support for visuohaptic object processing is present by 7 years, but requires fine-tuning to be adult-like. Finding a haptic-preferring region in the LOC suggests that the multisensory signals integrated in the LOtv likely arrive via neighboring modality-biased regions within the LOC itself. We hypothesize that these modality-biased regions transform somatosensory and visual signals to facilitate multisensory integration in the LOtv. A future step should be identifying the exact nature of those transformations.

43.4058 **Inter-modal attention shifts trigger the selective activation of task-relevant tactile or visual working memory representations** Tobias Katus[1] (t.katus@bbk.ac.uk), Anna Grubert[1], Martin Eimer[1]; [1]Department of Psychology, Birkbeck College, University of London

The sensory recruitment account of working memory (WM) assumes that the short-term retention of visual or tactile stimuli is implemented by cortical areas that are also responsible for the perceptual processing of these stimuli. Focal attention supports the short-term retention of sensory information, but it is unknown whether attention can also be flexibly shifted between visual and tactile WM representations. This study explored such inter-modal attention shifts in a task that required memory for simultaneously presented tactile and visual stimuli. A set of bilateral tactile and visual sample stimuli was followed after a retention period by a set of test stimuli. In different blocks, participants were instructed to memorize all stimuli on either the left or the right side. An auditory retro-cue, presented 500 ms after the sample sets, signalled whether the tactile or visual stimuli were relevant for the upcoming memory test. To study how these cues affect tactile and visual short-term storage, we measured the visual contralateral delay activity (CDA component) of the event-related potential (ERP) and its tactile counterpart (tCDA) that are elicited over modality-specific visual and somatosensory cortex. Scalp current density transforms were used to minimize volume-conduction, and to simultaneously measure these components over somatosensory and visual regions of interest (ROIs). A significant ROI x cued modality interaction demonstrated that visual and tactile WM was affected by the cued task-relevance of these sensory modalities. The tCDA component over somatosensory scalp regions was present only when touch was cued. The CDA over visual cortex was present in both cueing conditions, but was larger when vision was cued. Our results suggest that tactile and visual stimuli are stored separately in modality-specific memory systems. We conclude that retro-cues elicit inter-modal attention shifts that selectively activate information in the currently task-relevant modality.

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43.4059 **The influence of scene rigidity and head tilt on vection.** Pearl Guterman[1] (pearljam@cse.yorku.ca), Robert Allison[1]; [1]Centre for Vision Research, York University, Toronto, Canada

Changing head orientation with respect to gravity changes the dynamic sensitivity of the otoliths to linear accelerations (gravitational and inertial). We explored whether varying head orientation and optic flow direction relative to gravity affects the perception of visually induced self-motion (vection). We previously found that vection was enhanced when upright observers viewed lamellar flow that moved vertically relative to the head (i.e., simulating self motion along the spinal axis) compared to horizontal flow. We hypothesized that if this benefit was due to aligning the simulated self-motion with gravity, then inter-aural (as opposed to spinal) axis motion while laying on the side would provide a similar vection advantage. Alternatively, motion along the spinal axis could enhance vection regardless of head orientation relative to gravity. Observers stood and lay supine, prone, left and right side down, while viewing a translating random dot pattern that simulated observer motion along the spinal or inter-aural axis. Vection magnitude estimates, onset, and duration were recorded. The results showed that aligning the optic flow direction with gravity enhanced vection in side-laying observers, but when overlapping these signals was not possible—as in the supine and prone posture—spinal axis motion enhanced vection. However, perceived scene rigidity varied with head orientation (e.g., dots were seen as floating bubbles in some conditions). To examine the issue of scene rigidity, we compared vection during simulated motion with respect to two environments: a rigid pipe structure which looked like a complex arrangement of plumbing pipes, and a field of dots. The results of varying head and motion direction and perceived scene rigidity will be discussed, and may provide insight into whether self-motion perception is determined by a weighted summation of visual and vestibular inputs.

43.4060 **Direction discrimination of self motion consistent optic flow stimuli in multisensory integration cortices.** Nadine Hummel[1,2] (Nadine.Hummel@lrz.uni-muenchen.de), Virginia Flanagin[1,2]; [1]German Center for Vertigo and Balance Disorders (DSGZ), Ludwig-Maximilians University Munich, [2]Graduate School of Systemic Neurosciences, Ludwig-Maximilians University Munich

Introduction When we move, optic flow generated on our retina, provides information about the speed and direction of our motion. Conversely, self-motion consistent optic flow presented to a stationary observer can evoke the perception of self motion, or vection. Patterns of activity in primary and higher visual areas can be used to decode information about the orientation and motion direction of visual stimuli. Self-motion consistent optic flow stimuli activate additional regions of the parietal cortex involved in multisensory integration of visual and vestibular information, but it is not yet clear whether direction sensitivity also exists there. Here we analyze activation patterns in these regions, during the presentation of self motion consistent optic flow stimuli. Methods Twenty-six subjects judged their heading direction based on self motion consistent optic flow stimuli in a 2 AFC paradigm, during fMRI. Brain activation patterns of eight heading directions in the fronto-orthogonal plane were evaluated using both univariate and pattern classification approaches. Functional localizers were used to identify area MT/MST and vection sensitive parietal regions. Results The univariate analysis revealed different BOLD levels for the eight heading directions throughout the dorsal visual stream. This included primary, as well as higher visual areas, parietal regions and some frontal regions. Cardinal and oblique directions showed differential activation within these regions. In a searchlight analysis, the stimuli were successfully classified within the same regions of the brain. Region-of-interest analyses revealed that area MT/MST, as well as the vection sensitive intraparietal sulcus show reliable pattern discrimination of the eight heading directions. Discussion Our results show that direction sensitivity for self motion consistent optic flow exists in primary as well as in higher visual areas. Heading direction is successfully decoded in brain regions involved in visuo-vestibular integration. This provides important insights towards an understanding of human navigation in space.

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43.4061 **Combining visual and proprioceptive cues to improve the discrimination of object location** Mark Adams[1] (mark.adams246@gmail.com), Peter Scarfe[1], Andrew Glennerster[1]; [1]School of Psychology and CLS, University of Reading

Little is known about the way in which visual and proprioceptive cues for object location are combined. In order to investigate this, we measured the ability of participants to discriminate the location of a virtual target in the presence or absence of proprioceptive information. Participants viewed three virtual reference spheres using a head mounted display. The spheres lay on a circle of radius 14 cm and defined a reference plane that was located within easy reaching distance of the participant. In the proprioceptive condition, participants moved a hand-held pointer to the centre of each sphere in turn. When the pointer was fully inside the reference sphere, the sphere changed colour from red to green to indicate cor-

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rect alignment. Once all three spheres had turned green, the participant clicked a mouse which made the spheres disappear to be replaced by a target sphere. A similar reaching movement was then performed to locate the centre of the target sphere. Once both the reference and target spheres had been located, the participant's task was to judge the depth of the target sphere relative to the plane defined by the previously-displayed reference spheres. For the vision-only condition, the procedure was similar but participants made their judgements without reaching towards either the reference or target spheres. Thresholds (defined as the standard deviation of the fitted cumulative Gaussian) were measured both with and without hand movements and also for two levels of transparency of the spheres. Results show that thresholds for combined proprioception and vision were significantly lower than for vision alone. In other words, proprioceptive input significantly improved depth discrimination despite vision being both sufficient to complete the task and necessary to define the proprioceptive cue.

Acknowledgement: EPSRC

43.4062 Visual and Haptic Shape Recognition Memory

J Farley Norman[1] (farley.norman@wku.edu), Jacob Cheeseman[1], Olivia Adkins[1], Connor Rogers[1], Andrea Cox[1], Michael Baxter[1], Hideko Norman[1]; [1]Department of Psychological Sciences, Ogden College of Science and Engineering, Western Kentucky University

Little is known about memory for solid (3-D) shape, especially for unfamiliar naturally-shaped objects. In the current Experiment 1, participants haptically explored or viewed a set of six bell peppers (Capsicum annuum) either once, four times, or seven times. On each study trial, the participants either viewed or haptically explored a particular bell pepper for 15 seconds. The participants' recognition memory was tested immediately. Twelve bell peppers were then presented (visually or haptically); the participants judged whether each one was either old (previously presented during the study phase) or new. Recognition performance was similar for vision and haptics when each of the original bell peppers was studied once. However, when the original bell peppers were studied multiple times (4 or 7 times), the participants' visual recognition performance was higher (by 33.7 percent) than that obtained for haptics. The procedure used for Experiment 2 was identical (objects were studied 4 times), except that a 10- or 20-minute delay was inserted in between the study and test sessions. There was no effect of delay upon haptic shape recognition. In contrast, a 10- or 20-minute delay produced substantial reductions in performance for visual shape recognition. Overall, visual solid shape memory was superior to haptic shape memory, especially when memory was tested immediately.

43.4063 Visual and haptic geometry of 3D shape discrimination

Flip Phillips[1] (flip@skidmore.edu), Emerson O'Donnell[1], Noah Kernis[1]; [1]Skidmore College, Neuroscience & Psychology

There are countless candidate 'features' useful for the perceptual discrimination of three-dimensional shape. Human vision and touch use both modality-specific and cross-modal information to accomplish this task. For example, only vision can make diagnostic use of shading, color and optical texture while only touch can detect temperature, vibratory and other proprioceptive information such as joint angle. Some characteristics such as the physical texture of an object provide both visual appearance and tactile roughness information. When attempting to determine the 3D shape of an object its structural geometric information underlies most if not all of the useful features used by both vision and touch, individually or in concert. It is an open question as to what specific geometric information is essential or useful when performing discrimination tasks that involve vision, touch or their interaction. This research investigates the use of statistical differential geometric information while performing detection and discrimination tasks, both within and across perceptual modalities. We use eye- and hand-tracking to determine which parts of an object our subjects explore while making shape discrimination and differentiation decisions. We correlate these high-exploration regions with the objects' underlying differential geometric structure. We find that object regions with high curvature contrast are useful across both modalities as they define 'sharp' linear structures. Similarly, areas with high relative curvedness provide useful point landmarks. We further show that some geometric structures are more useful within a particular modality than another. As a result the worst-performing modality limits cross-modal use of this information but simultaneous presentation is facilitative. Finally, the statistical distribution of differential geometric structures serves to define diagnostic 'features' available to either touch or vision. The relative occurrence of features and their magnitude determine their usefulness within and across modalities.

Attention: Divided attention and capture

Monday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4064 Time-Shared Visual Awareness of Multiple Moving Objects

Joseph Lappin[1] (joe.lappin@vanderbilt.edu), Douglas Morse[2], Adriane Seiffert[1]; [1]Psychology, Arts & Science, Vanderbilt University, [2]Psychology & Human Development, Peabody College, Vanderbilt University

How does vision encompass multiple moving objects? Well-trained observers monitored ongoing patterns of randomly moving objects, trying to quickly detect a non-random target motion (pursuit of a visible 'prey') by any one of the objects. Three experiments evaluated effects of the set size of observed objects (n = 1 – 12) on the temporal process of motion detection. Strikingly lawful effects on motion detection were observed: (1) Detection rates slowed in direct proportion to set size. (2) Two simultaneous visual processes governed motion detection — spatiotemporal motion integration (independent of conscious awareness), and constant-rate transfer into conscious awareness. The rates of both reflected time-shared parallel processes divided among the set of moving objects. Conventional RT analyses inadequately described the temporal process. Conditional detection rates for targets not yet detected — hazard rates (bits/sec), rates of change in RT — revealed simple lawful effects of set size on motion detection. For all observers, set sizes, motion speeds, and response times, detection rates had two phases: a first phase (~ 0.4 s) of motion integration in which detection rates increased linearly with time, followed by a second phase of constant-rate detection invariant with increasing time and motion. Detection rates decreased proportionally with set size in both phases. In Exp. 1, (n = 2, 4, 6, 8 objects), this two-phase process (3 parameters) described 98% of the variance of detection rates associated with set size and response time (Fig. 1). Exp. 2 (n = 1, 4, 12) found that greater motion speed yielded faster detections, but detection rate in spacetime was invariant with motion speed. Exp. 3 (n = 1, 2, 4, 8) found that early motion integration was hindered without a visible 'prey' object, but later awareness of the motion was unaffected.

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43.4065 Attentional tuning to events associated with long-term concerns

Jennifer Whitman[1] (jenwhitman@gmail.com), Kevin Roberts[1], Rochelle Picardo[1], Jiaying Zhao[1], Rebecca Todd[1]; [1]Department of Psychology, University of British Columbia

Stimulus features such as brightness, color, and subjective arousal level are potent in capturing attention. This capture facilitates perceptual encoding and subsequent processing. Yet, it is still unknown whether stimuli related to long-term personal concerns similarly capture attention. To address this question, we employed an attentional blink (AB) paradigm, where observers detected two targets embedded in a stream of distractors during rapid serial visual presentation. The second target (T2) was either a word related to climate change or a neutral word (Experiment 1). Observers were more likely to detect T2 if it was climate-related than neutral. We refer to this reduced attentional blink for words related to climate change as climate word AB sparing. To examine whether this was driven by emotional arousal, we added a condition with negative emotionally arousing words (Experiment 2). We again found that observers were more likely to detect climate-related and negative T2 words than neutral ones. However, the climate words (e.g. carbon) were rated as less arousing than the negative words (e.g. murder), suggesting that climate word AB sparing was not strictly due to immediate arousal. Finally, to examine whether the sparing was explained by semantic priming, because climate words share a semantic category, we performed a version of the experiment with health-related rather than climate-related words (Experiment 3). Observers were equally likely to detect health-related or neutral targets, suggesting that the climate-word AB sparing was not due to semantic priming. In all experiments, no mention of climate change was made in the instructions. In subsequent surveys, most observers expressed environmental concerns. Thus, the heightened perceptual encoding of climate change stimuli was driven by long-term concerns. In sum, these findings suggest that attentional tuning to salient stimuli can reflect associations with long-term concerns, rather than immediate arousal or priming of a semantic category.

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43.4066 The limitations of visual working memory in prioritizing visual stimuli for conscious access Dirk van Moorselaar[1] (d.van.moorselaar@vu.nl), Jan Theeuwes[1], Christian Olivers[1]; [1]Vrije Universiteit, Amsterdam

Models of biased competition assume that visual working memory (VWM) representations bias visual selection. Dual-task studies in which participants perform a visual search task while holding specific content in VWM, have suggested that only a single VWM representation at a time can interact with visual attention. The presents study tested more directly the limitations of VWM in prioritizing visual stimuli for a conscious experience. Recent evidence from breaking continuous flash suppression (b-CFS) studies shows that targets matching a single item in memory break through interocular suppression faster than non-matching targets. In the present set of experiments we used this technique to assess if memory-matching targets also break through more rapidly when more than one item was in memory. In the first experiment the target was the only item in the visual display. Results showed that targets matching the VWM content broke through the CFS sooner than non-matching targets. Moreover, breakthrough was as fast for one item as for two items in memory, suggesting that more than one item in VWM can affect prioritization for consciousness. However, in subsequent experiments the target was not the only item in the display, but accompanied by competing objects. Under these conditions, the breakthrough benefit was reduced by half when memory load went from one to two. The results are consistent with a dissociation between VWM functions: Filtering relevant from competing non-relevant information, and making this relevant information accessible for conscious report. The first process suffers from increasing load from one to two, while the second does not. Implications for models assuming a single active representation in VWM are discussed.

43.4067 Feature priming rather than visual working memory affects oculomotor selection in a bottom-up manner Jeroen Silvis[1] (j.d.silvis@vu.nl), Artem Belopolsky[1], Jozua Murris[1], Mieke Donk[1]; [1]Vrije Universiteit Amsterdam, Department of Cognitive Psychology

It has been demonstrated that objects held in working memory can influence rapid oculomotor selection. This has been taken as evidence that perceptual salience can be modified by active working memory (e.g. Hollingworth, Matsukura & Luck, 2013). The goal of the present study was to examine whether these results could be better explained by feature-based bottom-up priming. In two experiments, participants were asked to saccade to a target line segment that was presented together with a to-be-ignored distractor. Both objects were given a task-irrelevant color that varied per trial. In a secondary task, a color had to be memorized, a color that either matched the target, the distractor, or none of the objects in the eye movement task. The memory task was completed either after the eye movement task (Experiment 1), or before (Experiment 2). The results showed that memory content biased oculomotor selection, an effect that was most pronounced for short-latency saccades. Crucially, this effect was similar in both experiments. This suggests that bottom-up feature priming rather than the active maintenance in VWM is the driving force behind early biases in oculomotor selection.

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43.4068 Exploring Visual Search as a Paradigm for Predicting Medication Errors Nelson Roque[1] (roque@psy.fsu.edu), Timothy Wright[1], Walter Boot[1]; [1]Florida State University

According to the FDA, over a million injuries occur each year in the United States due to medication errors. Furthermore, medication management is considered an Instrumental Activity of Daily Living (IADL), and inability to manage one's medications can threaten an individual's independence. These errors occur for a number of reasons, including similar sounding/looking medication names and labels, but also due to pills that look extremely similar. We present initial work looking at whether a visual search paradigm might be used to help predict medication mix-ups. We extracted images of pills from the NIH's Pillbox database, and observers were asked to search for a target pill among similar or dissimilar distractors. Set size was also manipulated (3, 6, 9 items). Results indicated that search slopes may serve as a sensitive and continuous measure of pill confusability. For example, two pills that were extremely similar in terms of color, shape, and size produced relatively steep search slopes (28 ms/item target present, 80ms/item absent), while two pills that were similar in shape and size, but different in color produced parallel search slopes (< 2 ms/item for present and absent conditions). In this case, neither target present nor absent conditions indicated a significant effect of set size ($t(27) = -.22$, $p = .83$ and $t(27) = .59$, $p = .56$, respectively). Overall, these results indicate potential for this paradigm to be used to study and predict medication errors, and future work will extend findings to take into account changes in acuity and color perception associated with advancing age by testing younger and older adults.

43.4069 Active Suppression in Video-Game Players: An ERP Study James Patten[1] (jwpatten@gmail.com), John Gaspar[1], John McDonald[1], Thomas Spalek[1]; [1]Psychology, Simon Fraser University

Several aspects of visual attention are thought to be affected by time spent playing action-oriented video-games. One such aspect is attentional capture, which occurs in visual search when attention is involuntarily deployed to a task-irrelevant item in a search array. One recent study has found the strength of capture to be less for video-game players (VGP), and suggested that, once attention had been captured, VGPs were faster at redeploying attention to the relevant target. An alternative explanation is that both VGPs and typical individuals may not be captured by the irrelevant distractor, and may instead be actively suppressing it. This might suggest that VGPs are better able to suppress salient but irrelevant stimuli. This hypothesis was tested in an experiment using the Event Related Potential (ERP) components known as the N2Pc, which is thought to index the spatial deployment of attention, and the Pd, which is thought to index active suppression. ERPs were recorded from VGPs and typical individuals in a visual search experiment featuring task-irrelevant distractors. Additionally, subjects were evaluated using a measure of visual short term working memory capacity ("K"), as previous research has suggested that individuals with high K also show more active suppression. In keeping with the extant literature, VGPs performed significantly better in the K task. Additionally, both VGPs and typical subjects did not show an N2Pc to the salient distractor, but rather a Pd, suggesting that both groups were suppressing, rather than attending to it. Furthermore, VGPs showed a significantly reduced latency of the Pd component, which would indicate an improved ability to actively suppress distracting items. These electrophysiological results add to the body of literature on VGPs and provide evidence for the mechanisms underlying previously observed behavioral differences.

43.4070 Automatic incorporation of a top-down cross-dimensional attentional setting into the focus of attention Motohiro Ito[1] (moto.1100525@gmail.com), Jun Kawahara[1]; [1]Chukyo University

Contingent attentional capture involves the interference of a task-relevant distractor and impairs performance in a target-detection/identification task. The ability to identify a target embedded in a rapid sequence of non-target letters deteriorates when a peripherally presented distractor sharing a target-defining feature precedes the target. However, recent studies have revealed exceptional cases in which identification improved when observers searched for multiple targets. Specifically, identification of a target (e.g., a green letter) was enhanced when the preceding distractor (a green item) shared one of the target colors (green or orange), but no such enhancement occurred when the color of the distractor differed from that of the target (an orange letter). The present study examined whether such enhancement is specific to multiple-target searches based on one feature dimension (e.g., color) or whether it occurs in multiple-target searches based on multiple feature dimensions (e.g., color and shape). Participants identified a target letter surrounded by a target-defining shape (in any color) or a color frame (in any shape). We observed contingent attentional capture in Experiment 1, as target-identification accuracy was lower when the distractor contained a target-defining feature than when it contained a non-target feature. Accuracy was superior when the current target's feature (e.g., shape) corresponded to the defining feature of the present distractor (shape) than when the current target's feature did not match the distractor's feature (color). Experiment 2 ruled out the possibility that enhancement was due to perceptual priming by demonstrating that mere repetition of the same feature without a specific attentional setting did not improve identification. These results suggest that establishing an attentional setting induces both automatic incorporation of target-relevant features into the focus of attention and its subsequent use in target identification. The present study demonstrated that this principle held even when multiple target feature dimensions were monitored.

43.4071 Bow your head in shame, or, hold your head up with pride: Self-esteem concepts orient attention vertically Alison Chasteen[1] (chasteen@psych.utoronto.ca), Eric Taylor[1], Timothy Lam[1], Jay Pratt[1]; [1]Department of Psychology, University of Toronto

Embodied cognition holds that abstract concepts are grounded in perceptual-motor simulations. If a given embodied metaphor maps onto a spatial representation, then thinking of that concept should bias the allocation of attention. In this study, we tested whether self-esteem concepts, which are frequently discussed using vertical spatial metaphors, can cue attention. We also asked whether conceptual cueing requires semantic processing, or if it can be achieved with shallow visual processing of the cue words. Participants viewed centrally presented words consisting of high or low self-esteem traits (e.g. brave, timid) before detecting a target above or below the cue. Participants were faster to detect targets when their location was compatible with the self-esteem level of the word cues. This effect was observed when participants processed the semantics of the word, but not when processing its typography. This study is the first to directly manipulate the level of processing required to elicit conceptual cueing. The results show that self-esteem concepts orient attention vertically, suggesting they are grounded in a spatial metaphor, and that an explicit consideration of the word cues' semantics is required for conceptual cueing to occur.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

43.4072 **Attention expands visual space** Liu Zhou[1], Teng Leng Ooi[2], Zijiang He[3]; [1]Key Laboratory of Brain Functional Genomics, School of Psychology and Cognitive Science, East China Normal University, China, [2]College of Optometry, Ohio State University, [3]Dept. Psychological and Brain Sciences, University of Louisville

Whereas much is known about attention's role in object perception, little is known of whether attention affects the representation of the visual space. Here, we asked if a differential allocation of attention resource to either the lower visual field (ground) or upper visual field (ceiling) affects space perception. In Experiment 1, the observer fixated on a small, dimly lit LED (1.5m at the eye level) for 3-6 sec in a dark room. To ensure proper fixation, the LED was randomly turned off for 0.1 sec 1-3 times within a 3-6 sec fixation period. The observer had to correctly report each time the LED flickered. Meantime, he/she also attended to either the upper or lower field. Upon fixation removal, a texture surface (2x4 LED array spanning 1.4x3m area) was presented in either the upper or lower field (0.15 sec), followed by an LED target (1 sec) on the texture surface. The observer judged the target location using the blind walking-gesturing task. We found that when the target and texture surface were in the lower field, judged location was more accurate if the observer had attended to the lower field (cue-valid) rather than the upper field (cue-invalid). This indicates attention leads to less space compression in the attended field. Experiment 2 employed the same procedures except the target was located at the eye-level and the texture surfaces were presented in both the upper and lower fields. We found that judged target location was more accurate when the observer attended to the lower than upper field. This indicates the visual space is more extensive when one attends to the ground. Overall, our findings reveal that attention contributes to visual space representation, which perhaps is the first step in a cascade of operations leading to our perception of the visual world.

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43.4073 **Hemifield-specific resources for controlling apparent motion** Christine Nothelfer[1] (cnothelfer@gmail.com), Satoru Suzuki[1], Steven Franconeri[1]; [1]Department of Psychology, Northwestern University

The visual hemifields contain processing resources that are substantially independent across a handful of tasks, such as object tracking and extraction of visual statistics. We add a new task to this category - the ability to control ambiguous apparent motion. Participants viewed two simultaneous and identical dot quartet animations (300ms/frame) where each could be perceived as undergoing either vertical or horizontal motion. The default percept of such dual animations is to see both quartets move in the same manner, and careful mental control is needed to perceive them as moving differently. Each trial began with a cue for mental control: see this quartet moving vertically, and that quartet moving horizontally. The dependent measure was the amount of proximity-based 'help' (making dots closer either vertically or horizontally) that a participant needed to add using the method of adjustment, before they were confident that they could robustly perceive the cued motion pattern differently across the two quartets. This threshold level of needed help was lower when the quartets straddled the hemifield boundary in the lower visual field (mean aspect ratio of 1:1.2), compared to when the quartets were contained entirely within the left or right quadrant of the lower visual field (mean aspect ratio of 1:1.3), $p < 0.05$ with eccentricity controlled between conditions. We speculate that the separate resources that underlie this benefit for apparent motion share roots with the resources that bring hemifield benefits for object tracking tasks - more efficient deployment of multiple attentional 'spotlights' across the hemifield boundary.

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43.4074 **Catching The Mind's Eye: The Effect of Internal Distraction on Visual Attention** Matthew Windsor[1] (mwindsor@binghamton.edu), Daniel Simons[2]; [1]Binghamton University, [2]University of Illinois

To what extent is visual detection performance disrupted by auditory attention capture? More specifically, does visual detection performance suffer when an auditory stimulus induces people to direct attention inward to the meaning of that stimulus rather than outward toward the visual display? Studies of visual attention often focus on how individuals are able to allocate their attention to various perceptual sources in the environment. Yet, the internal processing of information, such as manipulating information in working memory or speech comprehension, is also attentionally demanding. If attention is conceptualized as a general pool of resources that gives processing priority to some sources over others, then internal information processing and visual attention must both draw from this pool. The ability for speech to impact visual attention, specifically the processing of incongruous or highly meaningful speech, was investigated in a series of experiments. Experiments 1 and 2 looked at how hearing a semantically inconsistent word in a stream of non-sentential, category-consistent words could affect visual detection performance. Experiments 3 and 4 assessed the impact of hearing taboo words on visual detection performance. Experiments 1 and 2 revealed no disruption to visual attention as a result of hearing semantically incongruent information, and actually trended toward showing a slight performance boost in the visual task when hearing category-inconsistent words. Auditory presentation of taboo words in Experiments 3 and 4 was consistently able to disrupt visual detection performance, delaying responses to visual targets presented immediately following taboo words. As a whole, the current data suggest that when attention is split between the processing of auditory information and a visual task, surprising or meaningful auditory information can impact visual attention and that the effects vary as a function of the nature of this information.

43.4075 **A Novel Approach to Measuring the Useful Field of View in Simulated Real-World Environments Using Gaze Contingent Displays: The GC-UFOV.** Ryan Ringer[1] (rvringer@ksu.edu), Zachary Throneburg[1], Tera Walton[1], Greg Erickson[1], Allison Coy[1], Jake DeHart[1], Aaron Johnson[2], Arthur Kramer[3], Lester Loschky[1]; [1]Kansas State University, Department of Psychological Sciences, [2]Concordia University, Department of Psychology, [3]University of Illinois, Beckman Institute, Department of Psychology

The Useful Field of View (UFOV) task assesses attentional breadth within a single glance. The UFOV has successfully predicted changes in attention that have real-world consequences (e.g. automobile collision likelihood), however its design prevents it from being incorporated into simulated environments (e.g. driving/flight simulators). Additionally, the UFOV task and other attentional breadth measures (e.g. the peripheral detection task) do not disentangle attention from hard-wired perceptual properties that change with retinal eccentricity (e.g., spatial resolution via cortical magnification). We therefore developed an alternative method of measuring attentional breadth using gaze-contingent (GC) displays, the GC-UFOV. Thirteen participants completed four sessions of testing to determine the effect of a secondary task (auditory N-back) on Gabor patch orientation discrimination at four retinal eccentricities (0o, 3o, 6o, and 9o). Gabor patches were occasionally presented gaze-contingently for single eye fixations while participants completed a scene recognition memory task. Gabors were size-thresholded under single-task conditions to disentangle eccentricity-dependent acuity from changes in attention occurring between single and dual-task conditions, while N-back levels were thresholded to ensure that cognitive load was equivalent across participants. Results showed a significant decrease in orientation sensitivity in the dual-task condition, but not as a function of retinal eccentricity. We conclude that interference with executive attention produces general interference with visual attention equally across retinal eccentricity. N-back sensitivity was only minimally impaired under dual-task conditions compared to single-task trials. Picture recognition memory was no different between N-back single and dual tasks, but was significantly better in the Gabor single task condition. Thus, the Gabor task did not interfere with processing picture information, making this method ideal for use in simulated real-world tasks. Furthermore, we propose that future adaptations of this method employ other ecologically valid sources of cognitive load (e.g., stress, traffic density) to observe their effects on attentional breadth.

Acknowledgement: Office of Naval Research

43.4076 **Cost of Dividing Attention Moderated by Contrast Level** John Plummer[1] (jpplummer@wichita.edu), Rui Ni[1]; [1]Department of Psychology, Wichita State University

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Previous research shows that dividing attention between multiple targets in the visual field occurs frequently in everyday activities. The cost of dividing attention has been found to be affected by various environmental factors. One such factor is the contrast of the targets from their background (Plummer & Ni, 2014), which has important applications for activities such as nighttime driving. In the current study, contrast was manipulated to examine its effect on the cost of dividing attention. Eighteen younger adults participated in the study, whose contrast sensitivity thresholds were first measured on a contrast detection task. They then completed a modified version of the UFOV test (Richards, Bennett, & Sekuler, 2006), which consisted of measures of peripheral-focused attention and divided attention thresholds at three eccentricity locations (4, 12, and 20 degrees) from the center of the screen. These measures were carried out at 5 different contrast levels, with the high set at .3 Michelson contrast, the low at each participant's contrast detection threshold, and the other three intermediate levels evenly distributed along a logarithmic scale. The threshold of display duration was derived using the best PEST procedure for each eccentricity under each contrast level. Attention cost was calculated by subtracting the threshold scores of the peripheral-focused attention from those of the divided attention task. The results showed that, for both tasks, thresholds increased with increased eccentricity and decreased contrast. The interaction between contrast and eccentricity was significant for the peripheral-attention task, but not for the divided attention task. Consistent with previous research, the current study found increased cost of dividing attention under low contrast conditions. Our results might explain the increased accident risks associated with driving under low visibility conditions, such as at night or in fog.

43.4077 Are accuracy and reaction time equivalent measures of the attentional blink?

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Perception of the second of two rapidly sequential targets (T1, T2) is impaired when presented soon after the first (attentional blink; AB). AB magnitude is indexed by the difference between performance at short and long inter-target lags. Conventionally, T2 performance is assessed using accuracy as the dependent measure. An inherent problem with this measure, often encountered in AB experiments, is the 100% response ceiling. For example, Visser (2007) reported greater AB magnitude with hard than with easy T1 tasks. That conclusion is questionable, however, because the two functions converged to the ceiling, thereby confounding the effect of T1 difficulty with the ceiling constraint. To avoid this problem, we used reaction time (RT) as the dependent measure and found AB magnitude to be invariant with T1 difficulty (Experiment 1). One interpretation of this result is that the invariance seen with RT would also obtain with accuracy but for the response ceiling. This implies equivalence of the two measures, which is not always the case (Santee & Egeth, 1982). In Experiment 2, we checked the equivalence of RT and accuracy measures of the AB using the phenomenon of lag-1 sparing, which refers to the finding that T2 performance is relatively unimpaired when T2 comes directly after T1 (Lag 1). Using accuracy, Visser et al. (1999) found lag-1 sparing only when T1 and T2 were presented in the same spatial location. Lag-1 deficit occurred otherwise. We replicated Visser et al.'s finding with accuracy; with RT as the dependent measure, however, lag-1 deficit occurred even when T1 and T2 were presented in the same location. This pattern of results suggests that RT and accuracy are not always equivalent measures of the underlying processes involved in the AB. Therefore, RT may not be a good way of avoiding the ceiling problem inherent in accuracy measures.

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43.4078 Visual attention does not independently influence on chromatic and achromatic contrast-discrimination processes

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When chromatic and/or achromatic discrimination tasks were performed in central and peripheral visual fields in a dual-task paradigm, performance reduction was observed for the peripheral task, and degree of its reduction depended on combination of colors between the central and peripheral stimuli (Uchikawa et al., 2014). On the other hand, when the observer performed a pattern discrimination task using a dual-ring pattern in the central visual field, the color of the central pattern did not affect the peripheral performance (Sato et al., 2014). In the present study the first experiment was repeated using the dual-ring pattern for the central target to confirm that the importance of color combination was due to the central task itself, but not to the central pattern. The results were consistent with the previous experiments and positive to the hypothesis, i.e. those showed that threshold elevation was significantly larger when chromatic and achromatic discrimination tasks were combined than when both central and peripheral tasks were chromatic or achromatic. It appears that it is difficult to pay visual attention to chromatic and achromatic targets simultaneously.

43.4079 Perceptual and cognitive limitations interact in multiple object tracking

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Limitations on higher-order cognitive resources have been proposed as constraints on human performance in multiple object tracking (MOT). We report results from experiments testing a possible account of these cognitive limitations – observers rationally allocate attention to object locations to reduce the probability of spatial interference, they accomplish this reduction via increased spatial precision at attended locations, and drop targets within trials when their attention resource pool is overwhelmed. Our experiments used a standard MOT display following (Alvarez & Franconeri, 2007), but made two modifications to the standard design that allowed us to (i) probe the spatial precision with which subjects track individual objects during MOT, and (ii) whether subjects were aware that they had dropped any targets during trials where they made errors. We also conducted computational experiments, augmenting an existing model (Vul et al, 2009) with a central controller that assigns a limited attention resource to low-level object trackers, proportionately reducing their perceptual noise to minimize the chances of local perceptual confusion. We report three main findings. First, our computational model replicates the pattern of human errors on a per-trial basis to a considerably greater extent than a simple spatial interference model. Second, observers can localize targets with greater precision than non-targets, and that, contra simple spatial interference arguments, they localize targets with greater precision in crowded positions than when they are in open space. Third, observers were significantly less likely to report surprise (implying they knew they had dropped at least one target) for trials where our model predicted greater instances of attention resource scarcity. These results together support the case for rational attention allocation attenuating perceptual confusion during MOT trials, and limitations on this attention pool causing at least some of the difficulties that human observers encounter in multiple object tracking.

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43.4080 Perturbing object stability across saccadic eye movements facilitates displacement detection but hinders object recognition

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By making saccadic eye movements, we can bring interesting peripheral objects into the fovea for high-acuity examination. Every saccade abruptly displaces and alters the retinal image of objects. Nevertheless, we perceive objects as stable in their locations. The visual system seems to deal with the retinal image displacement by actively assuming object stability across saccades. This assumption seems to be responsible for concealing actual object displacements across the saccade, rendering them hard to detect (cf. Bridgeman et al., 1975, Vis Res). Pre-saccadic object representations are updated with post-saccadic information, leaving only the latter one accessible and impairing displacement detection. In contrast, briefly showing a post-saccadic blank screen prior to the shifted object improves displacement detection (Deubel & Schneider, 1994, BBS). Such blanking may violate the assumption of object stability. Pre-saccadic object representations should then be maintained separately from post-saccadic ones. Here, we investigated whether perturbing object stability during saccadic eye movements affects the recognition of post-saccadic objects. Observers saccaded to an abruptly appearing peripheral ellipse. The ellipse was displaced during the saccade to the left or right. After the saccade, the ellipse was either blanked for 100 ms (blank condition) or immediately shown (no-blank condition). Then a letter appeared within the ellipse (80 ms), followed by a pattern mask (300 ms). In two different blocks of trials, observers either reported displacement direction or letter identity. Reports of displacement direction were more accurate in the blank compared to the no-blank condition. Strikingly, this was reversed for reports of the post-saccadic letter, for which accuracy was lower in the blank than in the no-blank condition. Blanking may improve displacement detection by preventing updating of pre-saccadic object representations so that these are separately maintained (Schneider, 2013, Phil Trans B). This extra pre-saccadic and non-updated object representation interferes with competitive post-saccadic object recognition.

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43.4081 **The effects of red light running camera flashes on older and younger driver's covert and overt attention.**
Timothy Wright[1] (timwright@psy.fsu.edu), Walter Boot[1], Neil Charness[1], Thomas Vitale[1]; [1]Florida State University, College of Arts and Sciences, Department of Psychology

Recent empirical evidence suggests that the flashes associated with red light running cameras (RLRC) distract younger drivers, pulling attention away from relevant roadway information and delaying visual processing. Considering the perceptual and attentional declines that occur with age, older drivers may be especially susceptible to the distracting effects of RLRC flashes, particularly in situations in which the RLRC flash is highly salient (a bright flash at night). The current study examined age and situational differences in RLRC flash capture. Two experiments utilized both covert (inhibition of return) and overt (eye movements) indices of attention in order to explore potential age differences in the distracting effects of RLRC flashes. Salience of the flash was manipulated by varying its luminance and contrast with respect to the background of the driving scene (either day or night scenes). Results across both experiments suggest that simulated RLRC flashes capture observers' attention, but, surprisingly, no age differences in attention capture were found with either covert or overt markers of attention. An analysis examining early and late eye movements revealed that older adults may have been strategically delaying their eye movements in order to avoid capture by the flash. In addition, older adults took longer to disengage attention following an incorrect eye movement, suggesting at least one age-related disadvantage in capture situations. Findings have theoretical implications for understanding age differences in attention capture with more realistic and familiar stimuli and inform future work that will examine how the distracting effects of RLRC flashes influence driving behavior.

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Attention: Features and objects

Monday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4082 **Target 'on' or 'of' an object? It does not matter for object-based attention**
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An open question in the domain of object-based attention concerns the extent to which object-based cueing effects are affected by targets appearing as part 'of' an object (e.g., Watson & Kramer, 1999) versus 'on' an object (e.g., Egly et al., 1994). This distinction relates to whether or not the target involves a property change of the object. The aim of the present study was, therefore, to determine whether or not participants produce equivalent object-based cueing effects in a discrimination task when the target is 'of' rather than 'on' an object, all else being equal. On Day 1, participants discriminated whether a number that appeared on a wrench-like stimulus was odd or even. On Day 2, participants discriminated whether a gap that appeared as part of a wrench-like stimulus was large or small. With the exception of this target-object integration manipulation, the tasks were otherwise equated on factors of spatial cueing and object orientation. First, as expected, we found a significant spatial cueing effect in both paradigms. Second, and importantly for this study, we also found a significant object-based cueing effect in both paradigms. This latter effect suggests that neither the emergence nor magnitude of object-based cueing effects is affected by target-object integration. Interestingly, the object-based cueing effect was, however, affected by object orientation, such that it emerged in the horizontal condition and reversed in the vertical condition, consistent with Pilz et al. (2012). This vertical orientation same-object cost became a same-object advantage when we controlled our analysis for shifts across visual field meridians (Greenberg et al., VSS 2014). We also investigated the implications of endogenous spatial cueing on attentional shifts across the meridians. Thus, our findings suggest that target-object integration, on its own, is not sufficient to modulate the distribution of object-based attention and/or the strength of object representations.

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43.4083 **Unconscious processing of shape-pair relationship**
Matt Oxner[1] (matt.oxner@gmail.com), Edoardo Zamuner[1], Paul Corballis[1], William Hayward[1]; [1]School of Psychology, University of Auckland

Lin & Murray (2014) recently showed that processing of the sameness or difference of two stimuli could occur without conscious awareness. Participants learned a go/no-go response to pairs of visible shapes; slower reaction times were observed in stimulus pairs associated with response inhibition even when they were rendered invisible by metacontrast masking. We expanded on this paradigm to address common concerns that strongly-masked yet visible stimuli could drive reaction time differences between conditions. By considering "no-go" error rates for each visibility rating on a per-participant basis, we revealed and corrected for inconsistent use of the Perceptual Awareness Scale and identified participants who showed no or weak metacontrast masking. Furthermore, we added a control experiment to compare processing of masked sameness or difference (Shape-Relation) to the simpler task of responding to the shape of a single stimulus in the periphery (Shape-Identity). In our Shape-Relation experiment, participants provided a "go" response to same-shape stimulus pairs or to unseen pairs, withholding their response only when a different-shape pair was consciously perceived. Even with our more stringent criteria for determining masking effectiveness, the results closely matched those of Lin & Murray, with unseen different-shapes eliciting slower responses than unseen same-shapes. In the Shape-Identity control experiment, the same participants followed a similar procedure but responded based on the shape of a single stimulus, presented left or right of fixation to match locations used in the Shape-Relation experiment. Here, unlike previous demonstrations of unconscious processing of a stimulus presented foveally, we found no unconscious slowing for unseen "no-go" shapes despite the task being cognitively less demanding. We hypothesize that the uncertainty of stimulus location prevented participants from sufficiently processing the shape identity, while in the Shape-Relation experiment, attention was consistently diffused across the two stimulus locations, allowing unconscious effects to occur.

43.4084 **Object Substitution Masking for an Attended and Foveated Target**
Hannah Filmer[1] (h.l.filmer@gmail.com), Jason Mattingley[1,2], Paul Dux[1]; [1]School of Psychology, The University of Queensland, [2]Queensland Brain Institute, The University of Queensland

Visual masking can be used to prevent conscious detection and discrimination of a target image. Of the different types of masking, object substitution masking (OSM) is thought to be unique in that it arises only when attention is distributed across several possible target locations. However, several recent findings have suggested that the apparent interaction between distributed spatial attention and masking magnitude in OSM may reflect ceiling effects in performance. We report definitive evidence that OSM does not depend upon attention being distributed over space or time. In two experiments, we used constant, foveal presentations of a single target stimulus. Unmasked performance at discriminating the orientation of a line within the target was thresholded to 70% accuracy to avoid floor and ceiling limits to performance. Thresholding was achieved via manipulating the contrast of a forward mask (Experiment 1) or the transparency of the target (Experiment 2). After thresholding, an OSM mask consisting of four-dots was presented with simultaneous onset, and variable offset, relative to the target. Crucially, participants' attention was always focused on the target. Our results demonstrate reliable OSM with attended and foveated stimuli, thus discounting the hypothesis that a key requirement for OSM is distributed attention. The findings challenge how OSM is conceptualized in the broader masking literature and have important implications for theories of visual processing.

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43.4085 **Color dominates! The importance of color in attentional templates for target objects in visual search.**
Rebecca Nako[1] (beccanako@gmail.com), Tim Smith[1], Martin Eimer[1]; [1]Department of Psychological Sciences, Birkbeck, University of London

Attentional templates guide the selection of target objects in visual search. The efficiency of template-guided target selection can be determined by measuring the N2pc component of the event-related brain potential. When word cues specify the target object for three subsequent search displays, the N2pc is delayed for the first search display after the cue relative to the second and third display, demonstrating that word cues are insufficient to

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fully activate target object templates (Nako et al., in press). We conducted two experiments to determine how the acquisition of target templates is affected by color. Word cues (e.g., "apple") were followed by three search displays that each contained the cued target together with three distractor objects. In Experiment 1, grayscale or colored search displays were shown in different blocks. In Experiment 2, cued trial runs of search displays with grayscale or colored objects were presented in a random unpredictable sequence. In both experiments, N2pc components were delayed for the first relative to two subsequent displays in each trial run. The N2pc for the second and third display emerged earlier on trials with colored objects relative to trials with monochrome objects, demonstrating that color information facilitates target selection once a target object has been encountered at least once. There was no such facilitation by color for the display that immediately followed the cue in Experiment 1 where participants knew in advance that either colored or grayscale objects would be shown. However, when color and grayscale trial runs were mixed and thus unpredictable, the N2pc to the first display emerged earlier when it contained colored objects, indicating that color was included by default in the attentional templates set up in response to word cues. These results show that color information plays a central role in the guidance of object selection by attentional templates.

43.4086 Evidence for the role of Feature-Based-Attention at a very early processing stage

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To judge the mean location (centroid) of only a set of black dots when they are spatially intermingled with white dots, one needs a mechanism that passes information carried by the to-be-attended visual feature (black) across space (all locations of black dots) onto further mental processes while blocking the passage of the information carried by the to-be-ignored feature (white). This global, selective process, Feature-Based-Attention (FBA), can be quantitatively described as an attention filter (Drew, Chubb and Sperling, Journal of Vision, 2010). The filter's properties are derived from the observer's responses. Here, we measured the improvement of attention filters as a function of the time-duration available for subjects to process the stimuli. Method. A brief flash of the dot-containing stimulus was followed, at various Stimulus-Onset-Asynchronies (SOAs), by a post-stimulus masking array. Stimuli were random clusters comprising 1-, 2-, 4-, 6- or 8-each of black and white dots, randomly interleaved in blocks of different SOAs ranging from 12ms to 300ms. Control trials with stimuli composed of only black dots were interleaved in each block. Subjects mouse-clicked the mean location of all the black (target) dots. Results. (1) Judgment accuracy improved as SOA increased and reached an asymptote at 80ms whether or not white (distractor) dots were present. (2) Remarkably, the improvement in accuracy as a function of SOA for black-plus-white and black-only conditions was almost identical. (3) Attention filters, at their optimum, were very effective, giving a more than 4:1 transmission advantage to black versus white dots. Conclusion. The nearly equivalent performance with black dots alone (no attention filter) and with intermingled black and white dots (attention filter required) over a wide range of stimuli and SOAs indicates that FBA takes place at a very early stage prior to the computation of the mean of multiple locations.

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43.4087 Visual Features as Carriers of Information

Ronald Rensink[1] (rensink@psych.ubc.ca); [1]University of British Columbia, Vancouver BC, Canada

The perception of Pearson correlation in scatterplots can be described via simple laws (Rensink & Baldridge, 2010): just noticeable difference (jnd) follows a Weber-like (linear) law, and subjective estimate follows a Fechner-like (logarithmic) law. Behavior is largely invariant to the size, shape or color of the dots (Rensink, 2014), suggesting that correlation is (or is related to) a perceptually simple property carried via spatial position. To determine if features other than spatial position can carry information in the same way, a set of "augmented stripplots" was developed for visualizing two-dimensional data. As for the case of scatterplots, the first dimension was carried by spatial position along the horizontal axis. But the second dimension was carried by a visual feature such as orientation, size, or color. Precision was measured via the jnd in correlation for two above-and-below stripplots, each 2° high x 5° wide. Accuracy was determined via reference plots with fixed upper and lower values, with a test plot adjusted to have its apparent correlation be midway between them. Twenty observers were tested in each condition. Results showed the same pattern in all conditions. For all features, precision followed a Weber-like law, with jnds increasing linearly with distance from r=1. And for all features, accuracy followed a Fechner-like law, with subjective estimates a logarithmic function of the distance from r=1. The constants of these functions were similar as well; indeed, performance for color-augmented stripplots (both red-green and blue-yellow) was somewhat more accurate than that for scatterplots. These commonalities provide further evidence that correlation perception is a general process that is both sophisticated and rapid, relying on more than superficial appearance alone (e.g., the shape of the dot cloud). They also suggest that many if not all basic visual features can effectively carry information.

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43.4088 Ensemble summary statistics as a basis for visual categorization

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A core idea beyond ensemble perception is that the visual system is capable of representing features of multiple objects as abstract statistical entities – distributions characterized by the mean, deviation, numerosity, etc (Alvarez, 2011). This approach gives insights into some more complex processes, such as categorization – perceiving some items as representing the same or different types of objects. Even in highly heterogeneous displays (e.g., cars in traffic or berries among leaves), ensemble summary statistics can provide massive categorization, probably via distribution comparisons which are akin to statistical tests. In first-order categorization, the visual system decides whether multiple features along a single dimension represent same or different categories. A plausible way of doing that is testing the distribution for normality. If all pooled features can be collected under the same Gaussian, then they probably represent the same category; but if the test fails showing normality then the distribution is decomposed into several Gaussians, each representing a separate category. Behavioral and neural data show that the results of normality test may depend on feature separation in an ensemble (Treue et al., 2000; Yurevich & Utochkin, 2014). In second-order categorization, the visual system operates over separate distributions (as the result of the first-order processing). Second-order statistics can be analyzed in-depth, when one of first-order distributions (e.g., by color) is attended and a new dimension (e.g., size) is analyzed within it. On the other hand, second-order processing can be in-extent, when few selected distributions are compared with each other (say, if blue objects are larger on average than yellow). The latter type of processing behaves like standard statistical tests, such as compare means or proportion comparisons (Fouriezos et al., 2008; Utochkin, 2013). Anyway, it appears that second-order processing is severely limited by attentional and working-memory capacities (Attarha et al., 2014; Halberda et al., 2006).

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43.4089 Statistical Learning without Attention

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We sought to investigate the role of attention in statistical learning, an area where current results conflict. Given a stream of shapes including two different colors, and instructed to attend one of the colors (via a cover task), will observers learn statistical regularities associated with the unattended color? Following previous studies, we employed a reaction time (RT) test following encoding. Speeded responses are made to a target shape (on each trial) embedded within an RSVP stream, with learning demonstrated as an RT benefit for second and third triplet items. However, typical procedures repeat the same triplets as fillers and test items, making learning during testing possible. We therefore conducted an experiment with only a test phase (i.e. no incidental exposure), and we found significant RT benefits consistent with statistical learning, even in the first 48 of 96 test trials. These results demonstrate that statistical learning can take place rapidly during the course of procedures that are at times employed to diagnose prior learning. We thus returned to the question of attention with a modified test procedure. In addition to a set of eight triplets shown during incidental exposure, we generated a place-holder-set of 12 additional shapes. Each test trial then included a target shape from one of the learning triplets. It appeared embedded appropriately within its triplet, but with that triplet embedded within a larger set including nine of the 12 place-holder-items. After confirming a lack of statistical learning during the test phase (i.e. without pre-exposure), we used it as the test component for the attended and unattended color experiment described initially. We found significant learning effects for attended and unattended shapes. In addition to furnishing an updated RT test, these results demonstrate the robustness of statistical learning, which arose rapidly and for unattended stimuli.

43.4090 Interference in the Perception of Two-Population Scatterplots

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Monday AM

The visual system represents correlation in much the same way that it represents simple visual quantities such as density or brightness (Rensink 2014). For example, just noticeable differences (jnds) show linear behavior closely approximating Weber's law. But until recently, testing was done using only single populations of data. However, displaying two or more populations in a single graph is a common practice. Participants completed a two-condition correlation discrimination task, which was counterbalanced to control for order effects. The first condition closely resembled the original task from Rensink & Baldridge (2010); observers viewed two side-by-side scatterplots, each containing a single data population. They were instructed to select the plot with the higher correlation. The second condition had two data populations, each of a different color. As in the first condition, observers chose the higher correlation of the first (target) population, but were now required to ignore the second (distractor) population. Results from the first condition replicated earlier findings (Rensink, 2014). However, results from the second condition showed that when a distractor population was present, strong violations of Weber's law appeared. Jnds were now larger overall, and deviated from the linear pattern most when the correlations of target and distractor populations were the same. This suggests that the perception of correlation in scatterplots with two populations differs from the process underlying the perception a single population. These findings also stand in contrast to assertions that color feature selection, even with distinct colors, aids tasks such as visual search and target discrimination.

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43.4091 An EEG Study of Illusory Conjunctions

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An illusory conjunction is a feature binding error wherein a person incorrectly combines features from two different objects. Behavioral investigations have implicated spatial attention in successful feature binding, suggesting that failures of spatial attention lead to illusory conjunctions. We examined this phenomenon using electroencephalography (EEG) to identify neural markers of binding successes and failures. We hypothesized that EEG markers of covert spatial attention, the N1 and N2pc, would be greater when features were correctly bound compared with illusory conjunctions. We briefly presented (150 ms) two characters, an L or 7 and a 0, flanked by $s on either side. The characters, in one of three colors (red, green, or blue), varied in position. Stimuli were presented in the right or left visual field with distractors ($$$$) presented at the opposite location, and were bilaterally pre- and post-masked with distractors. After 1000 ms, participants reported the target identity (L or 7) and the color of that target. Illusory conjunctions occurred when participants reported, for example, a red L, when presented with a red 0 and a blue L. In 10 participants with adequate trials for EEG analysis, participants reported the correct target shape (L or 7) and color in an average of ~61% of trials, and illusory conjunctions in and average of ~20% of trials. We randomly down-sampled correct trials to equate conditions for each participant. We analyzed ERPs over posterior-lateral sites for correct responses and illusory conjunctions, for contralateral and ipsilateral target presentation. Though a marginal N2pc was present (contralateral more negative than ipsilateral, p = .069), there was no interaction between binding accuracy and laterality, contrary to our hypothesis,. However, correct trials demonstrated marginally greater mean amplitudes than illusory conjunctions for N1 and P3 (p = .054 and p =.068, respectively). These differences suggest physiological correlates required for successful feature integration.

43.4092 The interaction between spatial cueing and cue-target feature similarity

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Covert spatial cueing effects refer to the finding that targets appearing in the location of a previous cue stimulus are typically responded to more rapidly than targets appearing at different locations than the cue. One explanation of these effects is that the cue captures attention, so that attention is already at the target location when the target appears, resulting in faster responses relative to when targets appear at an uncued new location that requires a shift of attention. Here, however, we investigate the possibility that the relationship between cues and targets is more complicated than just location repetition by viewing cues and targets as separate event files which contain stimulus features (including location) that must be formed before responses can be made. To do this, we varied the relationship be the features of cues and targets to investigate the effect of cue-target similarity on spatial cueing effects, as cues and targets could either match in shape (Experiment 1) and/or color (Experiment 2), and could appear at same or different locations. Therefore, on each trial the target could switch from any of the cue stimulus's features or location or could repeat some or all these features allowing us to examine response time differences given event file repetition. If location repetition is sufficient to produce cueing effects then similar cueing benefits are expected regardless of cue-target feature overlap. Contrary to this prediction, spatial cueing interacted with shape repetition; shape switches between the cue and target attenuated (Experiment 1), or eliminated (Experiment 2), spatial cueing effects. When shape repeated, however, repeating location significantly improved performance. Shape and color also interacted with shape repetition having larger effect if color also repeated. Therefore, it seems that more than location repetition is a factor is spatial cueing effects.

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43.4093 Feature-based attention separately influences visual working memory resolution and encoding probability

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We use attention to select relevant portions of our environment for detailed processing—a process often directed by feature-based goals. Feature-based attention guides visual information processing by strengthening early representations (i.e., within perceptual cortex). Here we examined how feature-based goals affect the way visual information is represented at later stages of processing, namely within visual working memory (VWM). To address this question we used a continuous partial-report VWM task (i.e., a colour-wheel task) and measured the effects of attention on guess rate (the probability that an item is encoded into VWM) and standard deviation (the resolution with which an item is represented). On each trial of Experiment 1, participants remembered the colours of two squares and two circles over a delay, and then reported the colour of one probed stimulus. To manipulate feature-based attention we instructed participants that square stimuli were more likely to be probed (counterbalanced): Across four blocks, squares were probed on 60%, 70%, 80%, or 90% of trials. We found that increasing the value of a feature-based goal increases the probability that a goal-matching item will be encoded into VWM without altering its resolution. This pattern reverses, however, for non-matching stimuli: Attention affects resolution but not guess rate. In Experiment 2, we increased set size from four to six items (three circles and three squares), and observed the same effects of attention. The double dissociation observed in both experiments suggests that feature-based attention can affect both VWM encoding probability and resolution, and, for a given stimulus, these effects can emerge independently. Broadly, our findings add to recent studies investigating how the value of an attentional goal impacts VWM. Interestingly, as attention type (attend to feature vs. space) and stimulus type (report colour vs. location) change, so do the effects on VWM, suggesting a need for more research.

43.4094 Disc Size Supports Top-Down, Selective Attention in a Task Requiring Integration across Multiple Target

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Introduction. Features that support "pop out" in visual search are often assumed to be associated with preattentive mechanisms that can support feature-based attention in other tasks. We have found that this assumption holds for luminance and hue; however, a companion presentation shows that, although differences in absolute bar-orientation support pop out, this feature dimension apparently does not support top-down, selective attention in a centroid task that requires integration of information from multiple targets. Disk size has been previously shown to enable pop out in visual search (Stuart, 1993). Here we examine whether top-down attention to disc size is possible in an information-integration task. Methods. Stimuli were briefly presented random clusters comprising 1-, 2-, 3-, or 4-each of equiluminant small-green, small-red, large-green, and large-red discs. In four different attention conditions, participants strove to mouse-click the centroid of only the (1) small, (2) large, (3) red, or (4) green discs in the stimulus display, ignoring the discs with the opposite feature. Performance was characterized in terms of the selectivity and efficiency of the attentional "filter" deployed in each condition. Results. Within each condition, both selectivity and efficiency declined slightly as the number of discs increased. Although the filters for size may have been slightly less effective than those for color, the numerosity effects were identical across

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conditions. Conclusion. Like luminance and hue, but unlike orientation, disc size supports top-down, selective attention in a task that requires integration of information from multiple targets such as the centroid task.

43.4095 Attention in Low Resolution: Learning Proto-Object Representations with a Deep Network Chengyao Shen[1,2] (scyscyao@gmail.com), Xun Huang[3], Qi Zhao[2]; [1]Graduate School for Integrative Science and Engineering, National University of Singapore, [2]Department of Electrical and Computer Engineering, National University of Singapore, [3]School of Computer Science and Engineering, Beihang University

While previous researches in eye fixation prediction typically rely on integrating low-level features (e.g. color, edge) to form a saliency map, recently it has been found that the structural organization of these features into perceptual objects (proto-objects) can play a significant role, and many times more important than low-level features. In this work, we presented a computational framework based on deep network to demonstrate that proto-object representations can be learned naturally from low-resolution image patches from fixation regions. We advocated the use of low-resolution inputs in this work due to a number of reasons: (1) Stimuli triggering eye movements are usually in para-foveal or peripherial regions of the retina, which are in lower resolution compared with fovea. (2) People can perceive or recognize objects well even it is in low resolution. (3) Fixations from lower resolution images can predict fixations on higher resolution images. In the proposed computational model, we extracted multi-scale image patches on fixation regions from eye fixation datasets, resized them to low resolution and fed them into a two-layer neural network. With layer-wise unsupervised feature learning, we found that many proto-objects like features responsive to different shapes of object blobs were learned out in the second layer. Visualizations also show that these features are selective to potential objects in the scene and the responses of these features work well in predicting eye fixations on the images when combined with learned weights.

43.4096 Learned Attention in an Object-Based Frame of Reference Kao-Wei Chua[1] (kaochua@gmail.com), Isabel Gauthier[1]; [1]Vanderbilt University

Visual attention can be implicitly associated with spatial locations that are informative, in environment-based or viewer-based reference frames (Chun & Jiang, 1998; Jiang & Swallow, 2012). Features can also capture attention differently depending on spatial context (Anderson, 2014). In prior work we suggested that category-selective attentional biases to object parts could develop because of a history of these parts being diagnostic for individuation (Chua, Richler & Gauthier, 2014; Chua, Richler & Gauthier, VSS2014). Here, we tested whether attentional biases could develop for the top or bottom of objects, as a function of object category, when object identity is irrelevant. Subjects performed a visual search task to indicate which direction the target, a valid "T," is pointing. Targets and distractors were superimposed on several objects from two categories (Greebles): Ploks and Glips, varying in location on the screen. Critically, for the first two blocks of the study, targets appeared in different parts of Ploks and Glips (e.g., the top vs. bottom) 89% of the time. The final two blocks had targets appear in both halves of both object categories equally often. In Experiment 1 (n=21), we found faster search times in the "rich" half of each category persisting in the third block ($F_{1,20}$=6.91, p=0.016, $\eta_p 2$=.26), evidence for learned attention in an object-based frame of reference, as a function of category. In Experiment 2 (n=22), we replicated the result and verified it was driven by categories and not exemplars by switching to novel Greebles in block 3. Subjects categorized Ploks and Glips before the search task to make the two categories explicit. Again, search times were shorter in the "rich" half of each category persisting in the third block ($F_{1,23}$=11.17, p=0.0024, $\eta_p 2$=.35) blocks. These results demonstrate category-specific learned attentional biases in an object-based frame of reference.

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43.4097 Shifts of Object-Based Attention Differ Across Visual Field Meridians Adam Barnas[1] (ajbarnas@uwm.edu), Adam Greenberg[1]; [1]Department of Psychology, University of Wisconsin-Milwaukee

Object-based attention (OBA) leads to preferential processing of visual information within the boundaries of an attended object. Pilz et al. (2012) demonstrated that this preferential processing was larger for horizontally-oriented rectangles than for vertically-oriented rectangles. However, Greenberg et al. (VSS, 2014) showed that, when controlling for shifts of attention across the vertical meridian of the visual field (thereby eliminating attention shifts across this axis), effects of object orientation are eliminated, suggesting that object orientation may not affect OBA. These studies used the double-rectangle cueing paradigm (Egly et al., 1994) in which attention shifts between objects are contrasted against shifts within objects. Our goal here was to examine the distribution of solely within-object shifts across the meridians. Eighteen participants viewed an object consisting of a vertical rectangle and a horizontal rectangle joined to form a unified object in the shape of a right angle. While subjects fixated centrally, the object vertex was randomly positioned in one screen quadrant on each trial such that one object component always crossed the vertical meridian and the other always crossed the horizontal meridian. Following a peripheral cue at the object vertex, the target appeared at the cued location ("valid"), or at one of two locations equidistant from the cue - the uncued location of the horizontal component ("invalid-horizontal") or the uncued location of the vertical component ("invalid-vertical"). Results showed that participants were faster to detect valid targets compared to invalid targets. Furthermore, RTs varied by target hemifield, regardless of cue location. However, contrary to our hypothesis, participants were faster for invalid-horizontal locations than for invalid-vertical locations, suggesting that OBA is distributed more efficiently along the horizontal meridian than the vertical meridian. Thus, OBA may be allocated unevenly within objects that cross the vertical versus horizontal meridian of the visual field.

43.4098 Binding object features to locations: Does the "Spatial Congruency Bias" update with object movement? Avni Bapat[1,2] (bapat.11@buckeyemail.osu.edu), Colin Kupitz[1,2], Julie Golomb[1,2]; [1]Department of Psychology, The Ohio State University, [2]Center for Cognitive and Brain Sciences, The Ohio State University

When we look at an object, we assign it a place in our spatial surroundings. Simultaneously, we process details of the object such as color, shape, curves, and edges. However, what if the object moves from one place to another? Do we have to re-bind all of these features to the object, or are we able to keep the traits intact? Recent research has shown that an object's identity is bound to its location, resulting in a "spatial congruency bias" (Golomb et al, 2014, JEP:Gen). When two objects appear consecutively, we are more likely to deem them as identical if they appear in the same location, versus if the second object appeared in a different location. In the current experiment, subjects saw the first object for 500ms, then watched it move to a new location on-screen. A second object then immediately appeared either at the location where movement ended, the original starting location, or a control location. Subjects were asked to indicate whether the second object was the same (identical) or different (slightly altered) from the first. The "congruency bias" was found to remain at the starting location – subjects were more likely to deem the two objects as the same identity if the second object was presented at the original location of the first object. This suggests that features are bound to the original object location and may not automatically update with movement. However, in a follow up experiment, when the first object remained visible for 250ms at the end location after movement (allowing time to re-encode the object at the new location), the congruency bias was found at both the original starting location and the end location of the movement. These data suggest that features bound to a location may need time to re-bind following object movement.

43.4099 Dissociable effects of attention and expectation during orientation discrimination Nuttida Rungratsameetaweemana[1] (nrungrat@ucsd.edu), Sirawaj Itthipuripat[1], John Serences[1,2]; [1]Neurosciences Graduate Program, University of California, San Diego, [2]Department of Psychology, University of California, San Diego

Top-down factors such as attention and expectation have been shown to modulate visual discrimination by improving the quality of sensory processing. However, few studies have investigated these factors within the same experiment to determine if they operate via similar or independent mechanisms (Kok et al., 2012; Jiang et al., 2013). To address this question, subjects viewed a display containing flickering and randomly oriented lines, half of which were blue and half of which were red. On each trial, some percentage of the lines were rendered at the same orientation, either clockwise or counterclockwise relative to the vertical meridian. We manipulated attention (behavioral relevance) by cueing subjects to monitor either the red or blue lines (focused attention) or to monitor both (divided attention). Expectation of the target-defining orientation was also manipulated by varying the ratio between target orientations presented in a given block of trials. Finally, we examined interactions between the strength of sensory evidence and attention/expectation by manipulating the number of iso-oriented lines in the target display across two levels (low and high coherence). At high coherence levels, there is no main effect of attention or expectation on accuracy, but both factors lead to faster response times (RTs). In contrast, at low coherence levels, there is a robust effect of expectation on accuracy

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such that expected orientations are more likely to be correctly discriminated. However, this expectation effect is primarily observed in the divided-attention condition, suggesting that focused attention dampens the effects of expectation. In addition, at low coherence levels, there is a main effect of attention on RTs but little effect of expectation. Taken together, these results suggest that the effects of attention and expectation on behavioral performance during orientation discrimination are dissociable depending on the amount of relevant sensory information available in the display.

43.4100 **Expectancies about the frequency of a target-similar distractor impact target selection** Jeongmi Lee[1] (jmslee@ucdavis.edu), Carly Leonard[1], Steven Luck[1], Joy Geng[1]; [1]Center for Mind and Brain, University of California, Davis

For successful achievement of any task, it is critical to select goal-relevant information while suppressing distractors. Previous research has demonstrated that attentional allocation is biased by a target template that increases the gain of target-relevant features while decreasing the gain of other features. However, it remains unclear how attentional selection and suppression are related when they come into conflict (i.e. when distractors are similar to the target). We investigated this issue with event-related potentials, focusing on the N2pc and Pd components, which are indices of attentional selection and suppression, respectively. A visual search task was used in which the target was defined by a combination of color and shape, and distractors differed from the target in color and/or shape. We manipulated the frequency of a target-colored distractor over blocks, such that the probability of a target-colored distractor was 75% (high-frequency blocks) or 25% (low-frequency blocks). We hypothesized that in high-frequency blocks, participants would decrease the gain on the target color in order to reduce distraction by the frequent target-colored distractors. The results confirmed our hypothesis. Reaction times in the high-frequency block (compared to low-frequency block) were longer to targets that appeared without a target-colored distractor, but shorter when a target-colored distractor was present. Consistent with the behavioral data, the N2pc for the target (without a target-colored distractor) was reduced and the Pd was larger in high-frequency blocks compared to low-frequency blocks. Moreover, the N2pc to the target-colored distractor was smaller and the Pd was larger in high-frequency blocks than in low-frequency blocks. These results indicate that expectancies about target-similar distractors not only impact the ability to suppress them but also affect the ability to select the target. This suggests that feature-based attentional gain was adjusted to maximize the balance between the need to suppress distractors and to select targets.

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Objects: Numbers

Monday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4101 **Vertical and diagonal Kanizsa illusory contour targets in an enumeration task** Natasha Dienes[1] (ndienes@uoguelph.ca), Lana Trick[1]; [1]University of Guelph

Every day we view scenes wherein the contours of objects are not wholly visible either because an object is behind something or in front of a background homogeneous with itself. Illusory contour figures (items that can be seen as whole though they lack some of their bounding contours) can be used to study how the visual system deals with objects that are not fully visible. Research indicates than an orientation-based visual search task where rectangles were defined by Kanizsa-style illusory contours (induced by "pacmen" alone) was inefficient. In contrast, when the same rectangles were defined by real contours as well, search was efficient. The goal of this study was to determine whether these results replicate to a selective enumeration task, where participants had to enumerate targets among distractors. In enumeration, it has long been known that people can use a fast, accurate process called subitizing to enumerate small numbers of items in many situations. Generally, subitizing is evident in selective enumeration when targets "pop out" of distractors in the corresponding visual search. Because real contour Kanizsa figures promoted efficient search whereas illusory contour Kanizsa figures did not, we hypothesized that subitizing would only be evident in selective enumeration when participants were enumerating real contour figures. Participants enumerated 1-9 vertical targets in 4 or 8 horizontal distractors when items were defined by real as compared to illusory contours. As expected, the Kanizsa illusory contour figures were not subitized. However, surprisingly, the corresponding real contour figures were not subitized either. This result replicated when the targets were diagonal rectangles. This discrepancy between visual search and selective enumeration may indicate fundamental differences between tasks as it relates to processing complex figures.

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43.4102 **Early Cortical Contributions to Object Individuation** Paul Dux[1] (paul.e.dux@gmail.com), Claire Naughtin[1], Jason Mattingley[1,2]; [1]School of Psychology, The University of Queensland, [2]Queensland Brain Institute, The University of Queensland

In object individuation, spatiotemporal episodic cues are used to register an object as a distinct perceptual event, relative to other stimuli. The present study examined the time course of individuation to assess the information processing stage at which it arises and the extent to which it draws on early sensory cortices. Previous research has failed to provide definitive evidence on these issues, as individuation manipulations have co-varied with other low-level physical differences (e.g., hue, luminance). Similarly, no previous study has had both high spatial and temporal resolution, and consequently has been unable to speak directly to both the neural and cognitive substrates of individuation. Here we used a multimodal EEG/fMRI approach and a novel enumeration paradigm that equated physical stimulus properties across conditions. We could therefore pinpoint the time window and visual sensory regions associated with individuation for items in attended and unattended locations, as indexed by set-size-dependent changes in activity. P1 (100-140 ms) and N2 (185-250 ms) event-related potentials both increased in amplitude with the number of attended targets, but unattended non-targets only modulated the N2. Using fMRI, we found that V2 and other extrastriate visual areas were the likely source of the early P1 effect observed for attended targets. Thus, object individuation appears to arise at a perceptual stage of processing and can be detected in early sensory brain regions. In addition, individuation of unattended items occurs at a later stage of processing than attended targets, suggesting a role of selective attention in this operation.

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43.4103 **The influence of pre-stimulus brain oscillations on the visual sense of number: an MEG study** Rakesh Sengupta[1,2] (qg.rakesh@gmail.com), Philipp Rhinou[3], David Melcher[3], Raju Bapi Surampudi[2,4]; [1]Center for Cognitive Sciences, B. V. Raju Institute of Technology, Narsapur, India, [2]Center for Neural and Cognitive Sciences, University of Hyderabad, India, [3]Center for Mind/Brain Sciences, University of Trento, Italy, [4]Center for Cognitive Science, International Institute of Technology, Hyderabad, India

The visual system is able to rapidly and accurately enumerate a small number of items (subitizing) or, instead, to estimate less precisely a large number of items (estimation). Recent computational, behavioral (Sengupta et al, 2014) and fMRI (Roggeman et al.2010; Knops et al, 2014) studies are consistent with the idea that a single enumeration mechanism may be able to account for both small and large number perception under different levels of inhibition between nodes. In other words, the visual sense of number can be explained through the dynamics of a single recurrent on-center, off-surround network in which the network produces different regimes of numerosities by modulating the inhibition between nodes of the network. Accurate and precise subitizing would require high levels of inhibition between nodes, while low inhibition would account for performance in the estimation range. In the present study we used MEG recording to study the switches in enumeration ranges across series of small (1-4 items) or large (20-30 items) numerosity trials of different lengths. We found modulation of the pre-stimulus alpha (α) and beta (β) frequency bands as a function of whether the previous trials had involved subitizing or estimation. These results, combined with behavioral results showing a specific pattern of switch costs between small and large numerosity trials, are consistent with a change in the pre-stimulus state that prepares the visual system to most effectively enumerate items as either individuals or as an ensemble.

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43.4104 **Enumeration and Reentrant Processes** Marcus Cappiello[1] (mcapp001@ucr.edu), Weiwei Zhang[1]; [1]Psychology, Humanities Arts and Social Sciences, University of California Riverside

Extracting summary statistics from a visual scene requires little effort. However, it is unclear how fast this process can occur. The present study tested whether the initial feed-forward sweep in early sensory processing is sufficient for statistic perception by interrupting reentrant processes with Object Substitution Masking (OSM). OSM typically uses a 4-dot mask surrounding the briefly presented target, which either persists after the target offset (delayed-offset) or disappears with the target offset (simultaneous-offset). If the target duration is short enough, the 4-dots in the delayed-offset condition will interrupt the reentrant process. Previous literature has primarily relied on accuracy measurements to investigate masked summary statistics, finding mixed results. To resolve this issue, we adopted the dual-process signal detection (DPSD) framework to separate out two aspects of statistical perception: a discrete high-threshold process of seeing and a continuous feeling of sensing (analytically equivalent to recollection and familiarity in recognition memory, respectively). In Experiment 1, several groups of dots were flashed on the screen for 40ms. Participants first reported whether one group of dots contained more dots than other groups, and then reported their confidence on their choice. These responses were used to construct Receiver Operating Characteristics (ROC) from which seeing and sensing parameters were extracted. Three conditions were included: delayed-offset, simultaneous-offset, and no mask. The delayed-offset condition led to a large drop in the seeing component, with a small decrease in sensing, compared to the simultaneous-offset condition, suggesting that reentry processes were necessary for seeing numerosity. This decrease in seeing was eliminated in Experiment 2 when stimulus duration was extended to 80ms to allow reentry processes even for the delayed-offset condition. Taken together, the present results suggest that the initial feed-forward sweep is sufficient for sensing whereas reentrant processes are necessary for seeing in statistic perception.

Objects: Reading

Monday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4105 Individual differences in sensitivity to configural information predicts word recognition fluency

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Many theories and research findings have suggested that words are processed in a less holistic manner compared with faces, although most people have acquired a high level of perceptual expertise with both categories (e.g., Farah, 1998). Our recent studies using the composite paradigm have shown that words are also processed holistically, in that observers find it difficult to attend only to parts of a word while ignoring other parts (Wong et al., 2011, 2012; Chen et al., 2013). Here we further asked whether expert perception of words is associated with sensitivity to the configural information within a word, i.e., the spatial relationships between parts of a word. Fluent English readers with different degrees of fluency in Chinese reading performed a same/different matching of two upright or inverted words presented side by side. While same trials involved two identical images of the same Chinese character or English word, different trials involved the same character or word with different distances between parts, i.e., configuration differences. Participants in general showed an inversion effect, with faster responses in upright than inverted trials for both Chinese and English words. Importantly, individuals with more fluent Chinese character recognition showed a larger inversion effect for Chinese characters. Results indicated that perceptual expertise with words, similar to that with faces, is associated with processing of configural information. This calls for revision of existing theoretical frameworks that feature face and word perception as the most holistic and part-based examples of object perception respectively. Future research will need to investigate potential overlapping mechanisms underlying holistic and configural processing in words and faces.

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43.4106 Scrutinizing subliminal priming of numbers in the dissociation paradigm

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Unconscious response priming has been amply reported in studies adopting the dissociation paradigm, in which heavily masked prime stimuli modulate responses to targets (giving rise to a significant priming effect, mostly measured in reaction times, RT), whilst participants cannot classify the prime stimuli above chance level (e.g., measured in percent correct). The dissociation (significant priming effect vs. chance-level prime classification) is assumed to indicate that, even when participants are not consciously aware of the primes, they are nonetheless perceived and processed. Such purported dissociation, however, is predominantly based on a methodological problem of inequivalent metrics. We illustrated the problem by replicating and extending the behavioral part of Dehaene et al. (1998, Nature): In the masked priming experiment, one-digit numbers were visually presented as primes and targets. Participants judged whether target numbers were smaller or larger than 5. Subsequently, they were asked to ignore targets and classify heavily masked primes as smaller or larger than 5. The prime duration was manipulated by parametrically varying prime-mask stimulus onset asynchrony (SOA, from 10 milliseconds [ms] to 80 ms by 10 ms). At SOA=40 ms, a highly significant congruency priming effect (in RT difference) emerged, whereas prime classification (in percent correct) approximated chance-level. Upon closer inspection, however, no dissociation was found when the priming effect and prime classification performance was estimated in the same metric (e.g., in percent correct). Nor did a dissociation between priming task performance and prime classification performance arise at any other SOA. Furthermore, performance on prime classification increased monotonically along with increasing SOAs (from 20 ms upwards), which argues against chance-level prime classification at SOA=40 ms. In conclusion, performance dissociation, from which perception without awareness is to be derived, may purport to exist when the priming effect and prime classification is not compared in a shared metri

43.4107 The SNARC effect and visual and semantic features of Chinese numerals

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The SNARC (spatial numerical association of response codes) effect refers to an association between numbers and spatial properties of responses. The effect occurs in a multitude of stimulus notations, such that it is commonly thought to be amodal and notation-independent. In two experiments, we tested for a horizontal SNARC effect in participants from mainland China in Arabic digits, simple-form Chinese characters and Chinese hand signs to investigate whether the spatial mapping of numbers varied between notations with different visuospatial properties. We found a horizontal SNARC effect in all notations, the first time that a horizontal SNARC effect has been demonstrated in Chinese characters and Chinese hand signs. Chinese hand signs and Chinese characters were of particular interest to us, as these notations are represented non-symbolically through numerosity for low numbers (1…5 and 1…3, respectively) but symbolically for higher numbers, thus giving us a control condition within the same notation to investigate effects of numerosity on the processing of numbers. Our data indicate that numerosity is processed in parallel to number magnitude and substantially influenced the strength of the SNARC effect. We discuss both purely perceptual mechanisms for this influence, considering processing times and the different visual complexity of symbolically and non-symbolically represented numbers, and cognitive mechanisms taking into account previous studies on the role of reading and finger counting habit in numerical processing.

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43.4108 Word and Sentence Level Spatial Information In Reading

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Reading is considered an inefficient activity that requires independent detection of individual letters without integrating word or sentence information. We studied the use of word- and sentence-shape information using word discrimination and reading tasks with spatially distorted text in 18 naïve observers. Threshold durations were measured as a function of the wavelength and magnitude of spatial distortion applied to text for word/non-word classification of 4 and 8 letter words, and true/false classification of 4-word sentences. Spatial distortion slowed word recognition and reading. Unlike the uni-modal tuning functions observed in noise masking studies, we find multi-modal tuning functions that correspond to maximal impairment at around 2 cycles per letter, 2 cycles per word and 2 cycles per line of text. These data imply that information at these word- and sentence-length dependent scales

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are important for word recognition and reading, This finding is consistent with the robustness of reading letter-substituted text, proof-reading errors and the ineffectiveness of letter-based assistive reading methods.
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43.4109 The efficiency of trans-saccadic integration in foveal and peripheral word recognition

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Reading involves multiple eye movements and necessitates the integration of visual information from successive fixations. Here, we quantify the efficiency of trans-saccadic integration during foveal and peripheral word recognition by comparing performance for a human and an ideal observer. In Experiment 1, subjects were asked to identify random trigram letters presented at 13 possible positions on an invisible horizontal line at 0° or 10° eccentricity in lower visual field (horizontal distance from fixation dot: -6 to +6 letter slots). Trigrams were presented at a fixed size for different durations (62,125,250,500 ms followed by a post mask) while subjects steadily fixated a central dot. In Experiment 2, subjects were asked to identify single 7-letter words presented for 500 ms (followed by a post mask) at 0° or 10° eccentricity with lateral/horizontal positions identical to Experiment 1. First, a fixation dot appeared with '#' characters displayed at the word position. Subjects then pressed a button, which triggered the simultaneous appearance of a saccade-target dot and of the word. After execution of the saccade, subjects had to report the word. Eye movements were monitored to control fixation in Experiment 1 and to measure durations and positions of the two fixations in Experiment 2. Results for Experiment 1 show an inverted U-shape effect of the letter slot position on letter recognition performance. These visual-span curves (Legge et al, 2000) allow us to predict limitations in letter recognition performance for any fixation position and duration. Efficiency is then calculated using (1) human recognition performance from Experiment 2 and (2) recognition performance from an ideal observer based on visual span curves and a 7-letter word lexicon. Results show variability between subjects and suggest supplementary parameters to include in the model

43.4110 Behavioral and neural evidence of stored letter shape and abstract letter identity representations

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What are the learned representations that contribute to object identification? Using letter stimuli in behavioral and fMRI paradigms, we provide evidence for the role of stored "standard" letter shapes and abstract letter identity representations, also identifying their neural substrates within left ventral cortex. The behavioral experiments involved presentation of letter pairs in an unusual novel font; stimuli were 33 letter shapes, including letters that differed in font or case. Participants (n= 90) performed similarity judgments (Experiments 1a/b) and same/different physical identity judgments (Experiments 2a/b). To control for stimulus visual similarity and isolate the contribution of learned representations, stimuli were presented both upright and also rotated (90˚ccw, reflected across the vertical axis) to reduce identifiability while maintaining pixel-wise letter similarities across upright/rotated conditions. Pairwise similarity judgments, reaction times and accuracies were correlated with representational similarity matrices representing: pixel-overlap, similarity in a standard font, letter identity (across case/font). The assumption is that matrix correlations greater for the upright than rotated stimuli represent factors not reducible to stimulus similarity. Results revealed: pixel overlap correlations were comparable (r=.65/.63) for upright and rotated stimuli, while matrix correlations for standard shape and letter identity were greater for upright (r=.63; .59) than rotated (r=.34;.30) stimuli. The findings provide evidence for the role of stored standard letter shapes and cross font/case identity in letter identification. In the fMRI experiment, participants (n=11) viewed single upright letters in the novel font and underwent retinotopic mapping. MVPA computed the pairwise similarity of the multivoxel activation patterns which were compared to similarity matrices representing: stimulus similarity (from Experiments 1/2), standard font similarity and letter identity. Results indicated neural representation of: stimulus similarity in bilateral retinotopically defined cortex (V1, V2v, V3v, V4), standard font similarity left lateralized in LO, pF, and the mid fusiform and letter identity in the left mid fusiform.
Acknowledgement: NSF IGERT

43.4111 The VWFA and FFA have sharply contrasting functional selectivities and patterns of connectivity

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The visual word form area (VWFA), a small region on the lateral side of the left fusiform gyrus, responds at least twice as strongly to visually presented words and letter strings as it does to other visually similar stimuli, including words in an unfamiliar orthography (e.g. Chinese or Hebrew for English speakers), digit strings, and line drawings of objects (Baker et al., 2007). The VWFA is of particular interest in efforts to understand the functional organization of the ventral visual pathway, and its developmental origins, because reading is a recent cultural invention (on the scale of human evolution) so it is unlikely that specialization for reading could have arisen through natural selection. Instead, the existence of the VWFA provides evidence that specialized cortical regions may arise through experience alone. However, several recent papers (Vogel et al. 2012, 2014) have argued that the VWFA does not respond selectively to visually presented words, and others have argued on the basis of studies of neuropsychological patients for a "comingling of face and word mechanisms" in the brain (Behrmann & Plaut, 2014). Here, using individual-subjects analyses, we show that although there is a small amount of overlap between the left fusiform face area (FFA) and the VWFA in some subjects, the non-overlapping regions have sharply contrasting functional profiles (analyzed with left-out data), and the VWFA responds no more to faces than objects and no more to objects than to scrambled words (Figure 1). Further, diffusion tractography reveals clearly different connectivity fingerprints (Saygin et al. 2012) for the lFFA and VWFA. These findings underline the clear functional and anatomical distinction between the lFFA and VWFA. Of great interest for future studies will be how these regions arise in development.
Acknowledgement: NIH Postdoctoral National Research Award

43.4112 Interference between holistic processing of English and Chinese words

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Holistic processing refers to the obligatory tendency to process objects as a whole rather than parts. It has been suggested to be a common potential marker for perceptual expertise across domains, including faces, cars, chessboards, musical notes, words, etc. However, whether there is an overlap in the underlying mechanisms for holistic processing across some of these domains remain unknown. In our study, we aimed to address this gap by examining the interference between holistic processing of Chinese characters and that of English words in Chinese-English bilinguals, using a paradigm similar to the one in Gauthier et al. (2003) and Boggan et al. (2012). We measured holistic processing of Chinese characters, as indicated by the congruency effect in a composite paradigm, and how this was affected by holistic processing of English words. Two-part Chinese words and four-letter English words were alternately presented in each block. Participants had to attend only to the left or right part of the words, and make a two-back judgment on whether the attended part of the current word was identical to that of the last word of the same writing system (Chinese or English). If holistic processing is more engaged in perceiving English words with aligned letters than words with misaligned letters, and if it competes for common resources with holistic processing of Chinese characters, then the congruency effect for Chinese characters should be reduced when embedded in aligned vs. misaligned English words. This English alignment by Chinese congruency interference was found, indicating interference between Chinese and English holistic processing. Such interference is unlikely to have a verbal locus, since throughout each block participants had to repeat aloud eight numbers for subsequent matching (verbal suppression). Overall, the findings indicate that there is a shared holistic processing mechanism for words in different writing systems.
Acknowledgement: This research was supported by the General Research Fund (456311, 14411814) from the Research Grants Council of Hong Kong to A.W, and by the Strategic Research Grant (7004101 7004316) from City University of Hong Kong to Y. W.

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Vision in Neurological Disorders

Tuesday, May 19, 8:15 - 9:45 am
Talk Session, Talk Room 1
Moderator: Geoff Boynton

51.11, *8:15 am* **Ensemble perception of emotions in children with autism** Themis Karaminis[1] (t.karaminis@ioe.ac.uk), Louise Neil[1], Catherine Manning[1, 2], Marco Turi[3], Chiara Fiorentini[4], David Burr[3], Liz Pellicano[1]; [1]Centre for Research in Autism and Education, UCL Institute of Education, [2]Department of Experimental Psychology, University of Oxford, [3]Department of Psychology, University of Florence, [4]Swiss Center for Affective Sciences, University of Geneva

Ensemble perception, the ability to rapidly and automatically assess the summary or 'gist' of large amounts of information presented in visual scenes, is available early in typical development (Sweeny et al., in press). Ensemble perception might be compromised in children with autism, who have been proposed to present limitations in their abilities to maintain and/or use summary statistics representations for the recent history of sensory input, which might be responsible for their unique perceptual experience (Pellicano & Burr, 2012). Here we examined ensemble perception of emotions in 29 children with autism, aged between 6 and 14 years, 30 age- and ability-matched typical children, and 12 typical adults. Participants received three child-friendly tasks: a) an average (ensemble perception) emotion discrimination task, assessing their ability to judge the average happiness of a set of 'morphs'; b) a non-average happiness discrimination task, evaluating baseline emotion discrimination; and c) a face identification task, estimating children's ability to identify morphs that had been previously presented to them. We also monitored participants' eye movements while they performed the three tasks using a Tobii X2-30 eye tracker (30 Hz). All three groups presented better precision in the non-average than in the average emotion discrimination task, while children's precision and accuracy in the three tasks were worse than those of adults- suggestive of a gradual and parallel maturation of emotion discrimination, ensemble perception, and face-processing abilities. Unexpectedly, children with autism were indistinguishable from typical children in their precision and accuracy across the three tasks. On eye-movement variables, the three groups did not differ in terms of the average number of fixations and the number of morphs sampled per trial. Contrary Pellicano and Burr (2012), these findings suggest that autistic children's abilities for ensemble perception of emotions are largely similar to those of typical children.

Acknowledgement: Medical Research Council

51.12, *8:30 am* **GABA Measured in Visual Cortex using MRS Predicts Atypical Dynamics of Binocular Rivalry Associated with Autism** Caroline Robertson[1,2] (carolinerobertson@fas.harvard.edu), Katherine Hermann[2], Eva-Maria Ratai[3], Nancy Kanwisher[2]; [1]Harvard Society of Fellows, Harvard, Cambridge, MA, [2]McGovern Institute for Brain Research, MIT, Cambridge, MA, [3]Martinos Imaging Center, MGH, Charlestown, MA

Intro: The primary agent of inhibitory neurotransmission in visual cortex, GABA, has been linked to autism etiology in animal, genetic, and post-mortem studies. Specifically, GABA is thought to be down-regulated in the autistic brain, producing an overabundance of excitatory neurotransmission. Yet, perturbations in GABAergic signaling have never been experimentally associated with behavioral symptoms in people with autism. We recently demonstrated a striking autistic deficit in binocular rivalry (Robertson et al., 2013), a visual behavior that is governed by Excitatory/Inhibitory dynamics in the brain. Here, we tested whether the dynamics of binocular rivalry in typical adults are correlated with levels of excitatory (glutamate) and inhibitory (GABA) neurotransmitters measured in vivo. Methods: We measured binocular rivalry dynamics in 18 control participants, as well as the concentration of excitatory (glutamate) and inhibitory (GABA) neurotransmitters in the primary visual (test) and motor (control) areas of each individual's brain using Magnetic Resonance Spectroscopy (MRS). Results: GABA in V1 strongly predicted the dynamics of binocular rivalry in control individuals (Proportion of mixed percepts: rho = -0.61, $p < 0.008$) – where less GABA predicted slower binocular rivalry dynamics with longer mixed percepts, corresponding to the atypical dynamics we previously observed in ASD. This relationship was observed for rivalry using both simple (gratings) and complex stimuli (objects) (both $r < -0.6$, $p < 0.009$). Further, these results were specific to visual cortex: while GABA concentration in M1 predicted performance on a Go/No-Go motor task (rho = 0.67, $p < 0.002$), it did not predict rivalry dynamics (rho = -0.35, $p > 0.19$). Conclusions: Here, we demonstrate that a robust behavioral alteration in individuals with ASD strongly predicts GABA concentration measured in controls. This research may lead to the first experimental demonstration of a link between a robust autistic symptom and a prominent theory of autistic neural circuitry.

51.13, *8:45 am* **Are reading and face processing related? A study of word processing in developmental prosopagnosia.** Randi Starrfelt[1] (randi.starrfelt@psy.ku.dk), Solja Klargaard[2], Anders Petersen[1], Christian Gerlach[2]; [1]Department of Psychology, University of Copenhagen, Denmark, [2]Department of Psychology, University of Southern Denmark

Traditionally, perceptual processing of faces and words is considered highly specialized, strongly lateralized, and largely independent. This has, however, recently been challenged by studies showing that learning to read may affect the perceptual and neural processes involved in face recognition. In this light, investigating face processing in dyslexia, and reading in prosopagnosia becomes interesting: Do deficits in the two domains dissociate? Developmental prosopagnosia (DP) is a disorder of face processing in the absence of brain injury, and in the context of normal intelligence and general cognitive development. In three experiments, we investigated reading performance in a group of 11 participants with DP and matched controls: First, we examined if reading speed was affected by word length. Secondly, we compared RTs for single word and single letter stimuli. Third, we measured the word superiority effect in accuracy of word and letter report with brief exposure durations. These data were also analysed using methods based on a Theory of Visual Attention1, to extract estimates of perceptual processing speed for words and letters. We find that the group of DPs perform well within the normal range on all reading tests. They show normal reading RTs, and no abnormal word length effects. They also show an RT advantage for short words over single letters, as we have previously found in normal subjects.2 The DP group also show the typical word superiority effect, reflected in better overall accuracy, a lower perceptual threshold, and higher processing speed for words compared to letters. In sum, we find no evidence that reading skills are abnormal in developmental prosopagnosia, a finding that may challenge the recently proposed hypothesis that reading development and face processing abilities are intrinsically linked. References 1 Bundesen, C. (1990). Psych. Rev., 97, 523-547. 2 Starrfelt, R., et al. (2013). Front.Hum.Neurosci., 7, 519.

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51.14, *9:00 am* **Frequency tuning in auditory but not occipital cortex predicts frequency discrimination in early blind individuals.** Elizabeth Huber[1] (ehuber@uw.edu), Jessica Thomas[1], Geoffrey Boynton[1], Ione Fine[1]; [1]Department of Psychology, University of Washington

Introduction: Early onset blindness is associated with enhanced auditory abilities, which may be supported by plasticity within auditory and/or occipital cortex. We previously reported auditory frequency selectivity within occipital cortex of early blind subjects, accompanied by significantly narrower tuning bandwidths within auditory cortex. To assess the functional role of these group differences, we now examine whether it is possible to predict individual auditory frequency discrimination thresholds based on estimates of frequency tuning within auditory and/or occipital cortex. Method: Tonotopic mapping was carried out in auditory and occipital cortex in 4 early blind and 4 sighted controls using fMRI. Stimuli were pure tones ranging from 88 to 8000 Hz, presented in pseudo-randomized sequences. Using methods developed by Thomas et al. (2014), we estimated a one dimensional Gaussian sensitivity profile on a log auditory frequency axis for each voxel within anatomically defined regions of interest. We next measured auditory frequency discrimination thresholds for the same subjects in a separate session using 6 pure tones with baseline frequencies ranging between 200 and 6400 Hz. Frequency discrimination thresholds were then estimated for each of these baseline frequencies by finding the increment in frequency that produced a criterion change in expected BOLD response across voxels. This allowed us to predict psychophysical frequency discrimination performance for each subject based on cortical responses with a single free parameter. Results: For both blind and sighted subjects, discrimination thresholds as a function of baseline frequency were

well predicted from estimated frequency tuning within auditory cortex. In contrast, frequency tuning within occipital regions (found only in the blind group) did not predict behavioral performance well, either alone or in combination with auditory cortex. Our findings suggest that, despite showing frequency tuning, auditory responses within occipital cortex may support auditory tasks more complex than simple frequency discrimination.

Acknowledgement: Auditory Neuroscience Training Grant: NIH 2T32DC005361-11, NIH RO1 EY014645

51.15, *9:15 am* **Effect of familiarity on Braille writing and reading in the blind: From graphemes to comprehension** Lora Likova[1] (lora@ski.org), Christopher Tyler[1], Laura Cacciamani[1], Kris Mineff[1], Spero Nicholas[1]; [1]The Smith-Kettlewell Eye Research Institute

While the brain network for Braille reading (BR) in the blind is well known, fMRI studies on Braille writing (BW) are lacking. Consequently, no comparative network analysis of BW vs. BR exists. Here, we report the first BW/BR study, together with the effect of text familiarity on both. Methods: FMRI was conducted in a Siemens 3T Trio scanner. Our custom MRI-compatible drawing/writing tablet was further modified to provide for BR and BW. Each of five paragraphs of novel Braille text describing objects, faces and navigation sequences was read, then reproduced twice by writing from memory, then read a second time (20s/task). Results and Conclusions: BR: During the initial reading (unfamiliar text), the tactually-sensed Braille letters strongly activated the classical grapheme area, but its activation was drastically reduced on the second reading (familiar text). Despite the lack of vision, visual areas (V1-3) were strongly activated during both readings. Interestingly, activation in key mirror neuron areas, including the anterior intraparietal sulcus (aIPS) and inferior frontal gyrus (IFG), significantly expanded as a function of the familiarity of the text, in contrast to the marked decrease in the grapheme area. Taken together, these patterns of activation imply a shift from detailed "visual" processing of Braille-letter forms to an embodied cognition interpretation of the same Braille text when familiar. BW: Braille writing engaged a significantly more extensive network than BR, particularly in the initial writing block. Also, in contrast to drawing in the blind (Likova, 2012), BW generated focal activation restricted to the most foveal part of V1, presumably reflecting the focal demands of such a precision task. This first study of the brain network for Braille writing-from-memory, its comparison to the Braille reading network, and the effects of text familiarity on them, further allows for comparison with visual writing/reading mechanisms.

51.16, *9:30 am* **Agnosic vision is crowded** Marialuisa Martelli[1,2] (Marialuisa.Martelli@uniroma1.it), Francesca Strappini[1,3], Enrico Di Pace[1,3], Denis Pelli[4]; [1]Department of Psychology, University of Rome La Sapienza, Rome, Italy, [2]Neuropsychology Research Centre, IRCCS Foundation Hospital Santa Lucia, Rome, Italy, [3]Neurobiology Department, Weizmann Institute of Science, Israel, [4]Department of Psychology and Center for Neural Science, New York University, New York, NY, USA

Visual agnosia is a neuropsychological impairment of visual object recognition. In spite of over a century of research, little is known about the nature of the functional damage underlying this deficit. We propose that the agnosic deficit is visual crowding: The central vision of agnosic patients is crowded, like the peripheral vision of normally sighted observers. To examine our hypothesis, for each patient who took multiple object-recognition tests, we converted each test score into an equivalent eccentricity, i.e. the eccentricity at which our normally sighted "standard" observer performs as poorly as the centrally-viewing patient. Our standard observer took 15 different screening tests for the diagnosis of visual agnosia at various eccentricities in his periphery. In normal peripheral vision, perception of a simple image (e.g. an isolated letter) is limited by acuity, and perception of a complex image (e.g. a face or a word) is limited by crowding. Our crowding hypothesis proposes that each apperceptive agnosia patient is limited by a degree of crowding that consistently corresponds to one equivalent eccentricity, across all complex images. Analyzing the published data of 32 apperceptive agnosia patients and a group of 14 Posterior Cortical Atrophy (PCA) patients, we find that acuity is spared, and each patient's pattern of object recognition deficits is well characterized by one number, the equivalent eccentricity (for crowding) at which our standard observer's peripheral vision is like the central vision of the agnosic patient. In other words, each agnosic patient's equivalent eccentricity is conserved across tasks. Across patients, equivalent eccentricity ranges from 4 to 40 deg. This indicates that the visual impairment of apperceptive agnosia is crowding. In concert with Song, Levi, & Pelli (2014), we report a double dissociation of acuity and crowding: apperceptive agnosia worsens crowding while sparing acuity, and anisometropic amblyopia worsens acuity while sparing crowding.

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Attention: Features and objects

Tuesday, May 19, 8:15 - 9:45 am
Talk Session, Talk Room 2
Moderator: Viola Stormer

51.21, *8:15 am* **Time course of early visual cortex dynamics during top-down modulated attention shifts within or between feature dimensions** Matthias Mueller[1] (m.mueller@uni-leipzig.de), Christian Keitel[1,2]; [1]Institute of Psychology, University of Leipzig, [2]Centre for Cognitive Neuroimaging, Institute of Neuroscience and Psychology, University of Glasgow

Shifting attention from one color to another color or from color to another feature dimension such as orientation is imperative when searching for a certain object in a cluttered scene. Most attention models that emphasize feature-based selection implicitly assume that within- and cross-dimensional shifts take equally long. In contrast, the dimensional weighting account (DWA) predicts that cross-dimensional shifts take longer than shifts within a dimension because attentional weights need to be shifted not only between features but also from one dimension to another. We investigated whether shifting costs between feature dimensions is a general mechanism beyond singleton feature search in a non-search task. To this end, we recorded time courses of behavioral data and steady state visual evoked potentials (SSVEPs) in human EEG that provide an objective electrophysiological measure of neural dynamics in early visual cortex. SSVEPs were elicited by four random dot kinematograms (RDKs) that flickered at different frequencies. Each RDK comprised dashes that uniquely combined two features from dimensions color (red or blue) and orientation (slash or backslash). Subjects were cued to either shift attention within a feature dimension (e.g. from color to color) or cross-dimensionally (e.g. from color to orientation) and to detect and respond to short coherent motion events of a subset of dots at the to-be-attended dimension while ignoring all other events. For behavioral as well as electrophysiological data we found that shifts between feature dimensions took longer than shifts within dimensions. Interestingly, shifts towards color were took less time than shifts towards orientation, regardless of the initially to-be-attended feature. In conclusion: While the first result is in line with the DWA the second might reflect – in line with previous studies – that color and orientation are preferentially processed at different stages of the visual cortical hierarchy that receive attentional top-down modulations with different latencies.

Acknowledgement: Funded by Deutsche Forschungsgemeinschaft (MU 972/20-1)

51.22, *8:30 am* **My Color Singleton: Visual Attention to Learned Action-Effects** Davood Gozli[1] (d.gharagozli@mail.utoronto.ca), Hira Aslam[1], Jay Pratt[1]; [1]Department of Psychology, University of Toronto

We examined the prioritization of a salient feature immediately after an observer performs an action. Previous work suggests that sensory salience is reduced for a feature that results from the observer's own action (i.e., self-caused) compared to a feature that is independent of the observer's action (i.e., externally caused). Similar to how difficult it is to tickle oneself (Blakemore et al., 1998) or to discriminate a self-caused sensory signal from noise (Cardoso-Leite et al., 2010), we expected reduced salience for self-caused visual features. In an initial acquisition phase, participants learned the perceptual outcome of two actions. One key always generated the color red, and the other generated green. By acquiring action-outcome associations, the appearance of red is coded as a self-caused event after performing the corresponding key, whereas it would be coded as an externally caused event after performing the non-corresponding key. In a following test phase, the two colors were presented as salient singletons in otherwise-white search displays. We compared the attentional impact of self-caused and externally-caused singletons, which could be either relevant (the singleton was the target) or irrelevant (the singleton was a distractor). Contrary to previous work, we found that participants were more efficient at both selecting and ignoring a self-caused singleton compared to an externally caused singleton. Specifically, the effective salience of a self-caused singleton can increase when it is relevant (larger cueing effect for the target) or decrease when it is irrelevant (smaller interference effect for a distractor), whereas no such relevance-based modulation was

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found with externally-caused singletons. These findings demonstrate how performing an actions prepares visual attention for the most optimal strategy toward the predicted action-outcome, discriminating between self-caused and externally caused events, in a task-appropriate manner.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

51.23, *8:45 am* **Evidence against global attention filters selective for absolute bar-orientation in human vision** Matthew Inverso[1] (matthew.inverso@gmail.com), Peng Sun[1], Charlie Chubb[1], Charles Wright[1], George Sperling[1]; [1]Cognitive Sciences, University of California, Irvine

Introduction: It is well documented that a vertical bar will pop out amongst many horizontal bars. Since this search task is so natural and automatic, and because orientation selective cells are so widespread in early visual areas, it is commonly assumed that people have access to preattentive mechanisms tuned to vertical bars and not horizontal ones. These mechanisms should enable feature-based attention to vertical versus horizontal bars across different tasks. However, we show here that in a top-down selective attention task, people do not have access to these mechanisms. Methods: Stimuli were random clusters comprising 1-, 2-, 3-, or 4-each of black horizontal, black vertical, white horizontal, and white vertical bars. In different attention conditions, participants strove to mouse-click the centroid of only the (1) black, (2) white, (3) vertical, or (4) horizontal bars in the stimulus display, ignoring the bars of the opposite feature. Results: We found that when there is only one of each type of bar, participants could attend to the feature of interest very well, regardless of what the feature was. However, when faced with two or more of each type of bar, they could only perform the task in the attend-to-black and attend-to-white cases. When attempting to attend to just vertical or just horizontal bars, participants gave nearly as much weight to the distractors as to the targets. We propose that instead of using a mechanism for absolute orientation, a local orientation-contrast mechanism is used. In a follow-up study with 4 targets and 16 distractors in which sparse targets stand out among the more numerous distracters, participant performance improved dramatically. Conclusion: As suggested by Nothdurft (Perception & Psychophysics,52,355-375, 1992), feature-based attention has access only to mechanisms sensitive to spatial orientation-contrast, not to mechanisms selective for absolute bar-orientation

Acknowledgement: This work was supported in part by NSF BCS-0843897

51.24, *9:00 am* **Attribute Amnesia: Failure to report attended, task-relevant attributes of a highly visible object** Hui Chen[1] (psychenhui@gmail.com), Brad Wyble[1]; [1]Department of Psychology,The Pennsylvania State University

We intuitively believe that when we attend to an attribute (e.g., color or identity) of a highly visible stimulus, we will be able to report it immediately afterwards. Conventional theories of cognition also suggest attention as a gateway to working memory (e.g., Awh, Vogel, & Oh, 2006), or regard working memory as an interface in which attention can operate in the absence of visual input (Chun, 2011). Despite extensive evidence showing the crucial contribution of attention in the storage and maintenance of information, recent experiments have revealed striking demonstrations that a more important determinant of robust memory storage is the expectation of the observer that the attended information needs to be remembered (Chen & Wyble, in press at Psychological Science; Eitam et al., 2013). In our experiments, participants were asked to locate a target among distractors by using one particular attribute (e.g., letter identity) for several repetitions and were then surprisingly asked to report that attribute. The results showed that participants could not report the attribute of the target, even though that attribute had been attended and used by participants to perform the primary task (e.g., localized a target letter among digits) just prior to the surprise question. Followup control trials ensure that this effect is not a failure of perception. We term this effect attribute amnesia. In an extension, participants counted passes of a colored ball in a video recorded from a real-world context. In a surprise trial, 35% of participants could not report the color of the ball they had just been tracking for 40 seconds. These results change our understanding of the link between attention and memory. Instead of memory being a record of attended information, we must view memory storage as a resource that is used sparingly in strict accordance with the goals of the observer.

Acknowledgement: NSF BCS 1331073

51.25, *9:15 am* **Feature correlation guidance in category visual search** Rachel Wu[1] (rachelwu2006@gmail.com), Zoe Pruitt[1], Megan Runkle[1], Kristen Meyer[1], Gaia Scerif[2], Richard Aslin[1]; [1]Brain and Cognitive Sciences, University of Rochester, [2]Dept of Experimental Psychology, University of Oxford

Compared to objects with uncorrelated features (e.g., jelly beans come in many colors), objects with correlated features (e.g., bananas tend to be yellow) enable more robust object and category representations (e.g., Austerweil & Griffiths, 2011; Wu et al., 2011; Younger & Cohen, 1986). It is unknown whether these more robust representations impact attentional templates (i.e., working memory representations guiding visual search). Adults participated in four visual search tasks (2x2 design) where targets were defined as either one item (a specific alien) or a category (any alien) with correlated features (e.g., circle belly shape, circle back spikes) or uncorrelated features (e.g., circle belly shape, triangle back spikes). We measured behavioral responses and the N2pc component, an event-related potential (ERP) marker for target selection. Behavioral responses were better for correlated items than uncorrelated items for both exemplar and category search. While the N2pc amplitude was larger for exemplar search compared to category search, the amplitude only differed based on feature correlation for category search: The N2pc was present for category search with correlated features, and not present in search for uncorrelated features. Our ERP results demonstrate that correlated (and not uncorrelated) features for novel categories provide a robust category representation that can guide visual search.

Acknowledgement: This research was funded by an NRSA (grant number F32HD070537) from NICHD to RW, and an NIH grant (HD-037082) to RNA.

51.26, *9:30 am* **Tuning attention to high-level objects: Spatially global effects of attention to faces in visual processing** Viola Störmer[1] (vstormer@fas.harvard.edu), Michael Cohen[1,2], George Alvarez[1]; [1]Psychology Department, Harvard University, [2]Department of Brain and Cognitive Sciences, McGovern Institute for Brain Research, Massachusetts Institute of Technology

When attending to a feature in the visual environment (e.g., the color red), sensory processing of stimuli sharing that feature is enhanced throughout the visual field. These global effects of feature-based attention are observed in lower visual areas for simple features such as color or orientation (Saenz et al., 2002) and have been shown to extend to basic shape processing in higher visual area LO (Peelen & Kastner, 2009). Here, by examining the face-specific N170 component in the EEG signal, we asked if the global spread of attention would be observed for higher levels of face processing. We presented grayscale images from different categories (faces, buildings, cars, chairs, fish) in a rapid RSVP stream presented either in the left or right visual field, and asked participants to covertly attend to either faces or buildings while recording their brain's electrical activity. During each trial, task-irrelevant images of faces or houses were briefly presented at random intervals in the unattended visual field ("probes"). On half of the trials, no target image was present in the RSVP stream, and these trials were used for the EEG analysis. We measured the event-related potentials (ERPs) elicited by the task-irrelevant probes and identified the face-sensitive N170 component at posterior electrode sites by comparing ERPs elicited by faces relative to houses. Next, we compared the N170 when participants attended to faces vs. buildings in the RSVP stream. We found an increased N170 (p=0.02) when participants performed the face task, suggesting that neural processing of faces – as indexed by the N170 component – was enhanced throughout the visual field. There was no attentional modulation of the ERPs elicited by house stimuli (p=0.50). These results suggest that when attention is tuned to complex, real-world face stimuli, tuning extends across the visual field, even to unattended locations.

Face Perception: Social

Tuesday, May 19, 10:45 am - 12:30 pm
Talk Session, Talk Room 1
Moderator: Constantin Rezlescu

52.11, *10:45 am* **The Face is the Mirror of the Cultural Mind** Chaona Chen[1] (c.chen.1@research.gla.ac.uk), Oliver Garrod[2], Philippe Schyns[1,2], Rachael Jack[1,2]; [1]School of Psychology, University of Glasgow, Scotland G12 8QB, [2]Institute of Neuroscience and Psychology, University of Glasgow, Scotland, UK

With the advent of the digital economy, increasing globalization and cultural integration, cross-cultural social communication is increasing, where the mutual understanding of mental states (e.g., confusion, bored) is a key

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social skill. One of the most powerful tools in social communication is the face, which can flexibly create a broad spectrum of dynamic facial expressions. Yet, systematic cultural differences in face signalling and decoding (e.g., see Jack, 2013 for a review) presents a challenge to the evolving communication needs of modern society (e.g., designing culturally aware digital avatars and companion robots that can adaptively recognize and produce both culture-specific and universal face signals). Understanding which face signals support accurate communication across cultures, and those that produce confusions therefore remains a central question. To address this question, we used a 4D Generative Face Grammar (GFG, Yu et al., 2012) with reverse correlation (Ahumada & Lovell, 1972) to model the dynamic facial expressions of four mental states – 'thinking,' 'interested,' 'bored' and 'confused' – in 15 Western Caucasian (WC) and 15 East Asian (EA) observers (See Figure S1 Panel A. See also Jack et al., 2012, 2014, Gill et al., 2014). Cross-cultural comparison of the dynamic models revealed, for each mental state, clear commonalities (see Figure S1, Panel B, Common Signals) and cultural specificities in AU patterns (Culture-specific Signals). To illustrate, in 'confused,' Cheek Raiser/Lip Stretcher are culturally common, whereas Upper Lip Raiser is WC-specific and Jaw Drop is EA-specific. Similarly, in 'thinking,' the Chin Raiser is culturally common, whereas the Dimpler is WC-specific and, in contrast, Brow Lowerer/Nostril Compressor are EA-specific. Together, our data provides a common face signalling basis for cross-cultural social communication, and identifies confusing face signals, with implications for the digital economy (e.g., algorithms designed to automatically detect face signals, e.g., Vinciarelli et al., 2009).

52.12, *11:00 am* **The serial dependence of perceived emotional expression** Alina Liberman[1] (alinal@berkeley.edu), David Whitney[1,2]; [1]Helen Wills Neuroscience Institute, University of California, Berkeley, [2]Psychology Department, University of California, Berkeley

People are not only able to quickly and accurately recognize emotional expressions, but are also highly sensitive to expression changes on short time scales. However, this sensitivity could result in unstable percepts of an individual's emotional expression from moment to moment. The visual system must therefore balance the need to accurately recognize emotional expressions with maintaining perceived stability over time. A mechanism that could serve this purpose is the Continuity Field, a spatiotemporal region within which the visual system biases object identity towards stability (Fischer & Whitney, 2014; Liberman et al., 2014). The Continuity Field may stabilize the expression attributed to an individual face by making it dependent on recently seen expressions. To test this, we showed subjects a variety of facial expression morphs ranging from happy to sad to angry and found a serial dependence in perceived expression. Each facial expression (target emotion) was shown for 250 ms after which subjects matched the expression of a test face to the target emotion they had just seen. Subjects made consistent errors when reporting the perceived expression of the target face, seeing it as more similar to the facial expressions presented on the previous two trials (up to 12 seconds previously). In a second experiment, we showed subjects a variety of emotional expression morphs for different identities. On each trial, subjects were presented randomly with one of two possible identities (a male or a female face). Results showed stronger serial dependence in expression when the 1-back identity was the same as the current identity. Overall, the results indicate that perceived facial expressions at any one moment are biased towards recently seen expressions, especially within the same identity. The Continuity Field may therefore support apparent stability of emotional expressions by introducing perceived serial dependence in an identity-selective manner.

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52.13, *11:15 am* **Cultural similarities and differences in processing facial expressions of basic emotions** Xiaoqian Yan[1] (xy760@york.ac.uk), Andy Young[1], Timothy Andrews[1]; [1]Department of Psychology, University of York

The ability to recognize facial expressions of basic emotions is often considered a universal human ability. However, recent studies have suggested that the commonality of recognition mechanisms across cultures has been overestimated and that people from different cultures (Western and Chinese) use information from different regions of face to internally represent expressions (Jack et al., 2009; Jack et al., 2012). We investigated this possibility by systematically examining cultural similarities and differences in the perception and categorization of facial expressions between participants from Chinese and British cultures. The perceptual task involved rating the degree of similarity between pictures of facial expressions of same or different emotions, and the categorization task involved forced-choice recognition of emotion from the same images. Our results showed no difference in perception of images of whole faces between British and Chinese participants, but both groups of participants were slightly more accurate overall at categorizing expressions shown on faces of their own ethnic group. To further investigate potential strategy differences we repeated the tasks but with presentation of only the upper (eyes and forehead) or lower (mouth and chin) half of each face. Again, perception of facial expressions was similar between the Chinese and British groups, and this held for upper and lower face regions. However, participants were better at categorizing facial expressions shown by members of their own ethnic group when only the lower halves of the faces were visible to them, indicating that the way culture shapes the categorization of facial expressions is largely driven by differences in information decoding from this part of the face. These findings clarify the way in which culture can influence the interpretation of facial expressions.

52.14, *11:30 am* **Exploring the relationship between body shapes and descriptions by linking similarity spaces** Matthew Hill[1] (mattqhill@gmail.com), Stephan Streuber[2], Carina Hahn[1], Michael Black[2], Alice O'Toole[1]; [1]The University of Texas at Dallas, [2]Max Planck Institute for Intelligent Systems

Human body shape variations can be measured physically and described verbally (e.g., curvy, stocky), though little is known about the relationship between body shapes and descriptions. We examined this relationship by linking two similarity spaces: one created from body descriptions (descriptor space) and the other from full-body laser scans (shape space). The descriptor space was generated from a multivariate correspondence analysis (CA) applied to participants' ratings of 164 female bodies using 27 body-descriptive terms. The shape space was made using a database of approximately 2000 full-body laser scans (cf. Anguelov et al. 2005). In interpreting individual axes, it appeared that similar information was captured in the first five components of both spaces, although axis ranking differed. To compare the spaces, the factor scores for the 164 bodies from the descriptor space (real bodies) were scaled and projected into the shape space, manually changing axis ranks according to interpretation. Synthetic bodies were created at these locations in the shape space. The resemblance between the synthetic and real bodies was tested as follows. Participants (n=60) rated the synthetic bodies using the original descriptor terms, in order to project them into the descriptor space. Next we measured the Euclidean distance between the real and synthetic body projections. The results indicated a resemblance between the real and synthetic bodies. First, matched pairs of real and synthetic bodies were closer, on average, than non-matched pairs, with a bootstrap test showing no overlap between the matched and non-matched mean distance distributions. Second, the coordinates of matched pairs were highly correlated (Axes 1-5; 0.94, 0.79, 0.71, 0.26, 0.32, all p's < 0.0008). We conclude that the verbal descriptions encapsulate critical dimensions of body shape. The combined space makes it possible to generate approximated body shapes from verbal descriptions and to generate approximated descriptions for arbitrary body shapes.

Acknowledgement: DoD

52.15, *11:45 am* **What is holistic processing, and is it related to face perception?** Constantin Rezlescu[1,2] (rezlescu@fas.harvard.edu), Tirta Susilo[3], Alfonso Caramazza[1]; [1]Department of Psychology, Harvard University, USA, [2]Institute of Cognitive Neuroscience, University College London, UK, [3]Department of Psychological and Brain Sciences, Dartmouth College, USA

Despite its central role in the face perception literature, holistic processing remains a poorly defined theoretical construct. Researchers investigating holistic processing typically use an operational definition, namely the size of the effect in classic paradigms such as the inversion, composite, and part-whole tasks. A basic hypothesis is that these effects tap the same mechanisms, and that they are important in accounting for variations in face perception abilities. Here we tested this hypothesis in an individual differences study (n=80). Face perception abilities were measured with the Cambridge Face Perception Test (CFPT) and a Face Matching task (FaceMatch). The holistic-related measures were the face composite effect, the part-whole effect, and the inversion effects obtained in the CFPT and FaceMatch. Inversion effects were also computed for the face composite and the part-whole tasks. We report three main findings. First, inconsistent with the hypothesis that they measure the same construct, the inversion, composite, and part-whole effects were not correlated (correlations between .01 and .19). Second, none of the holistic effects predicted face perception abilities. Third, the four inversion effects were not correlated (correlations between -.16 and .19; the correlation between the two most similar face inversion measures, derived from CFPT and FaceMatch, was .01). The lack of correlations between measures of interest is unlikely to be a methodological

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artifact because we found other predicted correlations (e.g. between CFPT and FaceMatch). We replicated the results with a subset of the original participants (n=58) and with a new group of undergraduate students (n=27). Our results indicate that the inversion, composite, and part-whole effects likely reflect the operation of distinct mechanisms. Furthermore, these mechanisms do not seem to influence face perception abilities across individuals in a significant way. The results challenge the traditional notion of holistic processing and the role of holistic processing in face perception.

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52.16, *12:00 pm* **Optimal point of fixation to faces for vision with a simulated central scotoma** Yuliy Tsank[1] (yuliy.tsank@psych.ucsb.edu), Miguel Eckstein[1]; [1]Department of Psychological and Brain Sciences, University of California, Santa Barbara

When identifying a face the majority of humans initially look at a point of fixation (just below the eyes) that optimizes perceptual performance as predicted by a theoretical foveated ideal observer (Peterson & Eckstein, 2012). Here, we use a simulated scotoma paradigm to investigate the potential effects of macular degeneration on human optimal points of fixation (OPF) in face identification and compare these to the predictions of a foveated ideal observer with a central scotoma (S-FIO). We also evaluate observers' ability to adapt to the scotoma and learn new initial fixation strategies to optimize recognition performance. Methods: Seven observers completed a 1 of 10 face (15 deg) identification task in luminance noise with a gaze contingent display which simulated a central scotoma (radius = 8 deg). In the first study, observers made free eye movements in eight alternating blocks (1000 trials) with face viewing times of 350ms and 1500ms. In the second study, we assessed the OPFs by having observers fixate 1 out of 4 horizontally centered positions on the face (~375 trials for forehead, eyes, nose, and mouth in random order) for 350ms. Finally, observers repeated the free eye movement study. Results: The human forced fixation study showed that the simulated scotoma shifted the OPF downwards toward the tip of the nose ($p < 0.05$) which was predicted by the S-FIO model. However, surprisingly, observers failed to change their eye movement strategy (first and third studies) to initially fixate the new scotoma-induced optimal point of fixation. Conclusions: Our findings show unlike object following and search tasks (Kwon et al, 2013), humans have difficulty adapting to the scotoma and re-learning optimal fixations for face identification. Results show the potential use of the S-FIO as a benchmark to evaluate changes in OPFs for humans with low vision disorders.

52.17, *12:15 pm* **Use of shallow, non-invariant representations in high-level face perception tasks** Sam Anthony[1] (santhony@wjh.harvard.edu), Walter Scheirer[2,3], Ken Nakayama[1]; [1]Department of Psychology, Harvard University, [2]Department of Molecular and Cell Biology, Harvard University, [3]Department of Computer Science, Harvard University

The most influential models of face perception over the past three decades have regarded the generation of an at least partially invariant representation as the necessary first step in most face processing tasks. Correspondingly, models of "high-level" face perception tasks such as personality judgment have relied on features likely to be measured or preserved in an invariant representation (e.g. physiognomy, pose). Several recent papers have proposed deep convolutional networks as a biologically-plausible mechanism for creating invariant representations, and have shown that those networks, when trained on recognition tasks, are able to predict activity in anterior portions of the ventral visual stream. We have created a series of models that predict human judgments of personality traits (such as trustworthiness and dominance). In these models, performance of "shallow" v1-like feature sets compares highly favorably to that of deep convolutional feature sets. By probing the feature space of these shallow models we show that the best-performing models' performance is driven by low-level features that are highly variable, even among images of a single individual. These features can be modified to change the relevant attribute rating for a given image without changing humans' subjective perception of invariant face characteristics such as identity or physiognomy. These results call into doubt the necessity or pre-eminence of an invariant face representation in the judgment of personality traits from face images. This in turn suggests that models of the face perception system – and of personality trait judgments – that operate on invariant representations of the type efficiently generated by biologically plausible deep convolutional networks may not capture the types of features most relevant for some high-level face perception tasks.

Color Perception: Material properties

Tuesday, May 19, 10:45 am - 12:30 pm
Talk Session, Talk Room 2
Moderator: Bei Xiao

52.21, *10:45 am* **Seeing transparent liquids from refraction-based image deformation and specular reflection** Takahiro Kawabe[1] (kawabe.takahiro@lab.ntt.co.jp), Shin'ya Nishida[1]; [1]NTT Communication Science Laboratories, Nippon Telegraph and Telephone Corporation, Japan

Without traditional luminance/color cues of perceptual transparency, dynamic deformations of a static image can produce a vivid sensation of a transparent layer. Moreover, this subjective transparent layer looks like a liquid when the deformation flow simulates, precisely or crudely, image deformation due to refraction of lights at a flowing liquid surface (Kawabe, et al., 2013, VSS). Transparent liquids not only refract lights from their body, but also reflect light. Refraction and reflection are never independent of each other, since both depend on the surface orientation map. If visual processing properly takes the physics of refraction into account, it is likely to be sensitive to the congruency between the refraction-based image deformation and the specular reflection. To test this, we synthesized, using Blender software, several scenes including transparent liquid flows in which the refraction-based image deformation was congruent with the specular reflection. To make incongruent stimuli, we combined the image deformation taken from one scene with the specular reflection taken from another. Observers viewed the congruent or incongruent scenes, and made ratings as to the strength of liquid and glossiness impression on five point scales. We found both rating scores to be generally high as long as the scenes were dynamic, regardless of the deformation-specular congruency. We also had observers discriminate congruent scenes from incongruent ones, and found that the discrimination was very difficult. These results indicate that, at least when perceiving a dynamic transparent liquid, the visual system is unable to check the congruency between the refraction-based image deformation and the specular reflection. The visual system may heuristically estimate the presence of a dynamic transparent liquid flow from the analysis of characteristic image deformations, likely produced by refraction, independently of analysis of the specular reflections, and without precisely considering the physical liquid structure.

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52.22, *11:00 am* **The influence of optical material appearance on the perception of liquids and their properties** Jan Jaap van Assen[1] (janjaap.vanassen@gmail.com), Roland Fleming[1]; [1]Department of Psychology, Justus-Liebig-University Giessen

In everyday life, we readily identify liquids with different viscosities, such as water, honey, and tar. Previous findings suggest we use both shape and motion cues to judge viscosity. However, many common liquids also have distinctive optical properties (colour, glossiness and translucency), which could influence how we perceive them. Although optical properties are independent of viscosity, it seems plausible we may associate specific appearances (e.g. caramel, milk, water) with particular viscosities. On the other hand, the visual system may correctly discount optical properties enabling 'viscosity constancy'. Here, we investigated whether optical characteristics influence viscosity perception. We simulated a wide range of viscosities from water to molten glass and rendered the resulting shapes with nine different surface characteristics. On each trial, subjects viewed a static frame from one such simulation ('test' stimulus) and performed two tasks. First, they adjusted the viscosity of a single frame from a later time-point in the simulation ('match' stimulus) to identify which shape appeared to have the same viscosity as the test. Match stimuli always had the same optical appearance (green goop). Next, observers rated six physical properties of the test stimulus. Subjects were good at matching viscosity apart from a consistent overestimation, especially of the runny liquids. Optical properties had almost no effect on matching, demonstrating good constancy. Wetness, liquidness, and sliminess ratings decreased systematically with increasing viscosity, with only weak effects of optical properties. In contrast, perceived shininess was invariant across viscosities but strongly affected by optical properties. However, perceived warmth and stickiness both showed substantial interactions between viscosity and optical properties, including non-monotonic relationships, suggesting subjects interpreted particular combinations of shape and reflectance as specific, recognizable liquids. These results suggest that although opti-

cal properties influence the perception of some characteristics of liquids, they have very limited influence on shape-based viscosity judgements.
Acknowledgement: EU FP7 ITN project PRISM (PITN-GA-2012-316746)

52.23, *11:15 am* **Visual perception of surface wetness** Masataka Sawayama[1] (masa.sawayama@gmail.com), Shin'ya Nishida[1]; [1]NTT Communication Science Laboratories, Nippon Telegraph and Telephone Corporation, JAPAN

We can visually recognize a variety of surface state. Just a quick look is sufficient to find the bath floor is dry, the road in front is slippery, the window glass is frosty, or the ornament is dusty. If a given surface state perception relies on the analysis of diagnostic image features, an effective strategy to reveal those features and the associated visual processing is to find a stimulus transformation that alters the apparent surface state. Here we report an image transformation that makes dry objects look wet. This wet filter consists of two operations: (1) Tone-remapping with an accelerating nonlinear function that renders the intensity histogram positively skewed: (2) color saturation enhancement. In an experimental test, we applied the wet filter to a variety of natural textures of the McGill Calibrated Colour Image Database. The results of a wetness rating experiment showed that the wet-filtered images were perceived as wetter than the original images. In addition, the perceived wetness depended on the variance of hue. The wet-filter was less effective for images with a small variance of hue. Optically, wetting a surface tends to increases the specular reflection. In addition, as the incoming light scatters repeatedly within the surface liquid layer, the light going out from the surface tends to be darker and more saturated. The effects of these optical changes can be simulated by the two wet-filter operations. However, positively skewed luminance histogram and high chromatic saturation may be caused by other factors — for instance, the visual scene may happen to include highly saturated glossy objects. This is presumably why hue variation matters. If the same image transformation simultaneously occurs in many different objects, the brain infers that the change likely has the same cause, such as water shower in the present case.
Acknowledgement: Supported by Grant-in-Aid for Scientific Research on Innovative Areas "Shitsukan" (No. 22135004) from MEXT, Japan.

52.24, *11:30 am* **Perceptual Dimensions of Material Properties of Fabrics in Dynamic Scenes** Bei Xiao[1,2] (bxiao@american.edu), William Kistler[1]; [1]Department of Computer Science, American University, Washington, DC, [2]Center of Behavioral Neuroscience, American University, Washington, DC

Deformable objects such as fabrics, rubber, and food can be distinguished by their textures, and also by the different motions they exhibit when interacting with external forces. These motion patterns can be used to estimate the intrinsic mechanical properties of the objects (Bouman et al 2013). Little is known however about human perception of mechanical properties (e.g. stiffness) in dynamic scenes. We use a dissimilarity scaling method to study how perception of mechanical properties of fabrics is related to the physical parameters of mass and bending stiffness using videos of both simulated and real fabrics. The stimuli are videos containing a hanging fabric moving under oscillating wind. In each trial, observers were shown a pair of these videos and asked to indicate on a scale of 0-100 how different the material properties of the two fabrics are from each other. In Experiment 1, we used Blender physics engine to simulate the cloth behavior. Four values are sampled for each of the 3 parameters: mass, structural stiffness, and bending stiffness. All the fabrics have the same textures. For each rendered video, the wind direction was randomized along a lateral plane. Five observers finished 2016 paired-comparisons, which were analyzed with a non-metric multidimensional scaling method to learn lower-dimensional embedding of the data. In Experiment 2, we performed the same experiment with videos of the real fabrics with similar scene settings. In the 2D perceptual embedding, we found that one dimension was best correlated with the mass, while the other dimension was correlated with the bending stiffness. Structural stiffness and wind direction did not predict perceptual dissimilarities. 2D embedding of the real fabrics also showed similar results. Together, the experiments suggest humans can estimate intrinsic mechanical properties of fabrics from dynamic scenes, while discounting variations in textures and direction of the wind force.

52.25, *11:45 am* **Gloss averaging and simultaneous contrast effects on real bicolored glossy surfaces** Sabrina Hansmann-Roth[1] (roth.sabrina@gmx.de), Pascal Mamassian[1], Sylvia Pont[2]; [1]Laboratoire des Systèmes Perceptifs, CNRS UMR 8248, Département d'Études Cognitives, École Normale Supérieure, Paris, France, [2]Perceptual Intelligence Lab, Industrial Design Engineering, Delft University of Technology, Delft, The Netherlands

Whether a surface is glossy or matte is physically independent of whether it is light or dark. Perceptually however, the albedo of specularly or diffusely reflecting surfaces can strongly influence perceived gloss (Pellacini et al., 2000, Proceedings of SIGGRAPH). Here we ask whether glossiness judgments are more constrained if there are variations of albedo within a single surface. To investigate the influence of different albedos on a single surface we first created a set of 45 real surfaces. Based on a 3D model, molds were cut out of polymer foam by the use of a CNC (Computerized Numerical Control) machine. Sheets of plastic (350mm x 350mm) were heated up inside a vacuum forming machine and then stretched onto the mold and later spray-painted in five colors and five gloss levels. Additionally, we also painted surfaces with combinations of two colors next to each other. 11 participants looked at each surface in a light box, through a viewing hole, and they were encouraged to rate the gloss on a scale from one to seven. In a second experiment participants rated only the left or the right half of each bi-colored surface. Our results confirm that perceived gloss varies with albedo. In addition, perceived global gloss of bicolored surfaces were close to the ratings of unicolored surfaces whose albedos are the average of the bicolored surfaces. However, results from the second experiment indicate that when participants rate gloss only on one side of the surface, judgments for lighter colors show simultaneous gloss contrast effects of the darker colors next to it. In conclusion we propose a fairly easy method to create mathematically defined bumpy, plastic surfaces with various colors and gloss levels. Our results from multi-colored surfaces show both averaging and simultaneous gloss contrast effects depending on the task.
Acknowledgement: This work was funded by the EU Marie Curie Initial Training Network

52.26, *12:00 pm* **Material-dependent shape distortion by local intensity order reversal** Shin'ya Nishida[1] (shinyanishida@mac.com), Masataka Sawayama[1], Takeaki Shimokawa[2]; [1]NTT Communication Science Laboratories, Nippon Telegraph and Telephone Corporation, JAPAN, [2]ATR Neural Information Analysis Laboratories, Advanced Telecommunications Research Institute International, JAPAN

The visual image of an object is formed by a complex interaction among the material (reflectance), geometry (shape) and lighting of the object. How, and how well, the visual system recovers these image-formation components from the resultant image is a longstanding problem in vision science. With constant shape and lighting, material changes drastically alter the intensity distribution of the object image. However, as long as these changes can be ascribed to variations in parameters for diffuse and specular reflectance (e.g., addition of highlights), they had only minor effects on the local intensity orders (Sawayama & Nishida, VSS2014). This observation led us to a hypothesis that the human shape-from-shading processing may be sensitive to the local intensity order information, while not to the steepness of intensity gradient to which material processing is very sensitive. To test this hypothesis, we examined human shape-from-shading perception for local-gradient-modulated images that shared the local intensity order map, but not the gradient magnitude map, with the original matte object images. Specifically, we randomly modulated the steepness of the intensity gradient between adjacent iso-intensity contours of the image. In the experiment, observers adjusted the tilt/slant of a gauge probe with the apparent surface normal direction. We found that the perceived shapes of the local gradient-modulated images were similar to those of the original images. We also examined the shape perception for objects with asperity scattering, a class of reflectance uncovered by diffuse/specular models, producing the appearances of velvet and peach. As compared to the matte image, the asperity scattering distorted the perceived shape when it caused local reversals of intensity order, while not when the asperity scattering completely reversed the intensity order map. These findings support the hypothesis that human shape-from-shading relies dominantly on the local intensity order information.
Acknowledgement: Supported by Grant-in-Aid for Scientific Research on Innovative Areas "Shitsukan" (No. 22135004 to SN and No. 25135737 to TS) from MEXT, Japan. TS is also supported by National Institute of Information and Communications Technology.

52.27, *12:15 pm* **Gloss constancy across changes in illumination** Gizem Kucukoglu[1] (gizemkucukoglu@gmail.com), Wendy Adams[3], Michael Landy[1,2]; [1]Dept of Psychology, New York University, [2]Center for Neural Science, New York University, [3]Department of Psychology, University of Southampton

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Images of glossy objects contain specular highlights. Human perception of gloss is correlated with such properties of the highlight field as luminance, contrast, highlight sharpness and coverage. However, these image properties are not only determined by object shape and surface reflectance, but also by characteristics of the illumination field. We explore the perception of gloss under complex, natural light fields and ask whether observers use the statistics of the light field to improve gloss constancy under changing illumination. Observers viewed pairs of smooth, random 'potato' objects and judged which was glossier in a 2-interval, forced-choice paradigm. Objects of varying specularity were rendered and displayed in complex, high dynamic range, natural light fields (spherical images of a scene from a single viewpoint), taken from the Southampton-York Natural Scenes (SYNS) dataset. Within any single trial, both objects were rendered as if placed in the same light field. One object was displayed with, as background, the visible portion of the light field with which it was rendered ('congruent'); the other was displayed against another, incongruent light field. We found modest but systematic effects of the incongruent light field. For example, when the incongruent light field in the background was a similar scene to the congruent one, but with artificially high contrast, the objects displayed against it were perceived as less glossy than those shown against the congruent light field. Observers also showed partial gloss constancy---using the background to interpret perceived gloss of the object---when objects were displayed against a novel, incongruent light field, or one that had been manipulated to simulate a low-contrast, foggy environment. Our findings suggest that observers are sensitive to the context in which objects are presented when making judgments of surface gloss.

Acknowledgement: NIH EY08266

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Tuesday Morning Posters

Visual Memory: Encoding and retrieval

Tuesday, May 19, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

53.3001 Visual and semantic subliminal priming by two unrelated images

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

There is little question that single visual images can subliminally prime (Bar & Biederman, 1998) but the question of whether multiple, unrelated visual objects also can subliminally prime is not clear. Two experiments, explored whether subliminal presentations of two unrelated, visual objects would each independently prime. Experiment 1 (N=22) had 180 primed and 60 non-primed trials. On primed trials two black on white line drawings of familiar objects were presented left (image a) and right (image b) of fixation for 14 ms, backward masked, and followed by 2 visible test images. Observers reported whether the test images were the same or different. Response times (RT) were recorded. When the test items were the same, they were a-a or b-b. When different, they were the prime pair itself, (a-b). Each prime pair was shown three times as a target and 3 times as a prime. On non-primed trials a blank screen preceded the mask, which was followed by 2 not previously shown images, either the same or different. RTs in primed and non-primed trials were compared. The final condition, a visibility check consisted of 120 trials, 60 with and 60 without the subliminal original prime pairs and confirmed that primes were largely unidentifiable. On average, only 4 of the 120 flashed images, which by now had been shown 7 times, were identifiable. Priming was confirmed by the fact that RTs on primed trials were significantly faster than on non-primed trials in the same ($p < .05$) and different conditions ($p < .05$). Experiment 2 (N=22) asked whether the images primed semantically by exchanging the target images for single descriptive words. Otherwise the procedure was identical. We again found significant priming for same ($p < .01$) and different responses ($p < .05$). The combined results confirm that two unrelated, subliminal images can both visually and semantically prime.

53.3002 The semantic advantage in object memorization

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Previous studies (Hwang et al., 2011) indicate that our strategies for memorizing objects in naturalistic scenes can be predicted by the semantic relationships between objects in that scene. That is, we tend to make saccades to objects that are most semantically related to the object in the current fixation. A possible explanation is that consecutive inspection of semantically similar objects facilitates object memorization. Previous work in our lab has shown that indeed, characteristic objects from a specific context have a close semantic relationship that facilitates recognition. The observed high recognition rate was not induced by gist-based errors, as performance did not decline even when false recognition rates were significantly reduced. When and how does this 'semantic advantage' arise during processing? We investigated this question using a rapid serial visual presentation task, which mimics sequential eye movements. A series of eight grayscale object images on a white background were shown for 250 ms each. Subsequently, participants saw another image and indicated whether it had been in the series (same/different judgment). The object sets were randomly chosen or taken from specific contexts such as airport, park or bedroom. In three experiments, we measured recognition accuracy as we varied target position (excluding first and last image in the series) and primed participants with context labels either before or after a trial. The context labels provided for random trials were randomly chosen and misleading. Results show that the semantic advantage starts after viewing approximately three objects in the context trials when compared to random trials. Priming with context labels (either before or after the trial) diminishes this advantage and in general hurts performance. These results reveal that object memory benefits from the semantic structure established by an efficient, unconscious mechanism that is impeded by conscious category processing.

53.3003 Exploring the visual components that make an image memorable

Rachit Dubey[1], Joshua Peterson[2], Bernard Ghanem[1], Ming-Hsuan Yang[3], Po-Jang Hsieh[4]; [1]King Abdullah University of Science and Technology, Saudi Arabia, [2]University of California, Berkeley, [3]University of California, Merced, [4]Duke-NUS Graduate Medical School, Singapore

Recent work by Isola et. al. (2011) has demonstrated that memorability is an intrinsic property of images that is consistent across viewers and can be predicted accurately with current computer vision techniques. Despite progress, a clear understanding of the specific components of an image that drive memorability is still unknown. While previous studies such as Khosla et. al. (2012) have tried to investigate this computationally, no behavioral study has systematically explored the memorability of image regions within individual images. Here we study which regions from an image are memorable or forgettable. Using a large image database, we obtained the memorability scores of the different visual regions present in every image. In our task, participants viewed a series of images, each of which were displayed for 1.4 seconds. After the sequence was complete, participants similarly viewed a series of image regions and were asked to indicate whether each region was seen in the earlier sequence of full images. A selection of these regions were taken from the sequence of images participants viewed previously while the others were taken from images never seen before. We then computed consistency ratings for the memorability of each region across participants. Results indicate the first direct evidence from subject data that memorability of specific image regions is consistent across observers (i.e. individual regions remembered by one viewer are remembered by others as well), and that certain regions within a particular image are more memorable than others. Furthermore, we show that this region memorability is different from bottom-up saliency by demonstrating a weak correlation between the two.

53.3004 Reexamining the Attention Rehearsal Hypothesis of Spatial Working Memory Maintenance

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It has been argued that the maintenance of spatial working memory contents is carried out by sustained activity of selective spatial attention that focuses on the specific locations at which the working memory items are presented (Awh et al., 1998). This attention-based rehearsal hypothesis, however, remains controversial (Belopolsky and Theeuwes, 2009). The current study re-examined this hypothesis using both behavioral and ERP measures of spatial attention. The behavioral experiment was an approximate replication of previous studies, whereas the ERP experiments further examined whether the retained attention, if it existed, was actively maintained or a mere passive after-effect of the encoding process. As in previous ERP studies, task-irrelevant probes were used to elicit the P1/N1 attention effect. Results showed that spatial attention was allocated to the to-be-remembered locations during the retention period, although this was not reliably detected by the behavioral index. Moreover, attention strength was unchanged even when a visual search task that presumably induced an additional workload was concurrently administered. These data indicate that an active, top-down, and location-specific maintenance of spatial attention is in fact at work during spatial working memory retention, although its functional significance is still not completely confirmed.

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53.3005 Evidence of probabilistic representation in assessing visual summary statistics

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People rapidly and precisely extract summary statistics (e.g. mean and variance) of visually presented ensembles. Such statistics are an essential part of their internal representation of the environment. Recently, we reported that human behavior in perceptual decision making tasks indicates that they handle simple visual attributes in a sampling-based probabilistic manner (Popovic et al. Cosyne 2013, VSS 2013; Fiser et al. ECVP 2013; Christensen et al. VSS 2014, ECVP 2014). In this study, we tested whether such probabilistic representations also may underlie the assessment of visual summary statistics. In each trial, subjects saw a group of circles (N=2...10, randomly chosen) of varying sizes and had to estimate either the mean or variance of

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the ensemble or the size of one individual circle from the group specified after the stimulus was taken off the screen. In addition, they also reported their subjective confidence about their decision on a trial-by-trial basis. Stimuli were presented at nine different durations (50, 75, 100, 133, 167, 200, 300, 400, or 600 msec). In accordance with previous results, participants could accurately estimate the mean, the variance and the size of an element within the ensembles. Interestingly, mean estimation improved significantly as the number of circles in the display increased. More importantly, we found an increasing correlation between error and uncertainty as a function of presentation time, which is the hallmark of sampling-based probabilistic representation. Thus, probabilistic representation is not used exclusively for the simplest visual attributes, such as orientation or the speed of small dots, but also in representing more abstract kind of summary statistics.

53.3006 **Spatial memory relative to the 3D environment guides body orientation in visual search.** M Pilar Aivar[1] (mariapilar.aivar@uam.es), Chia-Ling Li[2], Dmitry Kit[3], Matthew Tong[4], Mary Hayhoe[4]; [1]Facultad de Psicología, Universidad Autónoma de Madrid, Spain, [2]Institute of Neuroscience, The University of Texas at Austin, US, [3]Department of Computer Science, University of Bath, UK, [4]Center for Perceptual Systems, The University of Texas at Austin, US

Measurement of eye movements has revealed rapid development of memory for object locations in 3D immersive environments. To examine the nature of that representation, and to see if memory is coded with respect to the 3D coordinates of the room, head position was recorded while participants performed a visual search task in an immersive virtual reality apartment. The apartment had two rooms, connected by a corridor. Participants searched the apartment for a series of geometric target objects. Some target objects were always placed at the same location (stable objects), while others appeared at a new location in each trial (random objects). We analyzed whether body movements showed changes that reflected memory for target location. In each trial we calculated how far the participant's trajectory deviated from a straight path to the target object. Changes in head orientation from the moment the room was entered to the moment the target was reached were also computed. We found that the average deviation from the straight path was larger and more variable for random target objects (.47 vs .31 meters). Also the point of maximum deviation from the straight path occurred earlier for random objects than for stable objects (at 42% vs 52% of the total trajectory). On room entry lateral head deviation from the room center was already bigger for stable objects than for random objects (18º vs. 10º). Thus for random objects participants move to the center of the room until the target is located, while for stable objects subjects are more likely to follow a straight trajectory from first entry. We conclude that memory for target location is coded with respect to room coordinates and is revealed by body orientation at first entry. The visually guided component of search seems to be relatively unimportant or occurs very quickly upon entry.

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53.3007 **The Adaptive Nature of False Memories is Revealed by Gist-based Distortion of True Memories** Timothy Brady[1] (tbrady@wjh.harvard.edu), Daniel Schacter[1], George Alvarez[1]; [1]Department of Psychology, Harvard University

In addition to allowing us to remember objects and events that we have actually experienced, human memory systems are also subject to distortions, biases, and the creation of false memories. However, there are also potential benefits to our imperfect memory system: there are cases where memory distortion is actually adaptive, increasing the overall accuracy of memories. To examine one case where memory distortion might be adaptive, we had 24 participants view multiple real-world objects from a given category (10 airplanes, 10 backpacks…), and later recall the color of each object via a psychophysical adjustment task that allows us to examine both the variability of internal representations of color and the probability of forgetting an object's color altogether (see Brady et al. 2013, Psych. Science). According to a simple Bayesian analysis, the optimal response strategy in these circumstances involves systematic memory distortion: participants should report items' colors as closer to the mean color of the category than they were, since information from the category provides additional information above-and-beyond item-specific information. We found that participants were generally accurate, but even when they remembered having seen an item and remembered its color, they nevertheless reported the color as closer to the average color of its category than it really was (mean bias: 29°; $t(23)=7.9$, $p< 0.0001$). This bias remained even after accounting for the possibility that participants' guessed on some items using only category-based information. Thus, although participants' memories were systematically distorted, they were distorted in a way that is consistent with minimizing their average error according to a simple Bayesian analysis. This shows that memory distortion may not always be maladaptive: in some cases, distortion can result from a memory system that optimally combines information in the service of the broader goals of the person.

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53.3008 **Gestalt priors in visual working memory** Timothy Lew[1] (tim.f.lew@gmail.com), Edward Vul[1]; [1]University of California, San Diego

Visual working memory stores object features (e.g., locations) according to their statistical structure (Alvarez & Oliva, 2009). When recalling objects, people often use that structure information to compensate for uncertainty about the individual objects (Brady & Alvarez, 2011). Although any stimulus has its own ensemble statistics, people also have expectations from the real world about how objects are organized. Here we try to characterize Gestalt priors about the spatial arrangement of objects in an iterative visual working memory paradigm. We examined visual working memory's priors for locations by asking participants to recall the locations of objects, and then having someone else remember and reproduce those recalled locations. A long sequence of individuals remembering the positions recalled by previous participants yields a Markov chain that will overemphasize the priors that people use to encode object locations (Sanborn & Griffiths, 2008). Across iterations, subjects recalled objects more densely packed ($t(9)=8.03$, $p< .001$) and with more similar translational errors ($t(9)=9.11$, $p< .001$), suggesting that subjects grouped objects in memory. To determine how subjects grouped objects, we designed a non-parametric clustering algorithm that infers whether objects are parts of clusters or straight lines. The clustering model revealed that subjects increasingly grouped objects as lines, going from using line groupings 2% to 22% of the time. Furthermore, consecutive subjects were more likely to group objects the same way when arranged in lines ($t(9)=8.08$, $p< .001$) or very eccentric clusters ($t(9)=3.14$, Bonferroni corrected $p=.024$). This suggests that linear arrangements are particularly stable in memory. Our results are consistent with evidence that people use priors from the real world to efficiently encode information in visual working memory (Orhan & Jacobs, 2014). Additionally, the increasing likelihood of people remembering objects as components of lines rather than clusters suggests that these priors aid the perception of higher-level constructs from ensemble statistics.

53.3009 **Exogenous retro-cue modulates the precision of Visual Working Memory** Moran Israel[1] (morani.israel@gmail.com), Asher Cohen[1], Yoni Pertzov[1]; [1]Department of Psychology, Hebrew University, Jerusalem, Israel

Attention and visual working memory are assumed to be highly connected, sharing important similarities: Both connect low-level perceptual processes with higher-level cognitive processes, and both are highly limited in capacity. Attention cues were found to affect working memory performance not only when applied before stimuli are presented, but also well after they disappear (retro-cueing). All previous studies explored the effect of endogenous attention on visual working memory, using a retro cues that are informative of the target location. Endogenous attention was voluntarily shifted to the cued location, and memory performance improved. In the current study we explore the role of exogenous (as opposed to endogenous) attention on visual working memory by using cues that are uninformative, but are thought to shift attention automatically and involuntarily to target locations. We used a delayed estimation task with uninformative exogenous retro-cues, and a mixture model approach to characterize the type of errors done by subjects. Our results indicate that exogenous, uninformative, retro-cues improve the precision of visual working memory performance. This study strengthens the notion that memory precision is a flexible trait and that it is modulated by attention even when it is exogenous and applied well after visual stimuli are extinguished.

53.3010 **Retrieval-induced competition in visual short-term memory** Min-Suk Kang[1,2] (kangminsuk@skku.edu), Joongrul Choi[2]; [1]Center for Neuroscience Imaging Research (CNIR), Institute for Basic Science (IBS), Suwon, 440-746, Republic of Korea , [2]Department of Psychology, Sungkyunkwan University, Seoul, 110-745, Republic of Korea

Motion repulsion is a visual illusion in which perceived directions of the two sets of superimposed coherently moving dots are shifted away from each other than their physical directions. This illusion is thought to occur due to mutual inhibition of two pools of neurons representing different motion directions. We investigated competition between two mental representations by using the motion repulsion as a model system. Subjects were asked to remember direction of two random dot motion displays presented in sequence and then reported both of them. Similar to motion repulsion observed in perception, remembered motion directions were shifted away from their physical inputs. More importantly, the repulsion magnitude of an item was greater when it was retrieved following memory retrieval of the other item than when it was retrieved first. This suggests that earlier retrieval exerted greater inhibition on the item being held in short-term memory. Control experiments ruled out alternative hypotheses, such that neither reduced cognitive resources for maintaining short-term memory during memory retrieval nor continued interactions between short-term memory representations could explain distortion in short-term memory. Instead, our results indicate that reactivated representations during memory retrieval inhibit competing representations still being held in short-term memory. Our finding suggests that inhibition is a common feature of memory retrieval for both short- and long-term memory.

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53.3011 Incidental Learning and Memory for Spatial, Temporal and Spatio-Temporal Visual Stimuli Sujala Maharjan[1] (sujmaha@brandeis.edu), Jason Gold[2], Robert Sekuler[1]; [1] Department of Psychology, Brandeis University, Waltham, MA, [2]Department of Psychological and Brain Sciences, Indiana University, Bloomington, IN

Humans are highly skilled at recognizing patterns embedded within random stimuli. Gold, Aizenman, Bond & Sekuler (2013) generated such stimuli in order to assess memory and learning with rapidly presented sequences of quasi-random luminances. Adapting their paradigm, we tested the hypothesis that visual perception is more efficient in processing spatially distributed stimuli than time-varying ones like Gold et al.'s. In each of three experiments, subjects judged whether a subset of eight quasi-random luminances repeated or not. Experiment One compared detectability of within-stimulus repetitions embedded in spatially arrayed stimuli or in stimuli presented as a sequence of luminances. Subjects performed significantly better with spatial arrays than with temporally distributed sequences, even when the spatial arrays were presented for just a tiny fraction of the duration of a temporal sequence. Also, unlike what Gold et al. found with temporal sequences, performance was particularly good when the two halves of a spatial array were mirrored versions of each other. In Experiment Two, concurrent temporal and spatial information decreased performance relative to that seen when stimuli were presented in spatial mode alone. Finally, Experiment Three assessed learning for particular stimuli made to recur intermittently, interspersed throughout a block of trials. Performance improved steadily when a stimulus recurred, and did so at about the same rate for spatial and temporal stimuli, demonstrating equivalent accumulation of information in longer-term memory. Overall, our results show that detection of within-stimulus repetitions is better when items are presented spatially, in both mirrored and non-mirrored form, than when they are presented as a temporal sequence. Importantly, the incidental learning with both kinds of stimuli shows that, without motive or instruction, information from stimuli cumulates over successive recurrences. Keywords: Short-term memory, incidental learning, spatio-temporal sequences

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53.3012 Recognition-induced forgetting of objects is independent of remembering Ashleigh Maxcey[1] (AMMaxcey@manchester.edu), Kimberly Halvorson[2], Geoffrey Woodman[3]; [1]Department of Psychology, Manchester University, [2]Department of Psychology, Metropolitan State University, [3]Department of Psychology, Vanderbilt Vision Research Center, Center for Integrative and Cognitive Neuroscience, Vanderbilt University

What are the consequences of accessing a visual long-term memory representation? Previous work has shown that accessing long-term memories hurts memory for related items (i.e., recognition-induced forgetting, retrieval-induced forgetting) and improves memory for the targeted item (Anderson, Bjork, & Bjork, 1994; Maxcey & Woodman, 2014). Intuitively, these findings suggest that the suppression of related items in long-term memory facilitates the improved access of the targeted item, driven by the same visual memory mechanism. The goal of the present study is to determine whether these two outcomes are products of the same underlying visual memory mechanism or due to independent visual memory mechanisms. If remembering and forgetting in this paradigm are due to the same visual memory mechanism used to access a memory representation, then the magnitude of the memory benefit when remembering objects repeatedly will be directly related to the degree to which related items are forgotten. In contrast, if remembering and forgetting in this paradigm are due to different visual memory mechanisms that operate when accessing a memory representation, then remembering an item will be independent of the forgetting of related items. Here we used a parametric manipulation of the amount of practice each item received in the recognition-induced forgetting paradigm with visual objects. The results supported the independence hypothesis. Specifically, increased practice significantly strengthened memory for practiced items, but did not reliably effect recognition-induced forgetting. These results are inconsistent with competition-based accounts, which posit that strengthening associations should yield additional interference, and consistent with an inhibition-based account of the forgetting that occurs when accessing a memory representation (Anderson, 2003).

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53.3013 Temporal dynamics of immediate forgetting in visual working memory. Yoni Pertzov[1] (pertzov@gmail.com), Nori Jakoby[2]; [1]Department of Psychology, Hebrew University of Jerusalem, [2]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology

Forgetting impacts on many aspects of cognitive function in everyday life, but in spite of its significance, the underlying mechanisms remain unclear. It has been suggested that objects are maintained as integrated units in working memory and when forgotten they are lost as a whole, without leaving any trace. To study the validity of this claim we used a memory task with a continuous analogue scale of reporting with difficult-to-verbalize stimuli and variable delays. Analysis of the distribution of errors made by healthy participants showed that, contrary to the claim above, items are not only forgotten as a whole but the precision of report also deteriorates with time. While in short delays item "disappearance" seems to be a stationary process (not modulated by time) the decrease in precision rapidly saturates. Thus, the temporal dynamics of forgetting is different when considering the quality and quantity of memory representations. We continued by exploring the different neural mechanisms that might explain these temporal dynamics.

53.3014 Human egocentric position estimation Arash Yazdanbakhsh[1] (yazdan@bu.edu), Celia Gagliardi[1]; [1]Vision Laboratory, Center for Computational Neuroscience and Neural Technology, Boston University

The study of egocentric position estimation may shed light on visuospatial memory processes, such as physical space representation in our visual system. However, little has been done to test egocentric position estimation in humans and the few studies to date have investigated egocentric position estimation with context to ground or other stable visual cues. In this study, human participants are introduced to a three-dimensional virtual reality (VR) generated by a 120 Hz projector with a polarization filter and polarizing glasses that separated left and right eye images in a frame sequential stereoscopic configuration. Participants were placed in the center of a VR cylinder where 5,000 sesame dots were distributed at random distances (112cm to 168cm) from the participant, azimuth (+/- 29.12°), and height (120cm to 188cm from the floor). Nine possible targets were located on a horizontal plane 50cm from the participant's eye level on a three by three matrix at right, left, center azimuths (+/- 18.64°, 0°), and near, middle, and far distances (126cm, 137cm, 147cm from the participant). Participants were presented with one randomly selected target for 3 to 5 seconds before the target was relocated to a random location within the sesame dot field. The task was to reposition the target back to the original position. Depth was induced using disparity and size cues, except for sesame dots that had only disparity cues. Errors in distance repositioning occurred along the line of sight and repositioning showed an attraction bias toward the relocated target. Elevation repositioning was higher for farther targets ($P < 0.05$, $F = 3.19$). Azimuth repositioning for left targets were significantly shifted to the right ($P< 0.01$, $F= 18.42$). Standard deviations for distance repositioning were invariant against target distance, suggesting that egocentric visuospatial representation is based on Cartesian metrics rather than polar coordinates.

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53.3015 Evidence for parallel consolidation of motion direction and orientation into visual short-term memory Reuben Rideaux[1] (Reuben.Rideaux@anu.edu.au), Deborah Apthorp[1], Mark Edwards[1]; [1]The Australian National University

Recent findings have suggested the capacity to consolidate multiple items into visual short-term memory in parallel varies as a function of the type of information. That is, while color can be consolidated in parallel (JEP:HPP 2012, 429-438), evidence suggests that orientation cannot (APP 2013, 415-425). Here we investigated the capacity to consolidate multiple motion

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directions in parallel and re-examined this capacity using orientation. This was achieved by using a matching task to determine the shortest exposure duration necessary to consolidate a single item, then examining whether two items, presented simultaneously, could be consolidated in that time. The results show that parallel consolidation of direction and orientation information is possible. Additionally, we demonstrate the importance of adequate separation between intervals used to define items along a feature dimension when attempting to consolidate in parallel, suggesting that when multiple items are consolidated in parallel, as opposed to serially, the resolution of representations suffer. That is, performance is markedly poorer for parallel consolidation, compared to serial, when items are more similar, which is likely a result of low resolution representations being mistaken as neighboring items during the matching stage of the task. Finally, consistent with this interpretation, we showed that facilitation of spatial attention mitigates this affect, indicating that the deterioration of item resolution during parallel consolidation likely occurs during the encoding stage. Together, these results suggest that the variation in parallel consolidation efficiency observed for different features may, at least partially, be a result of the size of the feature perceptual space, i.e. the resolution at which features are processed relative to the size of their physical dimension.

53.3016 **The working memory Ponzo illusion: Involuntary integration of visuospatial information stored in visual working memory**
Jifan Zhou[1] (jifanzhou@zju.edu.cn), Haokui Xu[1], Haihang Zhang[1], Rende Shui[1], Mowei Shen[1]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University

Visual working memory (VWM) has been traditionally viewed as a mental structure subsequent to visual perception that stores the final output of perceptual processing. However, VWM has recently been emphasized as a critical component of online perception, providing storage for the intermediate perceptual representations produced during visual processing. This interactive view holds the core assumption that VWM is not the terminus of perceptual processing; the stored visual information rather continues to undergo perceptual processing if necessary. The current study tests this assumption, demonstrating an example of involuntary integration of the VWM content, by creating the Ponzo illusion in VWM: when the Ponzo illusion figure was divided into its individual components and sequentially encoded into VWM (so that the four lines in Ponzo figure components were never simultaneously presented), the temporally separated components were involuntarily integrated, leading to the distorted length perception of the two horizontal lines. This VWM Ponzo illusion was replicated when the figure components were presented in different combinations and presentation order. The magnitude of the illusion was significantly correlated between VWM and perceptual versions of the Ponzo illusion. These results suggest that the information integration underling the VWM Ponzo illusion is constrained by the laws of visual perception and similarly affected by the common individual factors that govern its perception. Thus, our findings provide compelling evidence that VWM functions as a buffer serving perceptual processes at early stages.

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53.3017 **Visual working memory for negative events is weakened by alternation between event types during judgments of trends.**
Rochelle Picardo[1] (rpicardo@psych.ubc.ca), Jennifer Whitman[1], Jiaying Zhao[1,2], Rebecca Todd[1]; [1]Department of Psychology, University of British Columbia, [2]Institute for Resources, Environment and Sustainability, University of British Columbia

In order to effectively assess trends in the severity of a problem, we must often integrate working memory representations of several types of event. Alternating between different event types may cause them to seem less salient in memory, leading to an overly optimistic view of a given trend. We tested this possibility in a visual task portraying a series of events related to the success of orchard crops over time. Each scenario in our task portrayed one decade worth of crops. Each "year", an icon was presented depicting either a healthy crop, a mild mold or insect infestation, a moderate infestation, or a severe infestation. In one condition, we structured the presentation order such that crop events of the same type occurred in sequence (e.g. mild mold, mild mold, moderate mold, healthy, mild insects, mild insects, moderate insects). Each "decade" in which crop events were grouped by type (the grouped condition) involved a different sequence – thus there was no statistical pattern to learn. In the ungrouped condition, the order of crop events within a decade was randomized (e.g. mild insects, mild mold, moderate insects, mild insects, healthy, moderate mold, mild mold). Participants were trained on four example scenarios depicting 'normal' frequencies for each type and severity of crop infestation within a decade. Next, following each decade in the main task, they rated the extent to which the crops had been better or worse than 'normal'. Participants were generally biased towards judging a decade worth of crops as better than it actually was. They also made a more optimistic rating of the crops in the ungrouped condition than the grouped one. This demonstrates how switching attention between different types of symptoms or signs of a problem can cause us to be blind to the severity of that problem.

Visual Search: Models and learning

Tuesday, May 19, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

53.3018 **The Information Theory of Vision: Evidence from Eye-Tracking**
Deborah Cronin[1] (cronin2@illinois.edu), Alejandro Lleras[1], Simona Buetti[1]; [1]Department of Psychology, College of Liberal Arts and Sciences, University of Illinois at Urbana-Champaign

Recently, our lab demonstrated a logarithmic relationship between reaction time and the number of items in a search display (e.g., Lleras & Buetti, VSS 2014; Cronin, Buetti, and Lleras, VSS 2014). Until now, the Reaction Time X Set-Size function was thought to be linear. Lleras and colleagues' displays differed from typical search displays in that there were various item-types differing in their similarity to the target. To account for their findings, the authors presented a new theory of visual search, the Information Theory of Vision (ITV). ITV proposes a two-stage model of visual search. The first stage is an unlimited capacity, but resolution-limited parallel processor. The second stage is a limited capacity, but resolution-unlimited processor. ITV uniquely proposes that the first stage of search proceeds logarithmically as unlikely targets (lures) are sequentially rejected. Items that are very dissimilar to the target are rejected rapidly, while items that are more similar to the target are rejected more slowly. The items most similar to the target (candidates) are passed on to the second stage for more detailed processing. The present study attempts to provide more evidence for ITV by replicating the results of two of Lleras and colleagues' behavioral experiments while monitoring for eye movements. Using eye-tracking allowed us to evaluate several unique claims made by ITV, in particular, the predicted rates of false alarm eye movements to items of different similarities to the target. This new analysis allows us to better differentiate ITV from other models of search, including Guided Search (Wolfe, 1994), Similarity Theory (Duncan & Humphreys, 1989), and the Target Acquisition Model (Zielinsky, 2008).

53.3019 **A nonlinear predictive model of natural scenes and visual saliency and search**
Jinhua Xu[1,2] (jhxu1008@yahoo.com), Zhiyong Yang[1]; [1]Brain and Behavior Discovery Institute,James and Jean Culver Vision Discovery Institute, Department of Ophthalmology, Georgia Regents University, [2]Department of Computer Science and Technology, East China Normal University

We now have models of visual neurons that account for responses to simple laboratory stimuli, but we do not know how and why neuronal responses are affected by a range of contexts. At the perceptual level, there is a long list of percepts that are influenced by contexts. This issue of visual encoding is also tied to visual search and attention. Much recent research on visual search has focused on visual saliency, which is a signal computed from an input stimulus and is proposed to guide the deployment of visual attention. A variety of measures of visual saliency are proposed, including self-information, Bayesian surprise, and discriminant power. However, it is unclear how these measures are related to neural encoding of natural scenes. To address these related issues, we propose a predictive model of natural scenes, neuronal responses, and visual saliency. In this model, 1) independent components (ICs) of natural scenes are basic visual features; 2) the ICs of the center are modeled as predictive, nonlinear functions of the ICs of the surround in a hexagonal center-surround configuration; 3) neurons estimate the probabilities of the predictive errors; and 4) visual saliency, perceptual quality that makes some items in visual scenes stand out from their immediate contexts, is based on the probabilities of the predictive errors. We performed statistical analysis of natural scenes and developed the predictive model. We then derived a measure of saliency from the model and used it to predict human behaviors on free-viewing of static and dynamic natural scenes and visual search in natural contexts. We found that the proposed predictive model accounts well for human performance on these tasks. This result suggests that, rather than detecting features, visual neurons estimate probabilities of visual stimuli in terms of predictive errors based on natural scene statistics.

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53.3021 **Spatial Reference Frame of Incidentally Learned Attention in a Probability Cuing Paradigm** Ying Fang[1] (fy090801@163.com), Shiyi Li[1], Nadia Wong[2], Shahan Tariq[2], Hanzhuang Zhu[2], Xuejun Bai[1], Hong-Jin Sun[2]; [1]Academy of Psychology and Behaviour, Tianjin Normal University, [2]Department of Psychology, Neuroscience & Behaviour, McMaster University

In a visual search task, if target appears more frequently in one region of the scene, over time participants will search faster when the target appears in that region compared to regions appeared less frequently. Previous research has demonstrated that the attended locations are viewer centered and are not updated with viewer movement (Jiang & Swallow, 2012). In the current study, we reexamined the frame of reference in this type of learning using computer rendered illustrations of realistic 3D scenes displayed on a table. The scene consisted of an array of chairs randomly positioned on the ground but with coherent orientation. The viewpoint information was readily available visually from the orientation of the chairs and a landmark positioned in the periphery of the scene. Participants searched for and identified a target positioned on the seat of a chair. During training, participants performed search from one side of the table. The target appeared more often in a "rich" quadrant (50% probability) than in any one of the "sparse" quadrants (16.7% probability). Following training, participants moved to another side of the table, producing a 90 or 180 degree changes of their viewpoints within the horizontal plane. During testing, the target appeared randomly with 25% of the time in each quadrant. Results demonstrated probability cuing during training with lower reaction time in the rich quadrant compared to the sparse quadrants. During testing, participants showed lowest reaction time in the quadrant that maintained the same spatial relationship with the viewer as the previously rich quadrant. However, one third of the participants also showed comparably low reaction time in the original rich quadrant. These data suggest while for most participants, the attended locations are viewer centered without update with their movement, some participants could possibly update with their movements (at least sometimes).

Acknowledgement: NSFC, NSERC

53.3022 **Learning visual search: increased retinotopic response to target vs. distractors in early visual cortex** Sebastian Frank[1] (sebastian.m.frank.gr@dartmouth.edu), Eric Reavis[2,1], Mark Greenlee[3], Peter Tse[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College, [2]Semel Institute for Neuroscience and Human Behavior, UCLA, [3]Institute for Experimental Psychology, University of Regensburg

What are the neuronal correlates of enhanced target stimulus saliency among distractors acquired while learning visual search tasks? We have addressed this question in three different experiments, each time using demanding visual search tasks that employ feature conjunction stimuli. In each experiment participants performed several training sessions. Brain activity, as measured by functional MRI scanning, was compared before and after training. In Experiment 1 participants learned to detect a red-green bisected disk among green-red bisected disk distractors by performing covert search (Frank et al., Hum Brain Mapp, 2014, 35, 1201-1211). In Experiment 2 we used the same red-green stimuli and, in addition, differently oriented T and L stimuli whereby a L-target had to be detected among T-distractors. As in Experiment 1 participants completed training sessions using covert search but, in contrast to Experiment 1, performed an attentionally demanding orthogonal task at fixation during scanning. In Experiment 3 participants viewed a radial array of moving dots and learned to detect a target dot with a "V"-shaped motion trajectory among distractors with an inverted "V"-shaped motion trajectory, again using covert search. In each of these experiments we found that the BOLD response in correct trials to the target at the respective retinotopic projection zone in visual cortex was enhanced relative to responses to the simultaneously presented distractors. Compared to pre-training, this effect was more pronounced after training and observed during covert search for the target (Experiments 1 and 3). This target-specific enhancement also persisted when attention was distracted by the fixation task (Experiment 2). We conclude that a retinotopic up-regulation of early visual cortical processing is associated with an enhanced target saliency while learning visual search tasks.

53.3023 **Variability during learning facilitates generalization in contextual cueing** Yoko Higuchi[1] (higuchi@cv.jinkan.kyoto-u.ac.jp), Yoshiyuki Ueda[2], Jun Saiki[1]; [1]Graduate School of Human and Environmental Studies, Kyoto University, [2]Kokoro research center, Kyoto University

Visual search performance is facilitated when fixed spatial configurations are presented repeatedly, an effect known as contextual cueing (Chun & Jiang, 1998). Although a previous study showed that contextual cueing occurred even when objects were jittered (Chun & Jiang, 1998, Experiment 6), it is not clear how variability influences contextual cueing. In the current study, we tested the hypothesis that variability during learning facilitates generalization in contextual cueing. 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. In Experiment 1, participants were assigned to either a jittered-pattern or a fixed-pattern group. During the learning phase, objects of repeated configuration were independently jittered trial by trial in the jittered-pattern group, while they were invariant in the fixed-pattern group. In a subsequent test, we presented "similar" patterns that were not presented in the learning phase. Both groups showed significant contextual cueing effects in the learning phase, but in the test, only the jittered-pattern group showed cueing effects. Thus, learning transferred to the "similar" patterns only in the jittered-pattern group, suggesting that variability is of sufficient importance to generalize contextual cueing. Experiment 2 expands these findings by using different jitter ranges. Participants were assigned to one of three groups: high, middle, or low variability group. During a learning phase, objects were jittered according to gauss distributions, and in a subsequent test, they were presented at high-probability or low-probability locations. The results showed that participants in the high and middle variability groups made equally fast responses to high-probability and low-probability location, while participants in the low variability group made faster responses to high-probability location than low-probability location. These results suggest that higher variability leads to flexible representation that can be generalized to similar patterns in contextual cueing.

3D Perception: Shading

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

Poster Session, Banyan Breezeway

53.3024 **Exploring the veridicality of shape-from-shading for real 3D objects** Jenny Bartov[1] (JennyBartov@gmail.com), Martin Giesel[1], Qasim Zaidi[1]; [1]Graduate Center for Vision Research, SUNY College of Optometry

Despite the large number of shape-from-shading studies, the degree of veridicality with which observers perceive real 3D objects has not been examined. Six observers viewed sinusoidal, triangular and trapezoidal corrugations made from gray cardboard of approximately uniform reflectance-presented either fronto-parallel or 33 degrees in slant. The object, placed inside a box, was illuminated from its top-left or left by a point light source. The corrugations were seen through an aperture that masked their terminating contours and the light source. Observers' were asked to draw the depth profile of the object as if it were seen from above. Using a computer mouse, they drew on a computer screen placed just below the object. The drawing area had the same size as the aperture through which the object was seen. Observers also indicated the orientation of the object and the location of the light source. In the first condition, the objects were viewed monocularly; in the second, a white matte sphere was placed in front of the object to help in locating the light; in the third, the task was repeated with binocular viewing. Drawings revealed that observers were quite accurate in inferring the objects' shapes when viewing binocularly. There was more variability among the observers when objects were viewed monocularly, with some systematic trends: 1. Many observers were able to recreate the veridical shapes despite monocular viewing, 2. The drawn shapes often differed from the shape of the luminance variations across the objects, thus rejecting heuristics such as "dark is deeper", 3. The slanted triangular corrugation was often confused with the trapezoidal and vice versa, as areas of uniform luminance could be interpreted as fronto-parallel or slanted. Detailed analyses of the drawings suggest possible heuristics that different observers might use to infer the shapes of the corrugations from shading variations.

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53.3025 Distinguishing between texture and shading flows for 3D shape estimation

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The visual system can infer 3D shape from orientation flows arising from both texture and shading patterns. However, these two types of flows provide fundamentally different information about surface structure. Texture flows, when derived from distinct elements, mainly signal first-order features (surface slant), whereas shading flow orientations primarily relate to second-order surface properties. It is therefore crucial for the brain to identify whether flow patterns originate from shading or texture to correctly infer shape. One possible approach would be to use 'surface appearance' (e.g. smooth gradients vs. fine-scale texture) to distinguish texture from shading. However, the structure of the flow fields themselves may indicate whether a given flow is more likely due to first- or second-order shape information. Here we test these two possibilities. We generated irregular objects ('blobs') using sinusoidal perturbations of spheres. We then derived two new objects from each blob: One whose shading flow matched the original object's texture flow, and another whose texture flow matched the original's shading flow. Using high and low frequency environment maps to render the surfaces, we were able to manipulate surface appearance independently from the flow structure. This provided a critical test of how appearance interacts with orientation flow when estimating 3D shape and revealed some striking illusions of shape. In an adjustment task, observers matched the perceived shape of a standard object to each comparison object by morphing between the generated shape surfaces. In a 2AFC task, observers were shown two manipulations for each blob and indicated which one matched a briefly flashed standard. Performance was compared to an orientation flow based model and confirmed that observers' judgments agreed with texture and shading flow predictions. Both the structure of the flow and overall appearance are important for shape perception, but appearance cues determine the inferred source of the observed flowfield.

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53.3026 The Effects of Smooth Occlusions and Directions of illumination on the Visual Perception of 3D Shape from Shading

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

Human observers made local orientation judgments of smoothly shaded surfaces illuminated from different directions by large area lights, both with and without visible smooth occlusion contours. Test-retest correlations between the first and second halves of the experiment revealed that observers' judgments were highly reliable with a residual error of only 2%. Over 88% of the variance between observers' judgments and the ground truth could be accounted for by an affine correlation, but there was also a systematic non-affine component that accounted for approximately 10% of the perceptual error. The presence or absence of visible smooth occlusion contours had a negligible effect on performance, but there was a small effect of the illumination direction, such that the response surfaces were sheared slightly toward the light source. These shearing effects were much smaller, however, than the effects produced by changes in illumination on the overall pattern of luminance or luminance gradients. Implications of these results for current models of estimating 3D shape from shading are considered.

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53.3027 Global constraints on integral curves of shaded surfaces

Benjamin Kunsberg[1] (bkunsberg@gmail.com), Daniel Holtmann-Rice[1], Steven Zucker[1]; [1]Computer Science, Yale University

The problem of shape from shading has been studied for many decades. Due to its ill-posed nature, almost every approach has attempted to reduce the ambiguity at the start. By making local assumptions regarding the light sources and surface, the problem can be reduced in complexity. However, due to the many ad hoc constraints, the resulting algorithms are often brittle and uninformative in describing possible biological structure. Rather, we use shape from shading as a test model to understand how the brain resolves geometric ambiguity. Our entire approach (VSS work 2012 - 2015) has been to mathematically represent ambiguity until it is at a scale sufficient to resolve itself. To this end, we have considered increasingly larger-scale features: local orientation flows (2012), critical contours (2013), and ridges (2013). In this work, we consider the global scale. There are global themes in an image that tie together the local patches. The difficulty is quantitatively describing these constraints without prior knowledge of the local patches. What does the boundary shape of a balloon animal tell you about the total air inside the balloon? We derive two theorems on the global geometry of a Lambertian surface. These are applicable regardless of light source direction or local geometry. Thus, they can be applied directly to constrain the local patches. One theorem restricts the total Gaussian curvature of the surface. The second is a relationship between the geodesic curvature of an isophote and its level value. To our knowledge, this is the first time that global constraints on isophotes have been derived. We prove these theorems and show experimental evidence illustrating their accuracy and use.

53.3028 Visual search using realistic camouflage: countershading is highly effective at deterring search.

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One of the most widespread patterns of colouration in the animal kingdom is countershading, a gradation of colour in which body parts that face a higher light intensity are darker. Countershading may help counterbalance the shadowing created by directional light, and, hence, reduce 3D object recognition via shape-from-shading. There is evidence that other animals, as well as humans, derive information on shape from shading. Here, we assessed experimentally the effect of optimising countershading camouflage on detection speed and accuracy, to explore whether countershading needs to be fine-tuned to achieve crypsis. We used a computational 3D world that included ecologically realistic lighting patterns. We defined 3D scenes with elliptical 'distractor' leaves and an ellipsoid target object. The scenes were rendered with different types of illumination and the target objects were endowed with different levels of camouflage: none at all, a countershading pattern optimized for the light distribution of the scene and target orientation in space, or optimized for a different illuminant. Participants (N=12) were asked to detect the target 3D object in the scene as fast as possible. The results showed a very significant effect of countershading camouflage on detection rate and accuracy. The extent to which the countershading pattern departed from the optimal pattern for the actual lighting condition and orientation of the target object had a strong effect on detection performance. This experiment showed that appropriate countershading camouflage strongly interferes with visual search by decreasing detection rate and accuracy. A field predation experiment using birds, based on similar stimuli, showed similar effects. Taken together, this suggests that countershading obstructs efficient visual search across species and reduces visibility, thus enhancing survival in prey animals that adopt it.

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53.3029 Shape from shading under inconsistent lighting

John Wilder[1] (jdwilder@yorku.ca), Richard Murray[1]; [1]Centre for Vision Research, York University

Shape from shading models traditionally assume that observers estimate a lighting direction and use this estimate to infer shape from shading. In real world scenes, local lighting direction varies in unpredictable ways. How locally consistent must lighting be to perceive shape from shading? We manipulated local lighting directions across a scene and measured how this affected perception of shape from shading. In exp. 1 subjects were shown surfaces that varied in depth and judged the relative depth of the surface at two nearby probe locations. The depth profiles of the surfaces were created by filtering Gaussian white noise with a kernel of one of three widths ($sigma_S$). The lighting direction varied smoothly from place to place. Lighting directions were generated using Gaussian noise filtered with one of six kernels ($sigma_L$). There was also one uniform-lighting-direction condition. Performance decreased smoothly as $sigma_L$ decreased (high $sigma_L$ = less lighting variation) but even with quite rapid changes in local lighting direction, performance was still well above chance. In exp. 2 a window of uniform-lighting-direction was placed around the probe locations; outside this window the local lighting direction varied rapidly. Window size varied each trial. Results show that if the local lighting direction is consistent over more than two bumps in the surface shape then observers can recover shape from shading. In exp. 3 subjects viewed a surface in which three quadrants were lit from one direction and the lighting direction of the fourth differed by a tilt of 90°. Between quadrants, lighting direction changed smoothly from one direction to the other. The task was to identify the different quadrant. All

subjects performed at chance. These results suggest that shape from shading mechanisms can tolerate rapid variations in local lighting direction, and furthermore observers cannot even detect strong lighting inconsistencies.

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53.3030 **Image Statistics and Surface Likelihoods under Generic Lighting** Daniel Holtmann-Rice[1] (daniel.holtmann-rice@yale.edu), Benjamin Kunsberg[2], Steven Zucker[1,2]; [1]Computer Science, Yale University, [2]Applied Math, Yale University

The problem of shape inference is famously ill-posed: even under simplified models of the image formation process, such as uniform-albedo Lambertian shading, different combinations of geometry and illumination direction can generate the same local image structure. However, not all combinations are equally likely. In particular, for a given image, geometries for which the image exhibits greatest stability under light source changes should be preferred---this amounts to an assumption of "generic lighting". A plausible hypothesis is then that the visual system attempts to identify the most likely geometry that is consistent with the observed image structure. Quantifying this likelihood requires formulating a probabilistic model for the image formation process. Assuming a uniform distribution on light source directions, we derive the joint density of the image intensity, gradient and Hessian (second derivatives) at a point, conditioned on up to third order knowledge of surface geometry. Geometries maximizing this conditional density (likelihood) for fixed image structure are then precisely those for which the image is maximally stable under changes of illumination direction. Additionally, our analysis reveals that the light source can be recovered given the image intensity, gradient, and second order knowledge of the surface. This uniquely determines the image Hessian provided third order surface geometry.

Perception and Action: Methods and models

Tuesday, May 19, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

53.3031 **An investigation of the relationship between apparent motion velocity and illusion of agency** Yoshihiko Hatada[1] (hatada.yoshihiko@marino.ise.eng.osaka-u.ac.jp), Masahiro Furukawa[1], Hideyuki Ando[1], Taro Maeda[1]; [1]Department of Bioinformatic Engineering Graduate school of Information Science and Technology Osaka University

"The illusion of agency" arises when individuals look at own and other's hand motions alternately from a first person perspective (Takumi Yokosaka, 2014). Here, agency is a kind of cognition whereby people perceive both congruent movement (CM) and incongruent movement (IM) as a united, single, and continuous motion of one's own hand. The report says apparent motion (AM) perceived between CM and IM. Then, we consider there are two directional AM repeatedly (from own hand toward other's one and vice versa) and integration between the two occurs. So, to make AM occurrence denser despite, a CM-IM sequence lasts 250ms despite the former 500ms. And to prevent from interaction between the lasting time ratio of CM:IM and the two AM velocity difference, we used 1:1 despite the former 1:2. IM is a recorded movement of a gloved hand. We asked subject to keep his hand close to the IM. We experimented under three conditions below: (#1) CM lasts 125ms and IM does 125ms without black frame, (#2) 83ms black frame inserted after the sequence of 83ms CM and 83ms IM, (#3) after 83ms CM, two split 41ms-black frames were inserted before and after 83ms IM. As a result, the three in four subjects told the recorded movement is observed in each trial under the condition #1 and #3 while hardly did under #2. "The illusion of agency" was relatively observed under all condition. The fact that the CM and IM were not integrated as a single movement under #1 and #3 indicates the illusion was weaker than #2. Supposing the inserted black frame makes the AM slower, the two-AM-velocity difference is dominant. Therefore, the integrated difference yields the polarity of direction towards the other's hand. This seems to induce own hand's predicted position closer to the other's hand unconsciously.

Acknowledgement: SCOPE

53.3032 **Disentangling the neural bases of action intentions: evidence from fMRI studies** Gregory Kroliczak[1] (krolgreg@amu.edu.pl), Bartosz Michalowski[1,2], Agnieszka Kubiak[1], Mikolaj Pawlak[3]; [1]Action and Cognition Laboratory, Institute of Psychology, Adam Mickiewicz University in Poznań, Poznań, Poland, [2]Faculty of English, Adam Mickiewicz University in Poznań, Poznań, Poland, [3]Department of Neurology and Cerebrovascular Disorders, Poznań University of Medical Sciences, Poznań, Poland

The way we interact with manipulable objects varies substantially depending on the goal of the intended action. Surprisingly, very little is known about the neural underpinnings of planning disparate actions and interactions taken with tools, e.g., whether or not the praxis representation network (PRN) of the left cerebral hemisphere is involved in each case. To address this issue, in a series of functional magnetic resonance imaging (fMRI) studies involving both event-related and block-design paradigms, brain activity was measured while twenty (20) right-handed participants - using either their right or left hands - processed images of tools with the following intentions: (1) to subsequently use them according to their functions, (2) to pass them to a different person, (3) to simply move the tool in front of them with the back of their hands, or (4) to move the tool by grasping and putting the object aside. Counter to the hypothesis that PRN would be involved more in, or would mediate primarily, intentions related to the planning of the actual use of tools, we report convincing evidence showing that the crucial nodes of this network - the left supramarginal and middle frontal gyri - are engaged significantly more in preparation for actions that are not use related. This is the case both at the hand-dependent, i.e. separately for the right and left hand, as well as at hand-independent level of analyses. These findings shed a new light on how different goals and/or contexts influence the perception of object affordances, and to what extent they modulate the fMRI activity within the parieto-frontal action networks and beyond them.

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53.3033 **Retinal representation of escape-related visual information** Midori Matuzaki[1] (mmatsuzaki.0704@gmail.com), Hiroshi Ishikane[1]; [1]Department of Psychology,Senshu University

Frogs show escape behavior in response to a looming stimulus. It has been demonstrated that synchronized oscillations among retinal ganglion cells (Class-4 neurons) carry essential information for escape behavior (Ishikane et al., 2005). However, the information encoded by synchronized oscillations among Class-4 neurons is only one of the conditions necessary for eliciting escape behavior. Although synchronized oscillations can encode stimuli of any size and continuity, they cannot encode expansion. Activities of other types of retinal ganglion cells may play a functional role in escape behavior. To elucidate this issue, we recorded spikes from frog retinal ganglion cells with a planar multi-electrode array and conducted behavioral experiments. First, to identify neurons encoding the expansion at the retina, we presented two types of stimuli to all subtypes of ganglion cells: one was an expanding square and the other was a square that was gradually filled to the center from the outside. We found that compared with the other stimulus, Class-3 neurons respond preferentially to the expanding square. Following this, to investigate the relationship between activities of Class-3 neurons and escape behavior, we presented multiple squares. Each square was expanded or gradually filled to the center from the outside. These 25 squares eventually formed a single large square. Decreasing the number of expanded squares reduced both the responses of Class-3 neurons and escape rate. These stimuli caused strong synchronized oscillations among Class-4 neurons. Disrupting stimulus continuity did not reduce the responses of Class-3 neurons but inhibited synchronized oscillations among Class-4 neurons and the escape rate. These results suggest that Class-3 neurons could encode the expansion and contribute to the elicitation of escape behavior. The combination of activities of Class-3 neurons and synchronized oscillations among Class-4 neurons could trigger escape behavior.

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53.3034 **Confidence leak between independent tasks** Dobromir Rahnev[1] (rahnev@berkeley.edu), Ai Koizumi[2], Hakwan Lau[3], Mark D'Esposito[1]; [1]Helen Wills Neuroscience Institute, University of California, Berkeley, [2]Department of Psychology, Columbia University, New York, [3]Department of Psychology, University of California, Los Angeles

Recent research has demonstrated that the prefrontal cortex (PFC) has a critical role in metacognitive judgments of confidence. Given that PFC receives inputs from across the visual cortex, one counter-intuitive prediction is that signals that are represented in different visual areas may interact with each other at the metacognitive level. We tested this prediction by asking subjects to judge the dominant color and shape in a set of 40 letters. In Experiment 1 we found that confidence "leaked" between the two tasks (i.e., high confidence on the color task was associated with

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higher confidence on the shape task on that same trial) even though no such effect was found for perceptual accuracy. To ensure that the results were not due to response priming, in Experiment 2 confidence was given on a continuous scale for one task, and through the "opt-out" paradigm (in which subjects can choose to withhold their response and earn a certain small reward) on the other. Despite that difference in responding procedures, confidence leak between the two tasks was just as strong manifesting in 42 of the 44 subjects across the two experiments. Experiments 3 and 4 showed that confidence leak was also present for simple Gabor stimuli and that manipulations of signal quality through contrast and attention did not change the strength of confidence interactions. Finally, in Experiment 5 we disrupted PFC function with theta-burst TMS and observed a decrease in confidence leak compared to TMS to control regions. The results across all experiments are well described by a single-parameter model based on Bayesian inference, in which observers are constantly predicting the overall strength of signals in the environment in order to respond to them optimality. The model thus provides a normative explanation for the ubiquitous and novel phenomenon of confidence leak between different tasks.

53.3035 **Computing global confidence: psychophysical evidence for an integration mechanism** Alan Lee[1] (alanlee.ntu@gmail.com), Vincent de Gardelle[2,3], Pascal Mamassian[4,5]; [1]Division of Psychology, School of Humanities and Social Sciences, Nanyang Technological University, Singapore, [2]Centre d'Économie de la Sorbonne, CNRS UMR 8174, Paris, France, [3]Paris School of Economics, France, [4]Laboratoire des Systèmes Perceptifs, CNRS UMR 8248, Paris, France, [5]Département d'Études Cognitives, École Normale Supérieure, Paris, France

Perceptual judgments are often associated with a feeling of confidence, which is typically measured by collecting a confidence judgment after each perceptual decision. However, this single decision confidence is potentially quite different from the more general feeling of confidence that one has when facing a task. To address this issue, we designed a new global confidence task and found that observers can make a "global" confidence judgment over multiple perceptual trials (Lee et al., 2014, VSS). In the present study, we ask whether the global confidence system is capable of integrating information and delineate some characteristics and limits of such global confidence judgments. Observers (n=9) completed two small sets of first-order perceptual judgments (orientation-discrimination task: clockwise vs counterclockwise), one set after another. Both sets contained an equal number of trials (m = {1, 2, 4, 8}). After completing these trials, they performed a second-order 2IFC task (Barthelmé & Mamassian, 2009, 2010; de Gardelle & Mamassian, 2014): they had to choose the set for which they thought they had given more correct perceptual responses. Expected first-order performance for each set was targeted at d'=1 and d'=2, respectively (order randomized). If observers estimated global confidence from single perceptual decisions, the second-order confidence choice proportions would remain constant for different set sizes. On the contrary, we found that, the larger the set size (m), the more frequently observers chose the set with higher target d' (i.e., more accurate confidence judgment). This suggests that observers integrate confidence information over trials when making global confidence judgments. Furthermore, when compared to the benchmark of an "ideal integrator", we found that integration efficiency was close to ideal when m=2, but dropped significant when m>2. Finally, from an analysis of response times, this inefficiency seems in part related to a recency effect of confidence integration.

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53.3036 **Separating Noise from Suboptimal Inference in Choice Behavior Variability** James Tee[1,2] (james.tee@nyu.edu), Laurence Maloney[1,2,3]; [1]Department of Psychology, New York University, [2]Institute for the Interdisciplinary Study of Decision Making, New York University, [3]Center for Neural Science, New York University

INTRODUCTION: Choice behavior can vary from trial to trial, even with near-identical stimuli. This is commonly attributed to errors caused by internal neural noise (Faisal et al, 2010, Nat Rev Neurosci). An alternative theory (Beck et al, 2012, Neuron) is that variability could also arise from suboptimal inference. We designed two complementary tasks to separate noise from suboptimal inference. METHODS: During each trial in Task 1 (No Spin), a subject was presented with two roulette wheels where a fraction of each wheel is colored orange. The subject was asked to choose the wheel that has the larger proportion of orange. Making the correct choice won a monetary prize. In Task 2 (Spin), a subject was presented with the same pair of wheels and was asked to choose the wheel that has the larger chance of winning. After choosing, the wheels were spun and the subject won a monetary prize if the chosen wheel stopped in the orange. A staircase procedure was used to vary one wheel while the other acted as the test condition. There were 20 test conditions, uniformly distributed between [0.025,0.975] with 30 trials per condition. 20 naïve subjects performed both tasks. RESULTS: While the total number of wise (i.e. correct) choices differed from subject to subject, 20/20 subjects made more wise choices in the No Spin task (median=489/600) than the Spin task (median=444/600). For 19/20 subjects, the median angular difference between both wheels in unwise choice trials is significantly larger for the Spin task. CONCLUSIONS: Both tasks have the same optimal solution: choose the wheel with more orange. The No Spin task established a baseline for errors caused by internal noise while the Spin task measured the incremental error arising from suboptimal inference, allowing for separation of both types of errors.

Acknowledgement: NIH EY019889

53.3037 **Acquisition and transfer of models of visuo-motor uncertainty in a throwing task** Hang Zhang[1,2] (hang.zhang@gmail.com), Mila Kulsa[1], Laurence Maloney[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

We investigated how well people model their own visuo-motor error distribution in a throwing task and how well they transfer this model to a novel but predictable situation. Methods: The experiment consisted of three phases. Training phase. Subjects threw beanbags underhand towards targets displayed on a wall-mounted touch screen for 300 trials. The distribution of their endpoints was bivariate Gaussian. Choice phase. We used the 2-IFC task by Zhang, Daw, & Maloney (2013, PLoS Comp Biol): subjects repeatedly chose which of two targets varying in shape and size they would prefer to attempt to hit. Their choices allowed us to estimate their internal models of visuo-motor error distribution. Transfer phase. Subjects repeated the choice phase from a different vantage point, the same distance from the screen but with the throwing direction shifted 45 degrees. From the new position, visuo-motor error was effectively expanded horizontally by sqrt(2) and good performance required that subjects allow for this expansion in their judgments. Fifteen naïve subjects participated. For each subject, we estimated the horizontal and vertical standard deviations of her distribution models in the choice and transfer phases and compared them to those of her true error distribution. Results: (1) In their models for the choice phase, subjects underestimated the vertical-to-horizontal ratio of their true error distribution (mean 1.17 vs. 1.84), effectively assuming a more isotropic model. (2) Subjects' models in the transfer phase had a vertical-to-horizontal ratio close to 1/sqrt(2), agreeing with an objectively correct transformation of their incorrect isotropic models in the choice phase. (3) The horizontal and vertical standard deviations in subjects' models were highly correlated (Pearson's r = 0.89 for choice and 0.92 for transfer), while the counterpart correlation for the true distribution was only 0.58, favoring that subjects' distribution models were coded in polar coordinates.

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53.3038 **Sensory measurement and motor planning are not separable in interval timing** Evan Remington[1,2] (ereming@mit.edu), Mehrdad Jazayeri[1,2]; [1]McGovern Institute for Brain Research, Massachusetts Institute of Technology, [2]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology

The brain must integrate various sources of information and use that information to guide actions. Bayesian models of sensorimotor function describe how an ideal observer integrates information to generate behavioral responses that maximize the probability of a desired outcome. In most Bayesian models, it is assumed that the computations associated with estimating the state of the environment are distinct from those that generate the desired motor plans. Implicit in this formulation is the prediction that sensory estimates can be flexibly applied to different sensorimotor transformations. For example, a typical Bayesian observer would bias its sensory estimates based on prior knowledge of stimulus statistics independent of how the estimate will guide behavioral responses. We tested this prediction by asking human subjects to perform a time measurement and production task similar to a previous study (Jazayeri and Shadlen 2010). Subjects had to measure a sample interval that was drawn from a prior distribution, then immediately produce an interval that was equal to the sample interval multiplied by a gain factor. To test whether sensory estimation and motor planning computations are independent, each subject participated in multiple experimental sessions in which the sensory estimation parameters were kept fixed while the corresponding motor planning parameters were changed. In particular, across sessions, the prior distribution of the sample intervals was held constant while the gain factor was varied. We found that the effect of sensory prior on behavior depended on the gain factor suggesting that the computations underlying sensory estimation are not independent of the motor plan. Results were not explained by variants of the Bayesian model that consider additional uncertainty about the gain factor and/or additional noise in the production epoch. These findings suggest that, at least in this task, sensory estimation is not computationally separable from motor planning.

Acknowledgement: National Institutes of Health (NS078127), McGovern Institute for Brain Research, and Alfred P. Sloan Foundation

53.3039 **A New Context Effect of Human Resolving Power Distinguishes between Perception and Action** Gal Namdar[1] (namdargal@gmail.com), Daniel Algom[2], Tzvi Ganel[1]; [1]Department of Psychology, Ben-Gurion University of the Negev, Beer-Sheva 84105, Israel., [2]School of Psychological Sciences, Tel-Aviv University, Tel-Aviv 69978, Israel.

We report the discovery of a new effect of context that modulates the human resolving power for an individual stimulus. In particular, we show that the size of the difference threshold or the just noticeable difference around a standard stimulus depends on the range of the other standards tested simultaneously for resolution within the same experimental session. The larger this range, the poorer the resolving power for the given standard. We establish this result for the perception of linear extent, using different psychophysical methods and stimuli. We then proceed to show that this contextual influence is limited to perception and does not affect visually guided action. Notably, the difference threshold remained invariant when the participants were grasping rather than perceiving the same objects. Beyond adding a new member to the class of context effects in psychophysics, the findings lend further support for the idea that computations mediating the visual perception of object size are different from those mediating visually controlled actions toward the same objects.

53.3040 **Exploring new wearable sensing technology in perceptual experiments** Vilelmini Kalampratsidou[1] (vilelmini.kalabratsidou@gmail.com), Elizabeth Torres[2]; [1]Computer Science Department, Rutgers University, [2]Psychology Department, Rutgers University

Bodily rhythms are intrinsically related to changes in behaviors. As we perform exercises, sleep, identify percepts and make decisions our bodily rhythms change. Many studies assess motions of the body but few combine motions with other physiological signals such as skin surface temperature and electrodermal activity to provide objective metrics of natural behaviors. Here we provide various examples of such physiological signals and their analyses during a variety of tasks. Specifically we examine linear and angular acceleration in relation to temperature in 20 subjects as they performed different tasks. We describe ways to transform acceleration dependent signals to velocity dependent signals in order to study the kinematics of various natural behaviors in real time. Tasks include ballet training, sports training, perceptual tasks identifying visual illusions as well as decision making when confronted with various percepts and natural gait. In all cases we compare the velocity dependent kinematics registered by high-resolution sensors to those derived form lower grain accelerometers using our algorithms. We discuss our results in light of potential applications of our technology to basic research in the perceptual sciences, so as to go beyond key presses and verbal reports.

Perception and Action: Interactions

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

Poster Session, Banyan Breezeway

53.3041 **Are we overthinking it? Haptic perception of geographic slant is accurate when embedded within a secondary task** Jonathan Doyon[1] (jonathan.doyon@eagles.usm.edu), Alen Hajnal[1], Jeffrey Wagman[2], Michael McGathy[1], Joseph Clark[1], Zsolt Palatinus[1]; [1]Department of Psychology, University of Southern Mississippi, [2]Department of Psychology, Illinois State University

Recent research (Hajnal, Wagman, Bunch, & Doyon, 2014) suggested that geographic slants feel steeper than they look. Visual perception of the stand-on-able-ness of an inclined surface is generally accurate and corresponds to an action boundary of approximately 30 degrees. Haptic perception underestimates the action boundary in laboratory settings. This may occur because more overt attention is dedicated to the perceptual task than is typical in performing everyday behaviors. Does focused attention lead to overthinking actions such as upright standing? When perceiving maximum reaching distance participants are more accurate when the judgment is embedded in another perception-action task (Heft, 1993). It was hypothesized that embedding haptic perception of stand-on-ability within another perception-action task would bring haptic judgments in line both with visual judgments and action capabilities. Specifically, haptic judgments were expected to be more accurate and judgments made near the transition point (30°-36°) would show longer response times and lower confidence ratings (Wagman & Hajnal, 2014). Observers placed a foot onto an occluded ramp while viewing a dangling light socket overhead and reported whether they would be able to screw a light bulb into the socket if they were allowed to stand on the ramp. Socket height was scaled to the observer's maximal vertical reach and presented at that height as well as 5" above or below. Ramp presentations consisted of 7 angles ranging from 12° to 48° in 6° increments. Perceptual boundaries were compared against actual action boundaries, i.e., the point at which the ramp no longer supports upright standing. Haptic perceptual boundaries (36.9°) matched action boundaries (34.0°). Confidence was lowest and response time was the longest at the angle nearest to the transition point (36°). Results suggest that the affordance of stand-on-ability is best studied in the context of embedded everyday tasks.

53.3042 **To use, to pass, or to move: an fMRI study of neural bases of action intentions** Bartosz Michalowski[1,2] (bmairc@gmail.com), Agnieszka Kubiak[1], Mikolaj Pawlak[1,3], Grzegorz Kroliczak[1]; [1]Action and Cognition Laboratory, Institute of Psychology, Adam Mickiewicz University in Poznan, Poland, [2]Faculty of English, Adam Mickiewicz University in Poznan, Poland, [3]Department of Neurology and Cerebrovascular Disorders, Poznan University of Medical Sciences, Poland

While neuroscientific and behavioral studies indicate that the intention to properly use, transmit, or displace a tool may engage different mechanisms in the brain, no study has directly compared activation patterns associated with the control of actions motivated by such distinct goals. Here, we used functional magnetic resonance imaging to establish the neural underpinnings of planning and execution of visually-guided grasps with different intentions in mind. Brain activity was measured in an event-related design (cf. Króliczak & Frey, 2009) while 20 right-handers performed the following tasks with their dominant hands: (1) planning grasps directed at tools with an intention to (A) functionally use them, or (B) to pass them to a different person; (2) planning reaching movements directed at tools with an intention to move them with the back of the hand, and (3) pantomimed execution of the planned actions (grasping/reaching movements). A 1-s intention cue (a shape of different color) was followed by a 1.5-s tool image, a variable delay period, a 1.5-s action cue, and a variable inter-trial interval. The stimuli were high-resolution images of graspable tools presented at three different angles in their foreshortened views, emulating 3D viewing. Using a contrast of planning to grasp a tool irrespective of intentions vs. to move a tool, we first identified the praxis representation network (PRN). Subsequent contrast between planning grasping-to-pass vs. grasping-to-use actions showed greater activity in subdivisions of PRN, including the left supramarginal and middle frontal gyri. In the inverse contrast, one of the key modulations was found primarily in the left retrosplenial cortex. Thus, although object-affordance processing is not required to pass a tool, the areas traditionally associated with tool use were nevertheless invoked more. Unexpectedly, therefore, our results demonstrate that the greater engagement of key subdivisions of PRN is not specific to tool-use actions.

Acknowledgement: This research was funded by National Science Center grant Maestro 2011/02/A/HS6/00174 to G.K.

53.3043 **Localizing tool and hand-selective areas with fMRI: Comparing video and picture stimuli** Scott Macdonald[1] (smacd49@uwo.ca), Fiona van den Heiligenberg[2], Jody Culham[1], Tamar Makin[2]; [1]Department of Neuroscience, Brain and Mind Institute, Western University, [2]Nuffield Department of Clinical Neurosciences, FMRIB Centre, University of Oxford

Historically, brain areas implicated in tool and hand processing have been localized by contrasting pictures of tools and hands to pictures of objects or scrambled images using functional magnetic resonance imaging (fMRI). The goal of comparing these conditions in a localizer is to reliably and rapidly identify regions of interest. In contrast to the conventional use of static images, dynamic stimuli, such as videos, may have advantages as they are more engaging than pictures and fully depict the interaction between an effector and its target. The purpose of this project was two-fold: (1) to determine whether video stimuli are more effective than picture stimuli at localizing tool and hand-selective regions in individual participants; and (2) to test whether the nature of activity within these regions are comparable. Healthy subjects were scanned with fMRI while they viewed blocks of video and picture stimuli. The static stimulus set included pictures of tools, hands, objects, and scrambled images. The video stimulus set included short clips

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of tools interacting with target objects (but with the hand out of the scene), hands manipulating objects, objects in motion, and moving patterns (akin to a scrambled condition). The results show that the video localizer activates a more extensive network of areas than static pictures, particularly in the dorsal visual stream. Moreover, the robust activation for videos facilitated the localization of regions at the individual subject level. By cross-correlating parameter estimates of the video localizer with the picture localizer, we also validate that the video localizer activates the tool and hand-selective areas in a similar fashion as the picture localizer. In sum, using video stimuli better identifies areas involved in tool and hand processing while remaining consistent with the functional activity evoked by static stimuli.

53.3044 **Activity in hand- and tool-selective regions for prosthetic limbs in amputees is associated with prosthesis usage in everyday life** Fiona van den Heiligenberg[1] (fmzvdh@gmail.com), Scott Macdonald[2], Eugene Duff[1], David Henderson Slater[3], Heidi Johansen-Berg[1], Jody Culham[2], Tamar Makin[1]; [1]FMRIB Centre, Nuffield Department of Clinical Neurosciences, University of Oxford, Oxford, UK, [2]Brain and MInd Institute, University of Western Ontario, London, ON, Canada, [3]Oxford Centre for Enablement, Nuffield Orthopaedic Centre, Oxford, UK

The lateral occipitotemporal cortex (LOTC) contains subregions differentially responding to specific object categories, such as body parts and tools. This selectivity may relate to action knowledge, rather than visual properties of the objects. Prosthetic limbs share different commonalities with hands and tools (in terms of both visual and action features). Specifically, cosmetic prostheses look like hands, but can be used as tools (elongate the stump), whereas functional prostheses ("hook") do not resemble hands, but can be used as such (e.g. grasping). Here we presented images of functional and cosmetic prosthetic arms to 32 individuals with acquired or congenital limb loss, in an event-related fMRI paradigm. Hand- and tool-selective regions were identified using an independent localiser. Prosthesis usage was assessed in questionnaires and ecological behavioural measurements. We predicted that activation in hand- and tool-selective regions for prosthetic limbs would reflect the action-related properties of the prosthetic limb and would increase with usage. To identify the relationship between fMRI activation during viewing of prosthetic limb images and prosthesis use in everyday life, a whole-brain voxel-wise partial correlation was carried out (accounting for activation to objects). We found a significant correlation between prosthesis use and activation in LOTC and the posterior intraparietal sulcus for both functional and cosmetic prostheses. These regions overlapped with hand- and tool-selective regions. Strikingly, correlations with usage revealed activation patterns that reflect action knowledge, rather than visual properties. Specifically, cosmetic (hand-like) prostheses showed a left-lateralised pattern consistent with tool representation. Functional prostheses, whereas visually more similar to tools, show bilateral activation patterns, consistent with hand representation. Our findings suggest that ecological behaviour, in the form of prosthetic limb use, can shape how high-level visual cortex responds to visual stimuli. Further research will aim to determine how information in LOTC is shared across categories such as hands, tools, and prostheses.

53.3045 **Rethinking the Mirror Neuron System Theory** Sejal Mistry[1,3] (sejal.mistry.sm@rutgers.edu), Polina Yanovich[4], Elizabeth Torres[1,2,4]; [1]Sensory-Motor Integration Laboratory, Rutgers University, [2]Department of Psychology, Rutgers University, [3]Department of Mathematics, Rutgers University, [4]Department of Computer Science, Rutgers University

Humans recognize biological motion visually, even from such a minimalistic setup as point-light displays. The Mirror Neuron Systems Theory (MNST) is thought to account for this ability. However, the MNST's conceptual framework examines this type of motion perception as a top-down (vision-to-action) process. This view cannot explain how humans are capable of integrating that visual information that they perceive in the movements of others with the re-afferent kinesthetic information emerging as a bottom-up percept from their own movements. We address this new question here. A new paradigm and new analytics are introduced to extract statistics from data generated by wearable sensors registering natural movements from unconstrained behaviors. We ask the extent to which people are capable of discriminating their own motions from those of others. We recorded 16 subjects performing sports routines and walking. For each subject their veridical movements were recorded at 15 joints across the body (240Hz Polhemus-Liberty). The angular velocity was analyzed to extract signatures of noise from the peak joint-velocity in each segment and from the time to reach that value. In two independent sessions subjects decided ME vs. not-ME as they watched the animation of an avatar endowed with the actual physical movements and with their noisy variants in rotational space and in time. We found that subjects were accurate well above chance for the temporal-noise cases. In the spatial-noise cases ½ of the subjects performed below chance and needed more trials to begin responding correctly. Power laws linking velocity-dependent parameters were found at three levels: abstract (decision), physical (body motions) and hybrid (hand pointing the decision). Hand speeds while deciding were the most predictive and reliable of all three, while decision response times were the most variable. We discuss our results in the context of a newly proposed framework to redefine the mirror-neuron-systems theory.

Acknowledgement: NSF, The NJ Governor's Council Grant for Autism Research and Treatment

53.3046 **Response mapping interacts with perceptual thresholds and stimulus processing speed** Nir Shalev[1] (nir.shalev@wolfson.ox.ac.uk), Glyn Humphreys[1], Nele Demeyere[1]; [1]University of Oxford

Traditionally, response selection is considered to reflect a separate stage of processing to visual perception. An alternative view proposes action and perception to be closely linked; however the processing stage where any cross-modal interaction would then occur remains unclear. In this study, we investigated the influence of response-mapping on a simple classification task. We presented an array of eight frames arranged in a square around a fixation point, followed by a brief presentation of an arrow in one of them (varying SOAs of 10,30,50,80 and 100ms masked). The arrow could appear in a congruent, incongruent or a neutral location with respect to its direction. Participants indicated the direction of the arrow using a response-box organized in a corresponding configuration: eight response-buttons, arranged in a square; an arrow appeared on each button. In Exp 1, the directions of the buttons matched their locations (e.g., arrow pointing right appearing on the right side); In Exp 2, the arrows and the locations were mismatched (arrow appearing on the left side, pointing right). Subsequently we manipulated the response-mapping between the locations and directions of the arrows. We changed the task to respond to locations instead of direction, in a single (Exp 3) and a dual task (Exp 5); and replicated our original experiment with different exposure times (Exp 4). In our first experiment, we observed a robust congruency effect on accuracy for arrows appearing in their matching locations. Crucially, in our following experiments, we managed to invert and manipulate this effect by changing the motor-response mapping. Using mathematical modelling according to the Theory of Visual Attention, we demonstrate that motor-mapping modulates two low-level processes independently: perceptual threshold and stimulus processing speed. We discuss the implications of multi-modal integration within a general framework of attention as a proactive cognitive function, which predicts and formulates visual percepts.

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53.3047 **After-effects in the learning of sensorimotor mappings for the visually-guided control of hand gestures** Pouyan Fard[1,2] (pouyan.rafieifard@student.uni-tuebingen.de), Dominik Endres[1,3], Martin Giese[1]; [1]Section for Computational Sensorimotorics, Department of Cognitive Neurology, CIN & HIH, University Clinic Tübingen, Tübingen, Germany, [2]Department of Psychology, Technical University of Dresden, Dresden, Germany, [3]Department of Psychology, Philipps University of Marburg, Marburg, Germany

The learning of sensorimotor mappings is often associated with after-effects (Helmholtz, 1909/1962). We investigated after-effects during the learning of hand gestures that required participants to control a simulated hand in virtual reality (Adamovich et al., 2009). METHODS: Finger movements (joint angles) were recorded with a data glove and were exploited for the online animation of a human hand model using a game engine. In the first phase of the experiment (baseline), the measured joint angles were mapped one-to-one onto the joint angles of the virtual hand. In the second phase (adaptation), this mapping was modified by flipping the joint angles of the index and the middle finger, and the ones of the ring and the little fingers. In the final phase (deadaptation), again the original natural mapping was reestablished. Participants had to reproduce hand gestures that were indicated by static pictures of hand postures. Training was terminated after 32 trials in the adaptation phase and after 16 trials in the deadaptation phase. RESULTS: In the adaptation phase, humans adapt to the unnatural sensorimotor mapping in a gradually improving manner, typically taking about 10-15 trials. The postural error and the reaction time are increased significantly ($p < 0.001$) at the beginning of the adaptation phase, and both measures returned to the baseline at the end of the learning. In the deadaptation phase both measures were increased typically only one or two trials before they returned to baseline ($p > 0.95$ for both measures). CONCLUSIONS: The observed behavior seems not compatible with a standard sensorimotor adaptation effect, since the original sensorimotor mapping could be immediately established after adaptation within a single trial. Instead, after learning participants seem to recognize the appropriate sensorimotor mapping immediately, realizing it perfectly without observable after-effects. REFERENCES: Helmholtz, H. (1909/1962). Dover. Adamovich et al. (2009) Restor Neurol Neurosci, 27(3):209-23.

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Spatial Vision: Neural mechanisms

Tuesday, May 19, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.4001 Age-related changes in gray and white matter microstucture of patients with macular dystrophies and healthy controls as revealed by DTI

Anton Beer[1, 2] (anton.beer@ur.de), Sang-Yee Go[2], Tina Plank[1], Mark Greenlee[1, 2]; [1]Institute of Psychology, University of Regensburg, [2]Experimental and Clinical Neurosciences Programme, University of Regensburg

Previous research has shown that loss of central vision resulting from macular degeneration not only affects functional processing but also the macroscopic structure of the visual pathway. In particular, magnetic resonance imaging (MRI) showed volumetric reductions of the gray and white matter of patients with macular degeneration in portions of the calcarine sulcus that represent the central visual field. However, the basis of these macrostructural alterations due to partial vision loss is still unclear. Diffusion tensor imaging (DTI) based on MRI is a technique that allows inferences about the microstructure of brain tissue. Here, 25 patients with hereditary and 13 patients with age-related macular degeneration and an equal number of age-matched healthy controls (age range from 19 to 85 years) were examined with DTI. Patients and controls were compared on several diffusion-based quantitative indices including fractional anisotropy (FA), mean diffusivity (MD), axial diffusivity (AD), and radial diffusivity (RD). A surface-based analysis approach was adopted. In healthy people, diffusivity increased with age in the medial occipital cortex, the cingulate cortex, the temporal cortex, the insular, and the frontal cortex. However, dissociations between AD and RD were observed in several brain regions: Age-related increases of RD were primarily observed in the white matter of the medial occipital cortex, whereas age-related increases of AD were primarily observed in the gray matter of the temporal cortex. Compared to age-matched healthy controls, young but not elderly patients with vision loss showed increased RD in two distinct regions of the posterior calcarine sulcus and the inferior frontal cortex. No reduction in AD was observed. This finding suggests that fiber connections of afferent visual pathways are still preserved in patients with vision loss. However, the white matter microstructure of the visual cortex may be affected by changes in local connectivity or the extra-axonal structure.

Acknowledgement: Deutsche Forschungsgemeinschaft (FOR 1075)

53.4002 Topographic maps of depth in human visual cortex

Daniel Berman[1,2] (berman.72@osu.edu), Nonie Finlayson[1,2], Julie Golomb[1,2]; [1]Department of Psychology, The Ohio State University, [2]Center for Cognitive and Brain Sciences, The Ohio State University

Depth is a frequently overlooked aspect in vision research, despite the fact that recognizing and perceiving depth cues are essential when it comes to appropriately interacting with our surroundings. Behavioral and physiological studies have provided a solid framework for understanding depth perception, but we have yet to establish the precise neural organization of depth representation in human visual cortex. Here, we map depth representations using a phase-encoded stimulus that travels along the z-axis (depth), analogous to the standard 2D retinotopic mapping paradigm (wedges and rings; Engel et. al., 1994; Sereno et. al., 1995). Our stimulus was a large 2D patch filled with black and white moving dots. The stimulus moved forwards or backwards (in alternating runs) through 13 discrete depth planes, completing a full cycle every 28 seconds. Red/green anaglyph glasses were used to achieve depth perception while in the scanner. Using a standard phase-encoded cross-correlation approach, we found voxels selective for different depth planes in several intermediate and later visual areas. Preliminary results suggest that depth representations may be organized into a large-scale map-like representation across V3d, V3A, V3B, and V7. Our findings provide critical insights regarding the neural correlates of depth representations, and we detail for the first time depth maps in human visual cortex using fMRI.

53.4003 Freely viewed movie stimuli and connective field modeling used to identify far extrastriate and subcortical retinotopic organization

Andrew Bock[1] (bock.andrew@gmail.com), Ari Kahn[1], Geoffrey Aguirre[1]; [1]Department of Neurology, University of Pennsylvania

Connective field modeling (Haak 2013) assigns retinotopy to cortical points by modeling the connective field (ccRF) within early cortical areas, using data collected with retinotopic mapping stimuli (e.g. bars, wedges, rings) while subjects maintain fixation. Here we test if the ccRF approach yields useful retinotopic maps from data collected while subjects view a naturalistic movie without fixation. The retinotopic organization in V1 was assumed from a cortical surface template (Benson 2012; 2014) then projected to extrastriate cortex and subcortical visual structures (LGN, SC) using connective field modeling. Three subjects were studied at 7T (voxels=1.5mm3; TR/TE=2000/25ms) during 30 minutes of drifting bar stimuli with central fixation, and 30 minutes of free-viewing of Pixar shorts. Retinotopy of each cortical and subcortical voxel was determined using connective field modeling, maximizing time-course correlation with a V1 patch. Moving dot and flashing checkerboard stimuli were used to localize subcortical structures. Cortical retinotopic maps generated from the movie data were comparable to those obtained from traditional retinotopic mapping methods, with polar angle reversals extending beyond hV4 and V3a. The freely viewed stimuli produced a greater extent of mapped cortex at greater eccentricities. Subcortical ccRF analyses identified the LGN reliably, and the SC more weakly. Retinotopic assignment within the LGN was readily seen when ccRF approaches were applied to data collected with fixation and drifting bars, less for free movie viewing. It is unclear if this is a stimulus or fixation effect. Furthermore, we find that connective field size is not significantly different in the free-viewing runs compared to drifting bar stimuli across visual areas. These results indicate that retinotopic mapping in extrastriate cortex can be accomplished using connective field modeling and naturalistic stimuli without fixation, but that fixation and/or traditional mapping stimuli may be required to identify and map subcortical visual structures.

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53.4004 ON and OFF subfield organization of layer 2/3 neurons in tree shrew visual cortex.

Kuo-Sheng Lee[1,2] (kuo-sheng.lee@mpfi.org), Xiaoying Huang[1], David Fitzpatrick[1]; [1]Department of Functional Architecture and Development of Cerebral Cortex, Max Planck Florida Institute for Neuroscience, Jupiter, FL, USA, [2]Integrative Biology and Neuroscience Graduate Program, Florida Atlantic University, Boca Raton, FL, USA

In vivo 2-photon imaging of calcium sensors in visual cortex has provided a host of new insights into the fine scale columnar mapping of response properties like orientation, direction, and visual space. Extracellular recording in carnivores have shown a columnar segregation of ON- and OFF-center geniculate inputs in layer 4, which could provide the basis for the generation of orientation selectivity. However, the spatial arrangement of ON and OFF in layer 2/3 has not been addressed. In this study we used 2-photon imaging of GCamP6s calcium fluorescent signals to map the receptive fields of thousands of neurons in layer 2/3 of tree shrew visual cortex with reverse correlation using sparse noise. We found a diverse array of receptive field properties in layer 2/3 including neurons with classic simple, complex and single sign receptive fields (either ON or OFF). The ON and OFF subfields in layer 2/3 were found to exhibit topologically distinct relationships with the maps of visual space and orientation preference. In most cases, the centers of OFF subfields for neurons in a given region of cortex were confined to a compact region of visual space and displayed a smooth retinotopic progression, while the centers of the ON subfields were distributed over a wider region of visual space and displayed less retinotopic precision. Consistent with the arrangement of ON and OFF subfields of simple cells in other species, the angle of displacement in visual space of the ON and OFF subfields for individual neurons could be used to predict the organization of the orientation map. Taken together, these results suggest that the differential arrangement of ON and OFF subfield centers by cortical circuits meets the conjoint constraints of mapping both visuotopy and orientation in a single population of neurons and in a fashion that preserves continuity for both stimulus features.

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53.4005 **Spatio-temporal uncertainty and cortical-hippocampal interactions: fMRI study** Nisha Dalal[1,3] (Nisha.Dalal@lrz.uni-muenchen.de), Virginia Flanagin[1,2], Stefan Glasauer[1,2,3]; [1]Graduate School of Systemic Neurosciences, [2]German Center for Vertigo and Balance Disorders, [3]Department of Neurology, LMU Munich

Introduction: The hippocampus interacts with early visual cortex in a stimulus-dependent way. Previously our lab reported that when participants watched movement through a virtual tunnel there was a weaker correlation between the hippocampus and primary visual cortex than with videos where the phase content was scrambled (Figure S1). The hippocampus may provide an important function in interpreting unpredictable input. Here, we test this hypothesis using a similar fMRI paradigm, together with univariate and representational similarity analyses. Methods and results: We measured 27 healthy participants (mean age 25.6±3.8 years, 14 females) while watching three different types of videos (Figure S1): a. virtual tunnel, b. phase scrambled and c. noise videos. Phase scrambled videos share the same low level statistical properties of tunnel videos but lack the recognizable features such as edges, shapes etc. 1. Univariate group level analysis: Stronger activity of higher visual areas in processing of virtual tunnels compared to phase scrambled and noise video was found (n=27, p< 0.05, FDR corrected, T=2.62). Also, hippocampus and early visual areas were found highly active for noise videos compared to tunnel and phase scrambled videos (n=27, p< 0.05, FDR corrected, T=3.04). 2. Representational similarity analysis: Time dissimilarity matrices (TDMs) were created from unnormalized and unsmoothed ROI data from different regions using the RSA toolbox (Figure S2). Candidate Representational Dissimilarity Matrices (RDMs) were created using entropy and mutual information of the stimuli. Candidate RDMs correlate strongly (p< 0.005, FDR corrected signed rank test with subject as random effect) with TDMs, but none of them could completely describe them. Conclusion and future work: We found increase in hippocampal activity with increase in entropy of the visual input, independent of its meaning. Our next step will be to evaluate how the temporal characteristics of hemodynamic response are reflected during time-continuous perception of stimuli.

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53.4006 **Perceived illusory orientation from the flash grab effect induces the Tilt Aftereffect** Yijun Ge[1] (geyijun827@gmail.com), Lan Wang[1], Sheng He[1,2]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, Beijing, China, [2]Department of Psychology, University of Minnesota, Minneapolis, Minnesota, United States of America

Tilt aftereffect (TAE) (Gibson, 1937) is the phenomenon that the perceived orientation of a test stimulus is altered after prolonged exposure to an oriented adaptor. This phenomenon has been widely considered to result from adaptation of orientation-selective neurons in the early visual cortex. In this study, we investigated whether the TAE could be induced from a perceived illusory orientation of adapting stimulus dissociated from its physical orientation, by taking advantage of a new illusion—the flash grab effect (Cavanagh & Anstis, 2013). Subjects viewed a physically vertical line that was repeatedly and briefly flashed on top of a patterned disk that oscillated clockwise and counterclockwise, with the flashed line presented at the moment of the rotation reversals. Importantly the adapting line was perceived as tilted away from vertical. Following adaptation to 11 cycles of the flashed line, a test line was briefly presented near vertical orientation at the corresponding location without the background disk. Results showed that a significant TAE was induced by the perceived orientation. In contrast, when the physical orientation of the titled adapting line was adjust by each individual subject so that the adapting line was perceived to be vertical, no TAE was observed. Thus when perceived and physical orientations of the adapting lines are pitted against each other, the TAE is dependent on the perceived rather than the physical orientation. In separate experiments using multimodal neuroimaging methods, we have shown that the perceived tilt from flash grab effect is primarily due to feedback processing in the brain. Together, our results suggest that higher-level processes and feedback signals play a important role in the TAE.

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53.4007 **What information is 'decoded' from stimulus orientation with fMRI and MVPA?** Susan Wardle[1] (susan.wardle@mq.edu.au), J. Brendan Ritchie[1], Kiley Seymour[1], Thomas Carlson[1]; [1]Department of Cognitive Science, Macquarie University, Sydney, Australia

Multi-voxel pattern analysis (MVPA) is typically treated as a black box. Studies generally focus on whether stimuli can be decoded from a brain representation, while the source of decodable information is hidden within complex activation patterns. One notable exception is research aiming to understand how orientation information, represented in 1mm hypercolumns, can be decoded from visual cortex using fMRI, which measures brain activity at a coarser scale (~3mm). Some have argued that MVPA confers hyperacuity to fMRI by recovering fine-grained information derived from imperfect sampling of orientation columns within voxels. Others have argued that a coarse-scale radial bias is the source of information for orientation decoding. Recently, in modelling the cortical response to grating patterns we identified a third potential source of information, a non-uniform spatial response produced by the edges of the stimulus (Carlson, 2014). In the present study, we examined the contribution of edge-related activity to orientation decoding with fMRI. Subjects viewed annular square-wave grating stimuli of six orientations in a blocked design. Orientation was reliably decoded using a linear SVM. Localizers and retinotopic mapping were used to identify voxels corresponding to the inner edge, middle, and outer edge of the stimulus in retinotopic cortex. Analyzing these regions separately, we found that decoding performance was highest for the area of the cortex representing the inner edge of the annulus. We then used the method of Haufe et al. (2014) to transform the voxel weights from the classifier into interpretable activation space to examine the location of the voxels most significantly driving classifier performance. The majority of the highest-weighted voxels overlapped with the region of retinotopic cortex corresponding to the inner edge of the annulus. Our findings suggest that stimulus edges contribute to orientation decoding, and underscore the importance of considering the source of decodable information in MVPA studies.

Acknowledgement: NHMRC Early Career Fellowship to S.G.W.

53.4008 **Do cigars feed into contour integration mechanisms?** Lynn Olzak[1] (olzakla@miamioh.edu); [1]Department of Psychology, Miami University of Ohio

Collinear facilitation and contour integration are often attributed to facilitative interactions among low-level, V1 mechanisms with neighboring receptive fields. There are conflicting reports as to whether facilitation is polarity (phase) specific (e.g., . Williams & Hess, 1998 vs Yu & Levi, 1997). The latter conflict may be resolved by the existence of more than one type of mechanism. Evidence from experiments measuring orientation bandwidths with full annular surrounds suggests that at least two mechanisms exist, one narrowly tuned and the other broadly tune. In many previous works, we have described complex orientation-signaling mechanisms that sum over a large range of superimposed spatial frequencies but only over a very tight range of orientations (cigars). These mechanisms essentially signal the average orientation present. They have also been shown to be phase-independent. We have previously suggested (Persike, M, Olzak, L. A. and Meinhardt, G. , 2009) that at least one type of contour detector sums over wide ranges of frequencies; thus, contour integration may also be accomplished by cigars. Here, I tested this hypothesis directly by creating complex Gabor packets containing two gratings of very different frequency. Distractor frequencies were iso-oriented around random axes. Target components were both tilted either together (left or right) or in opposition (high-left, low-right and vice versa), relative to the line of the contour at each given location. Observers performed a two-alternative temporal forced-choice between a display containing only distractors and the one containing the contour. If contour integration occurs before the component summing stage, or is not mediated by cigars, performance will be equal in the two conditions. If the output of cigars feeds into the contour integrating mechanism, performance will be better in the opposition condition. Preliminary results suggest that performance with contours containing the components in opposition was superior.

53.4009 **Assessing the upper bound on performance of multi-voxel pattern analysis in peripheral V1** Rachel Millin[1] (rmillin@usc.edu), Bosco Tjan[1,2]; [1]Neuroscience Graduate Program, University of Southern California, [2]Department of Psychology, University of Southern California

Multi-voxel pattern analysis (MVPA) of fMRI data is a powerful technique for assessing the amount of information present in a cortical area for a given task. However, the utility of this method is limited by the areal size of the cortical region of interest, the spatial scale of the neural response, and the resolution of BOLD fMRI. These limitations are particularly relevant to the study of early peripheral visual processing, due to the small area of primary visual cortex (V1) devoted to processing information from the peripheral visual field. We used a forward model of BOLD fMRI to determine the bounds on the stimulus information available to MVPA for peripheral stimuli on the V1 cortical surface. The model captures the main spatial and temporal properties of BOLD fMRI in V1, regardless of

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the specific mechanisms of the neural response. It includes the V1 cortical magnification factor, the spatial and temporal correlation in BOLD signal and noise, the signal to noise ratio across voxels, and a biophysical model of the BOLD signal. The model also incorporates other factors that influence BOLD data, such as head and eye movements. After determining model parameters from an independent dataset, we simulated multiple BOLD data acquisitions from V1 when letter stimuli were presented in the visual periphery. A cross-validation scheme was used to assess the predictability of the stimuli as a function of letter size. The spatial and temporal factors of BOLD fMRI captured by the model place a lower limit on the stimulus size for which information is available through MVPA. This limitation was validated with empirical BOLD data. The model can thus be used to test the feasibility of using MVPA in a given experiment, and to optimize experiment design to maximize the probability of an informative outcome.

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53.4010 Human Pain Sensitivity Is Related To Visual But Not To Auditory Thresholds

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Purpose: Last year (VSS 2014), we reported that adults' ability to tolerate pain predicted performance on tests of spatial contrast sensitivity (CS). More specifically, those who were more sensitive to pain also showed higher sensitivity to contrast. It was suggested that the observed co-variation may be due to dopaminergic involvement. Here, we further explore these multisensory interactions by examining the relationship between spatial vision, pain and hearing, the latter a sense that appears to be influenced even more so by dopamine (Gitelman et al, 2013). Methods: Two measures of spatial contrast sensitivity (FACT, Vector Vision) and a full audiometric assessment (100 to 8000Hz) was conducted in 144 healthy young adults (M = 23 yr; 84 females, 60 males). Within the same session, pressure algometry was used to assess pain threshold and tolerance on the pinky finger. Results: Correlational analyses revealed a strong relationship between all measures of CS and pressure pain (all $r > -0.52$). Again, lower pain sensitivity was related with higher spatial CS. In addition, individual contrast sensitivity functions (CSF) correlated positively ($r = 0.46$) with audibility functions (the auditory counterpart of the CSF). However, auditory performance was unrelated with pressure pain threshold or tolerance Conclusions: Human adults show a relationship between spatial vision and pain sensitivity, between vision and hearing thresholds, but not between pain and auditory functioning. These results suggest the prominence of vision within basic sensory interactions. However dopaminergic involvement as a primary mediator of multisensory functioning is questioned somewhat by these data.

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53.4011 Imaging resolution affects neural response property estimation

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One of our primary goals in using functional magnetic resonance imaging (fMRI) is to be able to infer neuronal response properties from the fMRI signal. The mismatch in spatial scale makes this challenging: our best imaging resolution element contains hundreds of thousands of neurons. Here, we use size tuning in V1 to study the interaction between imaging resolution and inference of the underlying neural population response. We used 7 Tesla fMRI with 1 millimeter (isotropic) resolution to measure responses to sinusoidal luminance gratings with 0.25, 0.5, 1.0, 2.0 or 4.0 degree diameters centered at 3 degrees eccentricity. Stimuli were presented in a simple block design (8 cycles 12 sec stimulus/12 sec rest per scan) while subjects performed a contrast discrimination task; each scan contained one stimulus size. Seeds for computing regions of interest were located at the center of mass of the response to the smallest stimulus. Average response was then calculated for ROIs of increasing diameter; ROI diameter was computed on the cortical surface and translated back to the functional data. For ROIs less than 3 mm in diameter, the size-tuning function matched neural response predictions – the strongest response was to stimuli 1 degree in diameter, falling off as stimulus size increased until the response to a 4-degree (diameter) stimulus was 60% of the maximum (1-degree) response. For larger regions of interest the peak response occurred for larger stimuli: 4- and 6-millimeter (diameter) ROIs responded most strongly to 2-degree stimuli, for example. Predicting this result from spatial pooling by fMRI of the underlying neuronal population responses is straight-forward. However, it nicely illustrates the difficulty of inferring neuronal response properties from fMRI response: without an accurate encoding model with which to interpret the data, a low-resolution experiment would conclude that V1 neurons prefer larger stimuli than they actually do.

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53.4012 The Spatial Extent of Short-Term Plasticity Effects in the Human Visual System

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Depriving a small retinal area of patterned inputs against a dynamic background, known as an artificial scotoma, allows for investigations of the immediate changes in cortical visual representations in response to a loss of afferent sensory input (short-term plasticity). Previous research with artificial scotomas (Parks & Corballis, 2012) has demonstrated effects in the sensory components of the visual evoked potential (VEP) consistent with the occurrence of disinhibition within visual cortical scotoma representations and invading activity from surrounding spatial representations. This experiment sought to further probe the spatial extent of these effects by constructing a periscotoma spatial map of disinhibition and invading activity using event-related potentials (ERPs) in an artificial scotoma paradigm. EEG was recorded over two experimental sessions while participants viewed an artificial scotoma display and performed a two-alternative forced choice task, discriminating the tilt of a gabor probe. Scotoma discs were conditioned, bilaterally, for a six second period after which time varying spatial locations were probed relative to the edge of an artificial scotoma. These locations were two positions inside of the scotoma region, 1º and 3º from the edge of the scotoma disc, and three locations outside of the scotoma region, 1º, 3º, and 6º from the edge of the disc. A sham condition used an identical scotoma-probe configuration, with the exception that the scotoma discs were presented only one second prior to probe onset so as to minimize plasticity effects. VEPs were compared between scotoma and sham conditions at each of the five locations to examine modulations in early visual components (P1 and N1) attributable to the induction of short-term plasticity. Preliminary results reveal differential modulations these components between positions within, bordering, and distal from the artificial scotoma. These results support the induction of disinhibition within scotoma boundaries and establish the spatial limits of invading activity.

53.4013 Neural representation of a high-dimensional perceptual space in macaque visual cortex

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Perceptual spaces play a key role in intermediate stages of visual processing, as they constitute representations that support discrimination, categorization, working memory, and other judgments. The classical perceptual space of color has three dimensions; others, such as faces and textures, have very high dimension. Representing such spaces within biological constraints is challenging. To probe how visual cortex does this, we studied responses of macaque single neurons to a well-characterized 10-dimensional domain of visual textures. This model space consists of black-and-white colorings of a checkerboard, and its spatial structure is defined by multipoint correlations within 2x2 blocks (Victor and Conte 2012). The 10 parameters of the space are: a statistic that specifies the balance of white vs. black checks, four pairwise statistics that specify nearest-neighbor correlations, four three-point statistics that specify the prevalence of triangular regions, and a four-point statistic. This space captures the informative local image statistics of natural images (Hermundstad, 2014). Human perceptual sensitivities within the space are well-characterized, and suggest opponent mechanisms that combine via quadratic summation. We recorded from 214 neurons via tetrodes in V1 and V2 of 6 anesthetized macaques. Neurons responsive to one- and two-point statistics were common (>50%) in V1 and V2, with the previously-noted bias towards darks in both regions (Yeh et al., 2009). Responses to three- and four-point statistics were rare (< 10%) in V1, but more common in V2 (~20%). Consistent with an opponent representation, neurons that increased their firing in response to variation in one direction along a coordinate axis tended to decrease their firing in response to variation in the opposite direction. However, typical neurons responded to variations along several coordinate axes, with no clear pattern of "cardinal" directions. Thus, our data suggest a multidimensional opponent representation for local image statistics in the population of V1 and V2 neurons.

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53.4014 **Cross-orientation suppression and the topography of orientation preferences** Erin Koch[1] (ekoch@sunyopt.edu), Jiazhong Jin[1], Yushi Wang[1], Jens Kremkow[1], Jose Manuel Alonso[1], Qasim Zaidi[1]; [1]Graduate Center for Vision Research, SUNY Optometry

Parallel perception of multiple orientations is essential for identification of patterns and 3-D shapes from texture. While the primary visual cortex of primates and carnivores is organized in columns of neurons that respond to the same orientation preferences, neuronal responses to gratings of preferred orientation can be suppressed when another orientation is added to create a plaid. It is currently unknown how the different factors contributing to this cross-orientation suppression vary across the orientation map. To address this question, we performed horizontal penetrations with multielectrode arrays in the primary visual cortex of anesthetized cats and sampled populations of neurons in different cortical orientation domains (32-channel Neuronexus probe, 100 microns inter-electrode distance). Cortical neurons were stimulated with a sequence of static sinusoidal gratings (100 msec duration) containing 8 contrasts, 8 orientations, and 4 phases and a sequence of plaids consisting of superimposed pairs of gratings at 50% contrast, 8 orientations and 4 phases. We first confirmed contrast-invariance of orientation tuning and orientation-invariance of contrast response functions with these sequences of static gratings. We then calculated a Suppression Index as the ratio between the response to the preferred grating at 50% contrast (GR) and the average response to the plaids (PR), as (GR-PR) / (GR+PR). The distribution of Suppression Indices could be accurately fit with a Gaussian function ($R2= 0.96$, mean= 0.18 ± 0.10). In 95% of neuronal recordings (131 out 138), the added grating suppressed responses below that to the preferred component alone, which clearly rules out contrast saturation. Interestingly, the suppression index was negatively correlated with orientation tuning bandwidth ($r = -0.34$, $p < 0.0001$). In addition, preliminary analyses suggest that the response suppression is related to the rate of orientation change in visual cortical domains.

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53.4015 **Orientation-tuned surround suppression improves computational models of human visual cortex** Catherine Olsson[1] (catherio@nyu.edu), Kendrick Kay[2], Jonathan Winawer[1,3]; [1]Center for Neural Science, New York University, [2]Department of Psychology, Washington University in St. Louis, [3]Department of Psychology, New York University

In recent years, population receptive field models fit to fMRI data have been used to characterize responses in human visual cortex (Dumoulin and Wandell, 2008, Neuroimage). Initial population receptive field models represented stimuli as binary contrast masks, but recent models have incorporated a larger range of visual computations in order to predict responses directly from the image pixels. The model-based approach summarizes diverse findings from visual neuroscience and elucidates the visual computations performed in each area. FMRI has the particular advantage of enabling quick and effective exploration of computational properties throughout the entire visual system. A recent two-stage cascade model was shown to account for much of the observed variance of BOLD responses in early visual areas in response to a wide range of band-limited grayscale images (Kay et al. 2013, PLoS CB). However, the existing model still exhibits certain systematic failures. Response amplitudes to contrast patterns with a single orientation are systematically overpredicted, while amplitudes to contrast patterns with extended curved edges are systematically underpredicted. Here we asked whether updating the model to reflect additional findings about the visual response properties of neurons could improve model performance. Physiology, psychophysics, and theory support the hypothesis that neuronal responses are suppressed by an orientation-tuned surround (Schwartz and Simoncelli, 2001, Nature Neuroscience; Cavanaugh, Bair, and Movshon, 2002, Journal of Neurophysiology). We revisited data from Kay et al. and implemented an additional computation: a spatially extended, orientation-tuned divisive normalization step. The updated model produced systematically better predictions in V1/V2/V3, without introducing additional parameters or degrees of freedom. These results show steady progress in building increasingly accurate models of the computations performed in the human visual pathways.

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53.4016 **Comparison of four types of suppression using steady-state EEG** Daniel Baker[1] (daniel.baker@york.ac.uk), Greta Vilidaitė[1], Alex Wade[1]; [1]Department of Psychology, University of York

It has been proposed that distinct forms of neural suppression occur at different stages of visual processing. At a single neuron level, monocular and dichoptic cross-channel masking have very different properties consistent with pre-cortical and cortical neural substrates respectively (Li, Peterson, Thompson, Duong & Freeman, 2005, J Neurophysiol., 94: 1645-1650). Monocular cross-channel masking produces a lateral shift of the contrast response function (contrast gain) whereas dichoptic masking produces a multiplicative shift (response gain). We investigated how contrast response functions in human visual cortex are affected by four mask types: monocular and dichoptic cross-oriented (overlaid) masks, and aligned and orthogonal surround masks. We measured steady-state EEG responses at the occipital pole to 1c/deg target stimuli (contrasts 6-96%) flickering at 5Hz with or without drifting masks of various contrasts. We interpret the results in the context of a Naka-Rushton model (resp=rCn/(Sn + Cn), where C is contrast) for which the response gain parameter (r), the saturation constant (S), or both parameters could be altered by the mask. All masks reduced target signal-to-noise ratios (SNRs) at high mask contrasts, with monocular overlay and aligned surround masks showing evidence of contrast gain shifts, and dichoptic and orthogonal surround masks consistent with changes in response gain. We also plotted target responses as a function of mask contrast, revealing a novel facilitatory effect of low contrast surround masks that can be explained within the normalization framework. At high mask contrasts there was clear saturation for surround and dichoptic masks above the noise floor, which was not apparent for monocular orthogonal masks. Saturating suppression is consistent with the mask signals having passed through a stage of nonlinear transduction before impacting the target signals. These results bridge single cell studies in animals and psychophysical work in humans in delineating distinct suppressive pathways in the early visual system.

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53.4017 **The Functional Separability of Early Visual Evoked Potentials** Bruce Hansen[1] (bchansen@colgate.edu), Andrew Haun[2], Aaron Johnson[3], Dave Ellemberg[4]; [1]Department of Psychology and Neuroscience Program, Colgate University, [2]Department of Psychology, University of Wisconsin-Madison, [3]Department of Psychology, Concordia University, [4]Centre de Recherche en Neuropsychologie et Cognition (CERNEC), Université de Montréal

The early visual evoked potentials (VEPs) used as indices of early visual processing are traditionally parsed into three components, namely the C1, P1, and N1, with peak latencies between 60-90ms, 100-130ms, and 150-180ms respectively (all measured via scalp electrodes in the central occipito-parietal region). The polarity of the C1 component's peak is dependent on whether the experimental stimuli are presented peripherally in the upper or lower visual field, but has been argued to be negative for stimuli presented foveally. However, preliminary work from our group has shown a sizable peak latency difference (~30ms) between the C1 for peripheral stimuli compared to the C1 measured foveally, suggesting that the two may arise from different cortical processes. Here, we sought to provide more conclusive support for a functional separation of the C1 (relative to itself and the subsequent P1 and N1) by measuring VEP component tuning functions for spatial frequency (SF), using foveal and peripheral stimuli. The stimuli were high contrast Gabors (2.5 degrees in diameter) at 6 peak SFs (0.5, 1.0, 2.0, 4.0, 8.0, 12.0 cpd). During EEG recording, stimuli were presented for 50ms and followed by a spatial attention distractor task. Participants maintained central fixation throughout the experiment while the stimuli were presented at foveal (0 degrees eccentricity) and peripheral (6 degrees eccentricity: upper left or right, lower left or right) visual field locations. The results show a clear functional separation between the peripheral C1 and the foveal C1, with the former exhibiting no clear SF preference, while the latter exhibited a strong and systematic preference for increasing SF. Such a separation calls into question recent attempts to characterize general C1 processes measured solely at fixation, and argues for a careful re-examination of the C1 as it pertains to foveal or peripheral stimulus locations.

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53.4018 **Cortical sources of vernier acuity: an EEG-source imaging study** Chuan Hou[1] (chuanhou@ski.org), Yee-Joon Kim[1], Preeti Verghese[1]; [1]The Smith-Kettlewell Eye Research Institute

Vernier acuity determines the relative position of visual features with a precision better than the sampling resolution of the cone mosaic. Because the vernier offset is thought to be detected by orientation-tuned mechanisms, we expect cortical areas such as V1 to respond strongly to vernier stimuli. Here we use 128-channel EEG combined with cortical source imaging to identify multiple regions of visual cortex that underlie the detection of vernier offsets. Steady-state Visual Evoked Potentials (SSVEPs) were

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recorded from fifteen normal vision observers under two conditions. In the test condition, vernier offsets were periodically introduced and withdrawn at 3.75 Hz (alignment/misalignment) on a 2 cpd square-wave grating. In the control condition, the offsets were displaced symmetrically with respect to the reference (misalignment/misalignment), to produce the same displacement as in the test condition. In both conditions, the size of the offset was swept from 8 to 0.5 arcmin in 10-logarithm steps within a ten-second presentation interval. The vernier-offset (test condition) elicited robust odd harmonic responses in V1 and lateral occipital cortex (LOC). Thresholds for eliciting odd-harmonic responses were lowest in V1 and LOC, followed by V3a, with higher thresholds in middle temporal (hMT+) and hV4. Importantly, the control condition elicited very weak odd harmonic activity. Both the vernier test and the lateral-motion control condition elicited similar activity at even harmonics in all cortical regions of interest (ROI), related to the lateral-motion of the offsets. Our data indicate that V1, LOC and V3a are particularly sensitive to the detection of vernier offsets, while all visual ROIs are sensitive to lateral motion. Our results support a role for V1 in vernier acuity related to its exquisite sensitivity to orientation differences. The robust activation of LOC might be related to the texture characteristics of the extended vernier, or to its sensitivity to vernier offsets.

Acknowledgement: The Smith-Kettlewell Eye Research Institute, Pacific Vision Foundation

53.4019 **Factor analysis of individual differences in retinal (PERG) and cortical (VEP) visual contrast responses reveals two retinal and two cortical processes in adults with and without depression.**

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Recent studies of contrast response functions have found: 1) Separate cortical processes mediate amplitudes at high and low contrasts, as revealed by principal component analysis (PCA) of individual differences in visual evoked potentials (VEPs) (Hamer, Souza et al. 2013). 2) There is a strong reduction in contrast perception and retinal contrast gain in patients with major depression, which normalizes after antidepressive therapy and remission of depression (Bubl et al. 2009; 2010; 2012). The current analysis examines processes (statistical factors) underlying cortical and retinal contrast response functions. Further, it examines which of these processes change with depression. Thirty-five patients with a diagnosis of major depression (26 with and 9 without medication) and 21 healthy subjects participated. Pattern electroretinograms (PERGs) were recorded from both eyes. To quantify PERG and VEP based contrast responses, a sequence of five checkerboard stimuli was presented with 0.5° check size, contrast-reversing at 12 reversals per second, and Michelson contrasts of 3.2%, 7.3%, 16.2%, 36%, and 80%. Individual differences in left and right eye responses were highly intercorrelated, and thus averaged. Principal components were computed from log amplitudes and rotated to approximate simple structure using a Varimax rotation. (1) Two retinal (PERG) and two cortical (VEP) factors were found. The two cortical processes mediate high and low contrasts, consitent with Hamer et al. The two retinal factors also mediate high and low contrasts, but are independent of (uncorrelated with) cortical factors. The four factors were distinct from three additional factors found for VEP noise and PERG noise in left and right eyes. (2) The only factor of the four that changes significantly with depression is a retinal factor tuned to high contrasts. Our analysis identifies probable contrast-sensitive mechanisms, and shows a surprising independence of retinal and cortical gains. Changes in contrast perception in depression may be linked to a single retinal process.

53.4020 **Inconsistencies between simultaneously measured neural and behavioral sensitivities in monkeys performing a fine orientation discrimination task** Yuzhi Chen[1], Yoon Bai[1], Wilson Geisler[1], Eyal Seidemann[1]; [1]Center for Perceptual Systems, University of Texas at Austin

Neurons in the primate primary visual cortex (V1) are well organized into columns based on their orientation preference. Although this columnar organization has been studied for decades, it is still unclear how neural activity in these columns contributes to orientation perception. As a first step towards addressing this question, we used voltage sensitive dye imaging (VSDI) to measure the columnar signals in V1 of a monkey while it performed a fine orientation discrimination task. To assess neural sensitivity, we developed a linear decoder that pools the single-trial VSDI signals over space using weights proportional to the orientation response map at the columnar scale. The decoder then uses the pooled signals to perform the same task as the monkey. To test the hypothesis that columnar signals provide the main source of information in the orientation discrimination task, we varied the spatial frequency of the stimulus. Under this hypothesis, spatial frequency should have a similar effect on neural and behavioral sensitivities. However, we found systematic differences in the neural and behavioral effects of spatial frequency. The monkey was most sensitive at the middle frequency (2cpd), and performed worse at both low (0.5cpd) and high (8cpd) frequencies. In contrast, neural sensitivity was best at 8cpd, intermediate at 2cpd, and much worse at 0.5cpd. There are at least two possible sources that could contribute to these discrepancies between the neural and behavioral effects. First, additional sources of information beyond the columnar signals may contribute to behavioral performance at intermediate and low spatial frequencies. Second, the efficiency with which V1 signals at the columnar scale are decoded by subsequent processing stages may decrease with increasing spatial frequency. By studying trial-by-trial covariations between V1 signals and behavioral choices we may be able to distinguish between these possibilities.

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Motion Perception: Optic flow and heading

Tuesday, May 19, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.4021 **The Neural Correlates of Vection - an fMRI study** Ramy Kirollos[1] (ramyk1@cse.yorku.ca), Robert Allison[1], Stephen Palmisano[2]; [1]York University, Centre for Vision Research, [2]University of Wollongong, School of Psychology

Vection is an illusion of visually-induced self-motion in a stationary observer. This functional magnetic resonance imaging (fMRI) study measured psychophysical and blood oxygenation level-dependent (BOLD) responses to four different visual stimuli: (1) coherent optic flow simulating smooth forward self-motion, (2) coherent optic flow simulating forward self-motion combined with vertical head oscillation, and (3,4) scrambled versions of 1 and 2 respectively (which preserved local, but disrupted global, motion information). These stimuli were specifically designed to examine the interaction between visual and vestibular cortical regions during vection. The two coherent optic flow stimuli produced robust percepts of vection while the scrambled stimuli produced little or no vection. Of the putative self-motion areas we examined, the cingulate sulcus visual area (CSv) showed the clearest selective activation for coherent optic flow compared to incoherent (scrambled) flow suggesting that CSv is heavily involved in self-motion processing. Other regions such as parieto-insular vestibular cortex (PIVC), and precuneus visual region (Pc) showed change in BOLD activity during vection-inducing stimuli but to a lesser extent than CSv. These findings help clarify the relationship between visual and vestibular cortical regions during vection and highlight CSv as a region of primary importance in self-motion processing.

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53.4022 **Adult Observer's Sensitivity to Optic Flow Varies by Pattern and Speed** William Adamiak[1] (wadamiak311@gmail.com), Amanda Thomas[1], Shivani Patel[1], Rick Gilmore[1]; [1]Psychology, Penn State

In adults, radial optic flow evokes stronger brain activity than laminar or rotational flow. Optic flow also evokes different activation patterns depending on motion speed (Fesi et al., 2014). This study examined whether the detection of optic flow in adult observers varies by pattern and speed in ways consistent with prior physiological evidence. Adult observers (n=10; 19.2-22.2 years, M=21.4) viewed two side-by-side, time varying (1.2 Hz coherent/incoherent cycle) annular shaped (18 deg outer/5 deg inner diameter) optic flow displays at a viewing distance of 60 cm. One display depicted random (0% coherent) motion while the other depicted radial or translational motion at one of four fixed coherence levels (5, 10, 15 or 20%). Observers fixated centrally and judged which side contained coherent motion, indicating the choice by a keypress. Within a single run, speed was either 2 or 8 deg/s. Between 2 and 4 runs were collected per participant in a single visit. We analyzed proportion correct and response times using linear mixed effects modeling (nlme) in R. As predicted, proportion correct judgments increased with motion coherence, and the response time of correct judgments declined. There were no statistically significant differences in proportion correct judgments by speed or pattern type; however, a significant coherence by pattern interaction, $p < .0001$, indicated that observers more readily detect low coherence laminar flows than radial ones. Reaction time data suggest that observers are faster to detect laminar patterns, $p < .0001$, and slow (2 deg/s) speeds, $p < .001$. Taken together the results sug-

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gest that sensitivity to detect optic flow in noise varies by pattern type and speed, but not in ways that map consistently onto prior physiological results.

Acknowledgement: NSF 1147440

53.4023 **The robustness and stability of heading perception in dynamic environments**

Oliver Layton[1] (owl@bu.edu), Brett Fajen[1]; [1]Department of Cognitive Science, Rensselaer Polytechnic Institute, 110 8th Street, Troy, NY 12180

Several studies have revealed that human heading perception based on optic flow is biased when independently moving objects (IMOs) cross or approach the observer's future path. However, these biases are surprisingly weak (~2°) and perceived heading does not seem to abruptly shift at the moment that a moving object crosses the observer's future path. While previous studies have focused on biases, it is equally important to understand how heading perception is as robust and stable as it is. Such robustness and stability is surprising given that IMOs often occupy large portions of the visual field and occlude the focus of expansion (FoE). Why isn't heading perception, which is based on neurons tuned to radial expansion, biased by more than several degrees or abruptly shift when an object crosses the future path? Indeed, our simulations of existing models (differential motion and center-weighted template models) yield heading estimates that are far more erratic and unstable than human judgments. We present a dynamical model of primate visual areas V1, MT, and MSTd based on that of Layton, Mingolla, and Browning (2012) that explains how the visual system reliably estimates heading during navigation through dynamic environments. Unlike existing models, competitive dynamics between units in MSTd stabilize the model's heading estimate over time, even when an IMO crosses the future path. Soft winner-take-all dynamics enhance units that code a heading direction consistent with the time history and suppress responses to transient changes to the optic flow field. The model explains the surprising bias that occurs when an object disoccludes the future path, although the FoE is visible in the flow field (Layton & Fajen, Submitted to JoV). Our findings support competitive temporal dynamics as a crucial mechanism underlying the robustness of perception of heading.

Acknowledgement: Office of Naval Research (ONR N00014-14-1-0359)

53.4024 **Proximity of adjacent velocities and collision detection**

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Previous research has demonstrated that the detection of an impending collision on a linear trajectory is specified by an object maintaining constant bearing (position in the visual field). Additionally, velocity information adjacent to an approaching object has been shown to alter the ability to determine bearing information. In the present study we examined the effect of proximity of adjacent velocity on collision detection judgments. Observers were presented with 3D scenes consisting of either a ground plane or with a ground plane with objects in the scene that extended vertically from the ground. These scene objects were presented on either both sides of the scene or on only one the side scene (the side opposing the approaching object). Two independent variables were manipulated: the presence of adjacent velocities (scene objects absent, scene objects present on both sides, and scene objects present on only one side), and display duration (1000ms and 5000ms). We found that sensitivity to detect a collision (d') decreased with display duration ($F(1, 7)= 101.194$, $p< .001$) and with the presence of scene objects ($F(2, 7)= 5.744$, $p=0.015$). Post-hoc analysis indicated scene objects on both sides compared to scene objects on only one side did not differ significantly from one another but scene objects absent differed significantly from scene objects present on both sides. These results demonstrate that the effect of adjacent velocities found in previous research was not due to the mere presence of objects within the scene and that proximity of adjacent velocities is the important factor. This provides further evidence suggesting opponent motion mechanisms in area MT average velocities across local regions in the visual field.

Acknowledgement: Research supported by NIH EY0018334 and AG031941

53.4025 **Adaptation to the spatial smoothness of visual motion flow.**

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The spatiotemporal pattern of local motion vectors is a useful information source for visual recognition of moving objects, as demonstrated by our recent finding that human observers can recognize dynamic liquids and their viscosity only from the visual motion flow information (Kawabe et al., in press, Vision Research). Furthermore, the same study shows that the critical image parameter for the liquid-from-motion perception is the spatial smoothness of motion flow. However, it remains poorly understood how the brain processes the spatiotemporal pattern of motion flow, including the spatial smoothness. We have been analyzing the motion flow processing using the adaptation paradigm. Last year (Maruya & Nishida, 2014, VSS), we showed that the adaptation to a non-uniform motion field (a checkerboard pattern defined by two motion directions) significantly elevated the threshold (in terms of minimum direction difference) to detect a test motion-defined pattern. This time, we examined whether the adaptation to a specific range of spatial smoothness of motion flow would alter the apparent smoothness of the subsequently seen motion flows. The stimulus was an array of moving noise patches, each windowed by a stationary Gaussian. By rearranging patch positions of a motion field of a liquid flow, we generated motion flow fields with various levels of spatial smoothness — smooth and non-smooth fields for adaptation, and intermediate ones for test. To avoid adaptation to local motions and specific arrangements of motion flow, we updated the adaptation field to a new one every 1s. Observers' task was to score the perceived smoothness of the motion flow in the test pattern, which was presented briefly (1s) after adaptation. The results show that perceived smoothness with test patterns is higher after adaptation to non-smooth flows than after adaptation to smooth flows. This indicates the existence of adaptable encoder of the spatial smoothness of motion flow.

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53.4026 **Disentangling the effects of object position and motion on heading judgments in the presence of a moving object**

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Previous research has found that moving objects bias heading perception only when they occlude the focus of expansion (FOE) in the background optic flow, with the direction of bias depending on whether the moving object was approached or at a fixed distance from the moving observer. However, the effect of object motion on heading perception was confounded with object position in previous studies. Here, we disentangled the contributions of object motion and position to heading bias. In each 1s trial, the display simulated forward observer motion at 1 m/s through a 3D random-dot cloud that had a constant depth range of 0.5–2 m and consisted of 50 dots which were always seen in the field of view. In Experiment 1, an opaque square that had a fixed position on the screen contained 9 dots that moved uniformly laterally or in random directions at a fixed distance from the observer. In Experiment 2, the dots in the square had the same lateral motion component as in Experiment 1, but simultaneously approached the moving observer at 1 m/s. The distance between the center of the square and the FOE (±5° or ±10°) was constant throughout the trial. We found that heading perception was biased even when the FOE was not occluded and the bias was in the direction of object motion when the object was at a fixed distance from the moving observer and was in the opposite direction when it was approached in depth. In addition, when the object contained random motion (Experiment 1), heading bias was toward the object position. We conclude that occlusion of the FOE is not a prerequisite for moving objects to induce a heading bias, consistent with Royden's (2002) differential motion model, and that the bias can be due to either object motion or position.

Acknowledgement: Hong Kong Research Grant Council, HKU 7460/13H, 7482/12H.

53.4028 **Heading Detection From Optic Flow In The Presence Of Human Motion**

Hugh Riddell[1] (hugh.riddell@uni-muenster.de), Markus Lappe[1]; [1]Westf. Wilhelms-University Münster

A bias in heading estimation is observed if an extraneous object moves so as to obscure the focus of expansion of an optic flow field generated by linear translation. This bias, however, has only been shown for simple, non-articulated objects with no social or behavioural relevance. Contrastingly, objects in the real world are often much more complex and can be comprised of multiple, differently moving elements. Additionally, the movements of particular objects, such as other human actors, may carry information essential to the survival of the observer. In the current study we tested the accuracy of heading estimates in the presence of normal and scrambled point-light walkers. We found that both walkers biased heading estimation when crossing the focus of expansion. This heading bias, however, was significantly larger in the scrambled walker condition than the normal walker condition. Based on these results, we suggest that during translation the visual system is able to use biological form information to efficiently group and segment extraneous points from the optic flow field, thus simplifying the estimation of heading. This has important

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ramifications for models of heading perception, which generally ignore the characteristics of moving objects and simply treat them as noise.

53.4029 **During self-movement humans are better at judging whether an object is moving (flow parsing) than whether they will hit it (heading).** Simon Rushton[1] (rushtonsk@cardiff.ac.uk), Diederick Niehorster[2], Li Li[2]; [1]School of Psychology, Cardiff University, [2]Department of Psychology, University of Hong Kong

During locomotion we can use information in the retinal flow field to judge whether we will pass to the left or right of an object in the scene (heading). We can also use information in retinal flow to judge whether an object is moving relative to the scene (flow parsing). Both judgements rely on the brain identifying optic flow (global patterns of retinal motion that are characteristic of self-movement). How does the precision of these two judgments compare? Differences or similarities in precision may provide some insight into the underpinning mechanisms. We designed stimuli that allowed direct comparison of the precision of the two judgements. In the heading task, we simulated forward movement of the observer by moving a rigid scene containing wireframe objects, plus a coloured target sphere, towards the observer. Observers judged whether they would pass to the left or right of the sphere. Thresholds were measured as a function of the angle between the sphere and the simulated direction of movement. In the object movement task, the background scene and the target sphere moved on slightly different trajectories which led to a perception of scene-relative object movement. Observers judged whether the sphere was moving to the left or right in the scene. Thresholds were measured a function of the difference in direction of the background and target trajectories. Precision was significantly higher when judging object movement than when judging self–movement. Control experiments removed local cues and confirmed that the results were unchanged. In a simulated rotation experiment we found that performance on the object movement task was unaffected while judgements of self-movement were impaired. These results are compatible with the hypothesis that flow parsing is not dependent upon a prior estimate of heading; flow-parsing is either an independent process, or it precedes estimates of heading.

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53.4030 **Heading Perception with Simulated Visual Defects** Margarita Vinnikov[1] (rita.vinni@gmail.com), Stephen Palmisano[2], Robert Allison[1]; [1]The Department of Electrical Engineering & Computer Science, York University, [2]School of Psychology, University of Wollongong

Heading perception depends on the ability of different regions of the visual field to extract accurate information about the direction of the visual flow. Hence due to its ability to extract the most accurate information, the central visual field plays a major role in heading estimation. With experience people learn to utilize other regions especially if there is central field loss/impairment. Nevertheless, it is not clear what happens when information in central vision becomes altered or cannot be picked up. In the present study, we examined the effects of gaze-contingent alteration of regions of the visual field on heading. On each trial, one of six different directions of self-motion were simulated (headings ±7.5°, ±5.0° and ±2.5° from the centre of the screen). The simulated defects were analogous to two typical visual field disturbances resulting from macular degeneration, either metamorphopsia or scotomas. Specifically, with a force choice procedure we compared performance with no visual defects to that with five different simulated defects (either 5° or 10° horizontal perturbations, 5° or 10° Gaussian perturbations, or a 10° scotoma). We also looked at three gaze conditions - free viewing, directional viewing and tracking features in the scene. Heading performance was not significantly different in the two environments examined (translation over a plane covered with blue particles or through a forest). Performance declined in the presence of simulated visual defects, as well as when they were instructed to visually track specific scene features. Performance was most accurate for all heading directions during the free view conditions. We conclude that when people are free to direct their gaze in the scene they are able to minimize the impact of simulated central visual field loss/distortion.

Eye Movements: Pursuit

Tuesday, May 19, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.4031 **Evolution of the oculomotor tracking with an accelerating or decelerating target** Clara Bourrelly[1,2] (clara.bourrelly.int@gmail.com), Julie Quinet[2], Laurent Goffart[2]; [1]Laboratoire Psychologie de la Perception, Université Paris-Descartes, Paris, France, [2]Institut de Neurosciences de la Timone, Aix-Marseille Université, Marseille, France

A target that moves smoothly and continuously in the visual periphery triggers interceptive saccades that bring its image within the central field. Thus, the saccades increase the population of neurons (e.g., in the cerebral cortex) whose activity correlates with the visual presence of the object, facilitating its foveal pursuit. This foveation is maintained more or less efficiently by two types of tracking eye movements: low-velocity movements and catch-up saccades. We studied in four head-restrained monkeys the evolution of the oculomotor tracking in response to a small target that moved for less than one second (800 ms) along a horizontal or vertical path, after its sudden appearance at an eccentric position (16°) along the vertical or horizontal meridian, respectively. We tested target motions of different velocity profiles (accelerating or decelerating). During the first trials, the tracking consisted of saccades separated by periods during which gaze moved smoothly in the same direction as the target, but lagging behind its current position. The eye velocity mimicked the target velocity profile, i.e., it accelerated or decelerated. This slow tracking evolved: with the number of trials and training days, the animal developed the ability to match the kinematics of its eye movements with that of the target. This evolution in pursuit was obviously associated with a reduction in the amplitude of catch-up saccades and gaze moved as if it were locked onto the target. Our work shows that the oculomotor tracking is driven by sluggish dynamic signals that evolve to encode the "here-and-now" position of the target. Mostly saltatory at the beginning, the tracking transitions to a continuous mode that mimics the target kinematics, enabling the animal to foveally "grasp" the target where it is and when it is there.

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53.4032 **Anticipatory smooth pursuit of intentional finger movement** Jing Chen[1] (Jing.Chen@psychol.uni-giessen.de), Matteo Valsecchi[1], Karl Gegenfurtner[1]; [1]Department of Psychology, Justus-Liebig-University Giessen

The smooth pursuit system is known to have prediction mechanisms. In the present study we investigate whether the motor command for hand movements can be integrated in the prediction and used to anticipate pursuit. Some early studies have found that ongoing pursuit is more accurate and has fewer catch-up saccades when self-generated motion is tracked (e.g., Steinbach & Held, 1968). However, it is not clear whether anticipatory smooth pursuit can be observed before the hand motion starts. Five Observers were asked to place their index finger on a flat screen and to fixate it. They could freely decide to move their finger to the left or to the right as soon as an auditory signal was presented. They were asked to pursue the finger with their gaze. Both gaze and finger positions were recorded. In two control conditions observers tracked a finger-sized dot on the screen. The dot motions were the replays of each observer's own finger movements. In one condition the motion direction was predictable, in the other it changed randomly between trials. When tracking the finger, the eye started to move on average 30 ms before finger motion. In 76% of all trials the eye started before the finger. In the predictable motion condition, pursuit latency was 24 ms on average, indicating an effect of anticipation compared to a latency of 104 ms in the unpredictable condition. In addition, the finger tracking condition showed significantly fewer catch-up saccades (~2 s-1) than the dot tracking conditions (3-4 s-1). This was particularly evident in the initiation period of pursuit. Overall, the present study shows that the oculomotor system is closely tied to body movements, leading to anticipatory pursuit and a more accurate tracking of the target.

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53.4033 **Anticipatory smooth eye movements evoked by motor intentions** Eileen Kowler[1] (kowler@rci.rutgers.edu), Lakshmi Kolisetty[1], Cordelia Aitkin[1], Nicholas Ross[2], Elio Santos[3], Radha Shah[1]; [1]Department of Psychology, Rutgers University, Piscataway, NJ, [2]Department of Psychology, Justus-Liebig University Giessen, Giessen, Germany, [3]Department of Biomedical Engineering, NJ Institute of Technology, Newark, NJ

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Anticipatory smooth eye movements (ASEM) are predictive smooth eye movements in the expected direction of future target motion. ASEM are evoked by various cues that signal the direction of future target motion, including cues from our own motor intentions when we move targets ourselves (Kowler et al., 2014; Ross & Santos, 2014). How do motor intentions trigger ASEM? Does the pursuit system monitor motor commands directly, or, alternatively, use motor intentions, along with other cues, to represent the expected path of future target motion? These alternatives can be distinguished by imposing visuo-motor conflicts. Subjects pursued a target disk whose motion was controlled by a mouse. The disk was moved through an inverted Y-shaped tube, with subjects choosing either the right or left oblique pathway. In the absence of visuo-motor conflict, ASEM were found before the target entered the oblique pathway. Results were similar regardless of whether the mouse steered the target, or control was limited to choosing the right or left pathway via a brief deflection of the mouse at trial onset. In the presence of visuo-motor conflict, when the target moved opposite to the hand movement, ASEM on average corresponded to the expected direction of target motion, not the direction of hand movement. Managing the visuo-motor conflict introduced costs in that ASEM were slower when the target was guided through the entire path than when control was limited to simply choosing the right or left path at trial onset. The results show that high-level expectations dominate the influence of lower-level motor commands in generating ASEM with self-moved targets. Even expectations created by a simple choice of the path are effective. The results add to the evidence that neural signals representing the strength of beliefs about the trajectory of future motion are instrumental in controlling pursuit eye movements.

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53.4034 **Anticipatory smooth eye movements and reinforcement**

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When an object is moving in the visual field, we are able to accurately track it with a combination of saccades and smooth eye movements. These movements allow us to align and stabilize the object on the fovea, thus enabling visual analysis with high acuity. Importantly, when predictive information is available about the target motion, anticipatory smooth pursuit eye movements (aSPEM) are efficiently generated before target appearance, which reduces the typical sensorimotor delay between target motion onset and foveation. By manipulating the probability for target motion direction we were able to bias the direction and mean velocity of aSPEM (baseline condition). This suggests that probabilistic information may be used to inform the internal representation of motion prediction for the initiation of anticipatory movements. To further understand the nature of this process, we investigate the effects of reinforcement on aSPEM with two distinct experiments. First, it has been previously shown that several properties of eye movements can be modulated by reinforcement paradigms based on monetary reward (Madelain et al. 2011). We adapted and extended this framework to prediction-based aSPEM, by associating a monetary reward to a criterion-matching anticipatory velocity, in the gap before the target onset. Second, it has also been reported that accurate perception per se can play the role of an efficient ecological reinforcer for visually guided saccades (Montagnini & Chelazzi, 2005). With a gaze-contingent procedure, we manipulated the discriminability of a perceptual target (Appearing at the end of a pursuit trial and followed by a discrimination task). The difficulty level of this task has been matched depending on the velocity of aSPEM. This experiment taps on the very reason to produce anticipatory tracking movement, that is to grant a quicker high-acuity vision of the moving target. We compare predictive anticipatory eye movements across these conditions.

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53.4035 **Interactions between fixation and pursuit systems**

Scott Watamaniuk[1] (scott.watamaniuk@wright.edu), Elena Potapchuk[2], Japjot Bal[2], Stephen Heinen[2]; [1]Department of Psychology, Wright State University, Dayton OH, [2]The Smith-Kettlewell Eye Research Institute, San Francisco CA

Previous work suggested that the pursuit and fixation systems are separate (e.g., Luebke & Robinson, 1988). Here we present evidence of interactions between these two systems. In separate blocks of trials, observers either pursued a spot that started at the edge of the display and moved across the screen at a constant velocity on every trial, or did so with randomly interleaved fixation trails. When fixation trials were included, anticipatory pursuit was reduced relative to when only pursuit trials were present. This suggested an active inhibition of pursuit by the fixation system. Alternatively, inserting the fixation trials may have simply allowed time for a stored velocity signal thought to drive anticipatory pursuit (e.g., Barnes & Asselman, 1991) to dissipate. To test this, we interleaved 'blank' trials (no stimulus), of the same duration as the fixation trials, with the pursuit trials. Anticipatory pursuit was high under this condition, suggesting that fixation trials actively inhibit anticipatory pursuit. If so, why does the fixation period that typically precedes movement of the target in pursuit trials not have the same inhibitory effect? One possibility is that separate fixation trials introduce uncertainty about whether the stimulus will move or not. To test this, we manipulated the level of uncertainty by changing the proportion of fixation trials within a block. We found that anticipatory pursuit decreased as the proportion of fixation trials increased, suggesting that uncertainty about whether the target will move plays a role. However, we also found that pursuit latency increased as the proportion of fixation trials increased, consistent with an active interaction between fixation and pursuit circuitry.

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53.4036 **Directional asymmetry in contrast sensitivity during smooth pursuit eye movement depends on spatial frequency**

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It is known that smooth pursuit eye movement (SPEM) modulates visual contrast sensitivity in an asymmetric manner. For instance, Schütz et al. (2007) reported that contrast sensitivity to a 1 c/deg grating is higher when it drifts in the same direction with the SPEM than in the opposite direction. They interpret this asymmetry in terms of the effect of spatial attention that moves together with, or even leads, the eye. The present study shows that this asymmetry is reversed at high spatial frequency bands. We measured contrast sensitivity for a spatially localized grating (Gabor patch) of 11 c/deg. The spatial window of the grating (s.d. of H0.8 x V0.4 deg) moved in the same velocity with SPEM (1.5 deg/sec), and thereby it was static on the retinal coordinate. The grating within spatial window drifted on the retina either in the same direction or in the opposite direction of SPEM. We found that for a range of retinal temporal frequencies tested (1.4-22.5 Hz), the observer's contrast sensitivity was substantially higher (0.1-0.25 log unit) when the grating drifted in the opposite direction of SPEM than in the same direction. This asymmetry was also observed for the cut-off temporal frequencies for a grating with a contrast of 0.5. For gratings of a low spatial frequency (0.5 c/deg), the cut off frequency was little, or not, higher for gratings in the same same direction than in the opposite direction of SPEM, consistent with the previous study. These results indicate that during smooth pursuit, the visual system becomes more sensitive to high-spatial frequency signals that moves slower than the eye than those that moves faster than the eye. The results cannot be well accounted for neither by spatial attention nor by sensitivity modulations of parvocellular and magnocellular channels.

Acknowledgement: Japan Society for the Promotion of Science

53.4037 **Changes in visual sensitivity during smooth pursuit and saccadic eye movement**

Doris Braun[1] (doris.braun@psychol.uni-giessen.de), Alexander Schütz[1], Karl Gegenfurtner[1]; [1]Department of Psychology, Giessen University

Eye movements, attention and adaptation adjust visual sensitivity continuously. In particular, during the execution of saccades, visual sensitivity is reduced by an active process suppressing low-frequency luminance stimuli, but not isoluminant color stimuli (Burr, Morrone & Ross, 1994). During smooth pursuit, there is a small decrease in sensitivity for the detection of low-frequency luminance stimuli, but sensitivity to colored stimuli is actually improved (Schütz, Braun, Kerzel & Gegenfurtner, 2008). Here we investigated if these sensitivity adjustments interact when making saccades to moving targets. As a baseline, contrast thresholds were determined for the detection of a red isoluminant line flashed for 8 ms on a gray screen at an eccentricity of 2 degs above or below a central fixation point . Then the detection performance for the horizontal line was measured during smooth pursuit, saccades to stationary and saccades to moving targets. The target either moved horizontally at 11 degs/s after a small step in the opposite direction, was suddenly displaced left- or rightward by 13 deg, or moved horizontally after a 11 deg displacement. The large target steps were chosen to equate saccade amplitudes across conditions. Line detection was measured at two fixed contrasts at different points in time relative to the onset of the eye movement target. Consistently with earlier results, we found a steady increase in sensitivity to isoluminant targets during step-ramp pur-

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suit. The time course of sensitivity for isoluminant stimuli was quite similar for static and moving saccade targets. There was no performance increase before the beginning of pursuit. Contrary to our expectations, three out of our five observers showed a marked saccadic suppression for isoluminant targets. Whatever sensitivity improvement there is during pursuit eye movements, it is suspended during the initial saccade to a moving target.

Acknowledgement: DFG SFB/TRR 135

53.4038 **Foveal attention augments catch-up saccade frequency during smooth pursuit** Stephen Heinen[1] (heinen@ski.org), Elena Potapchuk[1], Scott Watamaniuk[2]; [1]Smith-Kettlewell Eye Research Institute, [2]Wright State University

Previously, we showed that foveal stimuli increase catch-up saccade frequency during smooth pursuit, presumably because a salient foveal spot activates a position correction mechanism (Heinen et al., VSS 2013). However, since saccades are linked to attention (Corbetta et al., 1998), attention may be needed to activate position correction during pursuit. To investigate this, we moved attention in and out of the fovea while observers pursued a stimulus composed of 4 peripheral dots arranged symmetrically about a central one. At a random time, either the central dot or the 4 peripheral dots dimmed briefly to draw attention into or out of the fovea, and observers identified the dot with a keypress. Saccade frequency was highest when attention was drawn foveally, and reduced when it was drawn peripherally, supporting the idea that foveal attention during pursuit was modulating the saccadic mechanism. However, removing the central dot altogether further reduced saccades, indicating that the central spot attracted attention even when observers knew it was not a potential task target. It could be that attention that is focused in one location, rather than spread out over a greater area, can increase saccade frequency. To test whether focused attention could increase saccade frequency if it were directed to positions other than the fovea, we had observers perform the identification task on a miniature version of the 5-dot stimulus (.5 deg diameter) located either in the fovea or the periphery. Saccades were again reduced when the task was performed peripherally, indicating that focused attention specifically at the fovea engages the saccadic mechanism. The results suggest that attention modulates a position-correcting system used during pursuit, and are consistent with the idea that pursuit of foveal stimuli requires attention. Furthermore, attention may preferentially modulate structures in the pursuit pathway that are also active during foveating saccades.

Perceptual Organization: Shapes and objects 2

Tuesday, May 19, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.4039 **Cues to closed-contour shape revealed using visual search.** David Badcock[1] (David.Badcock@uwa.edu.au), Krystle Haley[1], Edwin Dickinson[1]; [1]School of Psychology, The University of Western Australia

A central goal in the study of human object perception is to determine the code used by the visual system for the representation of globally-integrated shapes. The visual system determines the shape of closed contours and can find an object among a set of distractors very rapidly if it contains a unique cue. We use search speed and asymmetries in performance to determine elements of the basic code for shape in human vision. Observers can often detect the shape of objects rapidly and efficiently when presented in a set of distractors. In some cases efficient detection is not found when the roles of the two shapes are reversed (search asymmetry). Kristjansson and Tse (2001) argued curvature discontinuities (CDs) are critical local cues to shape, supporting rapid visual search with minimal distractor interference when present in the target but absent in the distractors. However, studies using Radial Frequency contours, without CDs, have suggested the polar angle between two points of maximum curvature plays an elementary role. Three visual search experiments will be presented in which performance within-observers is contrasted for patterns differing in curvature, CD, corner numerosity and internal polar angle. The results show that patterns without CDs were readily discriminable, but patterns with the same internal polar angles and extreme differences in curvature and corner numerosity were not, leading to the conclusion that internal polar angle is a primary discriminable shape feature; accounting for both 'pop-out' and search asymmetry data when closed-contour targets are employed. The results argue against important roles for corner numerosity and curvature but support the conclusion that polar angles are labelled cues to shape in the human visual system and therefore a critical element in the code for object shape.

Acknowledgement: Australian Research Council DP1097003

53.4040 **How perceived causality influences perceived symmetry** Patrick Spröte[1] (patrick.sproete@psychol.uni-giessen.de), Filipp Schmidt[1], Roland Fleming[1]; [1]Department of Psychology, Justus-Liebig-University Giessen

Many objects in our environment undergo visible processes of change, such as growth, weathering, bending or crumpling. Despite huge resulting changes in appearance, we can often identify both the object across the transformation and the transformation that has been applied to it, as if the visual system decomposes the object's features into distinct causal contributions. For example, a concavity in a cookie is readily perceived as a 'bite' whereas a similar concavity in a croissant is interpreted as a 'bend'. If—as we suggest—the visual system infers generative models to 'understand' shapes and their origins, different interpretations of parts of a shape (e.g. a concavity) should have profound effects on its perceptual organization. Here, we test the effects of causal interpretations on perceived symmetry. In one experiment, subjects viewed familiar symmetric 2D shapes, with a probe dot placed at different locations on the outline on every trial. Some objects appeared complete while others had a portion removed ('bitten'). Subjects had to place a second dot to indicate which location appeared symmetric to the probe relative to the shape's global symmetry axis. In a second experiment, using irregular shapes, subjects directly reported each object's principal symmetry axis by distributing a series of dots along the axis. We compared responses between pairs of objects that had small differences in shape but large reported differences in their perceived causal history: each pair contained 'bitten' and 'non bitten' versions. In both studies we find that concavities that are interpreted as 'bites' are suppressed from symmetry axis judgments. In other words, the visual system compensates for 'missing portions' of both familiar and unfamiliar objects. In contrast, geometrically similar concavities that are interpreted as intrinsic to the object are incorporated into symmetry axis judgments. This suggests that inferred generative processes substantially influence perceptual organization.

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53.4041 **Evaluating Phase Dependent Masking with Radial Frequency Contours** Michael Slugocki[1] (slugocm@mcmaster.ca), Allison Sekuler[1], Patrick Bennett[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Previous work on spatial contextual interactions between shapes defined by radial frequency (RF) contours has demonstrated that such interactions depend on the rotational phase alignment between a mask and target stimulus (Habak et al., 2004; 2009). When the points of maximum curvature in target and masking RF contours are aligned (i.e., zero phase difference), thresholds for detecting deviations from circularity are significantly elevated relative to a baseline condition that contains no masking stimulus, and the strength of masking declines as the relative phase difference increases (Habak et al., 2004; 2009). The current study extended this previous work by examining the effect of RF number on the magnitude of threshold elevation observed across seven target-mask relative phases. We measured detection thresholds for five RF contours (RF3, 5, 6, 8, 11) in the presence of a surrounding mask of the same RF number as the target in seven target-mask relative phase combinations (0°, 30°, 60°, 90°, 120°, 150°, 180°). Although the amount of masking varied considerably across RF contours, we found that the magnitude of masking declined with increasing relative target-mask phase difference for all RF combinations. However, we also found a significant interaction between RF number and phase such that the rate at which masking declined with phase differed across RF contours. Overall, these results suggest significant differences exist in how the frequency of local curvature affects the interference observed as a function of the alignment between two shapes. The results of this study serve as a foundation for interpreting the effect of rotational phase alignment between spatially separated shapes.

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53.4042 **Representing dynamic stimulus information during occlusion** Jim Maarseveen[1] (J.Maarseveen@uu.nl), Chris Paffen[1], Frans Verstraten[1,2], Hinze Hogendoorn[1]; [1]Utrecht University, Helmholtz Institute, Department of Experimental Psychology, The Netherlands, [2]University of Sydney, Faculty of Science, School of Psychology, Sydney, NSW 2006, Australia

When an object becomes occluded, many of its visual features (e.g. its colour or form) remain represented by the observer. Here we investigated whether changes in the object's visual features and the rate at which these

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changes occur, are also represented during occlusion. We focused on the temporal frequency content of a contrast-modulated stimulus. It has been shown that an increase in a stimulus' temporal frequency content causes an increase in its perceived duration (Kanai et al., 2006). If this temporal frequency induced time dilation also occurs in situations were the object becomes occluded, it provides evidence that information about temporal frequency content is represented during occlusion. Observers performed an online duration judgement task in which they matched the duration of a contrast modulated test stimulus (static, 4Hz, or 8Hz) to a previously presented (static) standard stimulus (600, 800, 1000, or 1200 ms in duration). During the test phase a black square moved behind or in front of the stimulus, causing it to either remain visible or to become occluded after a short delay. The results show that compared to the 4Hz and static conditions, the duration of the 8Hz condition was perceived to be longer (i.e. time dilation). This temporal frequency induced time dilation occurred both when the object was continuously visible and, more importantly, when it became occluded. Additionally, the amount of time dilation for the different standard durations did not differ between the two visibility conditions. Our findings show that dynamic stimulus properties are maintained in the representation of an object, even when it is temporarily occluded and therefore not visible. Furthermore, this representation affects the timing of the occluded object in a similar fashion as to when the object remains visible.

53.4043 Representation of shape and space when objects undergo transformations

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Objects in our environment are subject to manifold transformations, from simple rigid changes like rotation or scaling, to complex processes like twisting, bending or biological growth. Although many transformations have drastic effects on an object's physical appearance, we are often able to identify stable objects across such changes, and in many cases have strong subjective impressions of the type of transformation (e.g., in case of a crumpled can). This suggests the brain is equipped with sophisticated mechanisms for inferring both invariant object representations across transformations, and objects' causal history. Despite this, relatively little is known about how shape, spatial relationships and transformations themselves are inferred when objects undergo change. We used a simple, intuitive task to measure participants' shape representations across spatial transformation. We presented an untransformed 2D shape ('base shape') on the left side of the screen and its transformed counterpart on the right. On each trial, a dot was superimposed at a given location on the base shape and the participant's task was to place a dot at the corresponding location on the right side of the screen. Across trials many locations were probed. The resulting 'perceptual correspondence maps' allowed us to measure how well participants perceive shape across transformations; the extent to which they could infer the type of transformation; as well as its effects on the representation of space. We find that shape representations are remarkably robust against spatial transformations, especially rigid transformations. Performance is affected by the type and magnitude of transformation, as well as contour saliency. We also find that the representation of space within and around a shape is transformed in line with the shape transformation, as if shape features establish local coordinate frames. Together, these findings suggest sophisticated mechanisms for the inference of shape, space and correspondence across transformations.

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53.4044 Object Knowledge Shapes Properties of Early Feature-Detectors by Top-Down Modulation

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Classic models of visual perception assume that early stages of information-processing are carried out by arrays of specialized and static feature-detectors that operate independently of high-level representations of a stimulus. Current developments in computational vision research have challenged this notion, hypothesizing that feedback connections from higher- to lower-level stages of processing shape the properties of feature detectors to optimize their performance. Evidence to support this hypothesis is difficult to obtain since any experimental design trying to test it has to ensure that sensory stimulation of early detectors remains identical while high-level representations of the stimulus are manipulated. Here, we used two-tone images of objects in a psychophysical procedure to achieve this and demonstrate a significant influence of high-level object knowledge on response properties of early edge-detectors. Two-tone images feature stimulus regions that are physically homogenous but are experienced as an object contour (somewhat similar to illusory contours in Kanizsa figures) once the observer is provided with relevant image information. We embedded edge-elements in these areas that were consistent or inconsistent with the high-level contour representation and measured absolute contrast detection-thresholds for these elements before and after providing relevant object knowledge. Results indicate that prior knowledge facilitates absolute contrast-threshold for edge elements that are consistent with the high-level representation of a stimulus but has no effects on contour-inconsistent edge-elements. The experimental design of the study ensured that this pattern of results is unlikely to be due to uncertainty reduction about target orientation, a notion supported by a simulation based on a neurophysiologically-plausible population-code. Together, these findings provide clear evidence that early feature-detectors do not operate independently of visual cognition. Rather response properties of early information-processing units are shaped by top-down modulation from high-level image representations.

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53.4045 Numerosity perception is distinct from mean or sum perception

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The visual system is efficient at extracting a range of ensemble statistics. Most research has independently focused on the estimation of the number, the average, or the sum. Since these processes have been studied separately, their relationship is not well understood. Here we explore the interaction among numerosity, mean, and sum perception in one paradigm. In each trial, observers viewed an array of circles varying in size, and estimated the number, the mean size, or the total size of circles in each array in separate blocks (order counterbalanced across observers). Thus, for every array we obtained numerosity, mean, and sum estimates from the same observer. We noticed that there was consistent underestimation in the number, the mean, and the sum judgments. For every array, we also derived the arithmetic number (the estimated sum/the estimated mean), the arithmetic mean (the estimated sum/the estimated number), and the arithmetic sum (the estimated mean*the estimated number) for each observer. We found that the arithmetic mean was significantly closer to the estimated mean than to the objective mean, and the arithmetic sum was significantly closer to the estimated sum than to the objective sum. However, the estimated number was closer to the objective number than to the arithmetic number. This dissociation suggests that observers may have implicitly followed the arithmetic model for mean and sum estimation, but not for number estimation. Moreover, the errors in the sum estimates were highly correlated with the errors in the mean estimates, but the errors in the number estimates were not correlated with either the errors in the sum or the errors in the mean estimates. This provides further evidence that numerosity was calculated independently from the mean or the sum. Taken together, the results suggest that numerosity perception operates in a distinct manner from mean or sum perception.

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53.4046 Rejecting probability summation for RF patterns, not so Quick!

Alex Baldwin[1] (alexsbaldwin@googlemail.com), Gunnar Schmidtmann[1], Frederick Kingdom[1], Robert Hess[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University, Montreal

Investigations of shape processing frequently use radial frequency (RF) patterns. An RF pattern is a circular contour with a periodic modulation applied to its radius. The way in which the visual system detects these patterns has been studied in several previous summation experiments. Typically data is compared to predictions from a model that detects each part of the pattern independently and then combines those local outputs through probability summation (these models predict less summation). This is then rejected in favour of a model that detects the whole RF pattern globally (predicting more summation). The "Quick pooling" probability summation model they use is based on the High Threshold Theory (HTT) of detection however, which lacks empirical support. In our study we first measured receiver operating characteristic curves to demonstrate that models of RF pattern detection should be based on Signal Detection Theory (SDT). Our data followed the SDT prediction (curved lines) rather than the HTT prediction (straight lines). We then measured psychometric functions for a four-cycle RF pattern as its lobes were modulated individually and in combination. We also collected data for summation between individual cycles in a quad of RF patterns to see whether within-RF summation differed from between-RF summation. Although thresholds for the between-RF condition were higher, the level of summation was very similar to that in the within-RF condition. We analysed our data using a maximum-likelihood fit of SDT-based additive and probability summation models. These include five parameters: individual gains for each cycle of the RF and a transducer exponent. We find that our probability summation model is able to provide as good a fit to both datasets as the additive summation (global) model. We discuss how the use of a HTT model may have led to premature rejection of probability summation in the past.

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53.4047 **Integration times of global shape mechanisms are limited by low level processes operating prior to spatial integration** Jason Bell[1] (Jason.Bell@uwa.edu.au), Gideon Sacks[1], David Burr[1,2]; [1]School of Psychology, University of Western Australia, Australia, [2]Department of Neuroscience, Psychology, Pharmacology and Child Health, University of Florence, Italy

The temporal integration times of mechanisms detecting sinusoidal gratings, likely in V1, vary considerably, depending on spatial scale (BURR Proc Roy Soc, 1981). Here we investigate whether the temporal properties of higher level form mechanisms similarly depend on spatial scale, as would be expected if the temporal limitation were low level. We measure spatial and temporal summation in mechanisms responsible for decoding visual shape, using Radial Frequency (RF) patterns, globally processed stimuli that represent familiar shapes and objects, while being easy to control. We measured pattern deformation thresholds for one and three cycles of an RF3 (triangular pattern), as a function of SF profile (1.25 or 10 cpd), and presentation time (10-320ms). In all conditions, stimuli were matched for perceived contrast. SF and contrast matched backward masks were used to disrupt visible persistence. The results show that sensitivity to RF shape improved sharply as presentation time increased. The improvement was more rapid, and quicker to plateau for the low, compared with the high SF profiled pattern; indicating a shorter temporal integration time for the former (consistent with results with simple sinusoidal patterns). Sensitivity also improved with number of features, almost linearly (as previous shown: LOFFLER et al., Vis Res, 2003), irrespective of SF or presentation time. That the temporal properties of shape mechanisms vary with SF, in a similar way as for simple sinusoids, suggests that this integration may be limited at low levels, before spatial integration. This is consistent with the fact that there is not interaction between spatial integration and exposure time, as may be expected if the limitation were at a higher level. We will discuss these results in relation to the temporal properties of other visual mechanisms.

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53.4048 **The perception of multi-dimensional regularities** Sumeyye Cakal[1] (sumeyyecakal@psych.ubc.ca), Ru Qi Yu[1], Jiaying Zhao[1,2]; [1]Department of Psychology, University of British Columbia, [2]Institute for Resources, Environment and Sustainability, University of British Columbia

Regularities are prevalent in many aspects of the environment. How does the visual system extract structured information from multiple sources? One possibility is that the visual system selectively focuses on one source. Alternatively, it may incorporate all sources to form a weighted representation of the regularities. To address this question, we generated matrices containing cells that varied independently on the color dimension (red/blue) or the shape dimension (circle/square). Each matrix could be divided into two equal halves either horizontally or vertically. One half was fully random, whereas the other half was structured (i.e., organized in chunks). Observers discriminated the boundary between the two halves in three conditions (Experiment 1). In the color condition, the cells were structured only on the color dimension; in the shape condition, the cells were structured only on the shape dimension; and in the color+shape condition, the cells were structured both on the color and the shape dimensions. Importantly, each dimension contained an equal amount of regularities. We found that the boundary discrimination accuracy was higher in the color+shape condition than that in the shape condition, but not different from the color condition. This suggests that color was prioritized when regularities were present in both dimensions. To examine whether this prioritization was specific to color, we introduced a new surface dimension (solid/hollow) in the matrices (Experiment 2). Now the boundary discrimination accuracy was the highest in the surface condition, compared to the other dimensions. Critically, the accuracy was equally high when the cells were structured on all three dimensions. This suggests that the surface dimension was prioritized over the others. These findings demonstrate that the visual system relies on one feature dimension to extract regularities, even though every dimension is equally informative. Moreover, such extraction did not benefit from the presence of multiple sources of regularities.

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53.4049 **Decoding identity of spatiotemporal objects in intermediate and dorsal visual areas** Gideon Caplovitz[1] (gcaplovitz@unr.edu), Gennady Erlikhman[1]; [1]Department of Psychology, University of Nevada Reno

Background: Spatiotemporal objects are those whose parts become visible only gradually through motion and dis-occlusion, and must be integrated to form perceptual units. Rather than representational invariance, the perception of spatiotemporal objects requires precise positional and velocity information about fragments in order to accurately align them across space and time. The data we present here suggests that intermediate and dorsal visual areas may be critical for their perception. Design: Spatiotemporal objects were defined by spatiotemporal boundary formation (SBF; Shipley & Kellman, 1993, 1994, 1997). An invisible object expanded and contracted on a background of randomly oriented Gabor elements. Whenever the object came into contact with an element, that element rotated in place by a random amount or was displaced in a random direction. Even though only a few elements changed between frames, the percept was of an expanding global form with clear boundaries. fMRI data were collected while subjects passively viewed expanding and contracting and squares, circles, or radial frequency (RF) patterns defined by elements that either rotated or displaced (6 conditions). RF patterns did not produce clear global forms and were used as a control condition. In separate scanning sessions, we functionally identified 20 topographically organized ROIs in early, intermediate, dorsal, and ventral visual areas. Results: An SVM classifier was able to distinguish between shape (circle/square) and no-shape (RF patterns) conditions as well as between circles and squares throughout visual cortex including areas not commonly identified in shape-representation studies including: V3A,V3B, LO1, LO2, TO1, TO2, IPS0-IPS5. Conclusions: Spatiotemporal object identity is represented not only in ventral, but also in intermediate and dorsal visual areas. Dynamic perceptual units formed from object fragments distributed in space and time may first arise in dorsal and parietal areas and then be passed on to ventral ones for recognition.

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53.4050 **The perception of history: Seeing causal history in static shapes is powerful enough to induce illusory motion perception** Yi-Chia Chen[1] (yi-chia.chen@yale.edu), Brian Scholl[1]; [1]Department of Psychology, Yale University

The perception of shape, it has been argued, also often entails the perception of time. A cookie with a bite taken out of it, for example, is seen as a whole cookie that was subsequently bitten. Similarly, a twisted towel is represented as an untwisted towel that was subsequently twisted. It has never been clear, however, whether such observations truly reflect visual processing alone. To explore this, we tested whether the perception of history in static shapes is powerful enough to influence the perception of other visual features. Observers were told that they would see short movies of a shape (e.g. a square) changing from its complete form into a truncated form, with a "piece" of it missing, and that this change could occur in two ways: (1) all at once, in a single flash; or (2) gradually, with the missing piece quickly "growing" into the shape (as when you poke your finger into a lump of clay). Our primary manipulation involved the contours of the missing piece itself. On some trials, these contours implied a causal history: the static result looked as if another shape had at one time 'intruded' on the original shape. On other trials, these contours implied no such past gradual transformation. When presented as an actual change (from the full shape to the truncated shape), this variable influenced whether observers actually perceived motion. In particular, when the contours of the missing piece suggested a type of historical 'intrusion', observers actually saw that intrusion occur: it appeared as if the change actually occurred gradually, in a type of transformational apparent motion. (Catch trials with real gradual motion ruled out the possibility of a response bias.) Thus the perception of causal history in shapes is powerful enough to induce illusory motion percepts.

53.4051 **Representational biases in the perception of visuospatial orientation: Gravitational and other reference frames** Frank Durgin[1] (fdurgin1@swarthmore.edu), Brennan Klein[1], Christopher Thomson[1], Elizabeth Cifuentes[1]; [1]Department of Psychology, Swarthmore College

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Two very different bias functions may be observed in the study of perceived 2D orientation of visual stimuli. One bias function is symmetrical between vertical and horizontal. This "cardinal" bias (e.g., Gischick et al. 2011) has sometimes been argued to be a front-end coding bias due to the overrepresentation of vertical and horizontal in natural scenes and in visual cortex. The second, "categorical" bias function (Dick & Hochstein, 1989) is asymmetrical; it exaggerates angular deviations from horizontal while underestimating deviations from vertical with the consequence that orientations that are only 37-40° from horizontal are judged to bisect the angular distance between horizontal and vertical (Durgin & Li, 2011). Here we report that both of these biases appear to be yoked to the perceived gravitational reference frame: When observers are positioned at an attitude of 45° so that retinal and gravitational reference frames are dissociated, it is the perceived gravitational reference frame that matters most. In the case of the categorical bias, the gravitational horizontal seems to provide a particularly strong reference orientation, consistent with the importance of the gravitational ground plane. In the case of the cardinal bias, which is measured by comparison between two orientations, the gravitational reference-frame dominance is clearly inconsistent with an account based on cortical over-representation of cardinal orientations. More likely, for purposes of comparison, orientations are coded relative to a perceptually-given reference frame that is divided into quadrants. Cardinal bias might therefore be understood as resulting from representational range compression within each perceptual quadrant. In a series of five experiments we show that noisy orientation textures composed of variably-oriented gabor patches can show both kinds of cognitive orientation bias, and that both biases are yoked to perceptual rather than retinal reference frames.

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Binocular Vision: Rivalry and awareness

Tuesday, May 19, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.4052 Suppression of unformed visual hallucinations in homonymous hemianopia from occipital stroke using TMS

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Visual hallucinations represent the dissociation between visual perception and sensory input. We present the case of a 31-year old patient who perceived continuous unformed hallucinations in the hemianopic field immediately following right occipital cortex stroke, which have remained unchanged over 2 years. We performed 1 Hz repetitive transcranial magnetic stimulation (TMS) to the lesioned area for 30 minutes per day over 5 days in an attempt to suppress the perpetual hallucinations. fMRI was performed prior to and after TMS treatment to assess plasticity changes. Pre-TMS, the patient showed greater immediate activation at the boundary of the lesion compared to healthy controls; in the cuneus, lingual gyrus and surrounding areas. The associated "hyperactivity" corresponded to a reported perceptual increase in visual hallucinations. In addition, the patient displayed greater right frontal lobe activity compared to controls prior to TMS, indicative of a greater level of distress (Bartolic et al., 1999). During daily TMS sessions, the perception of hallucinations was greatly reduced. Post-TMS fMRI showed suppression of activity in the previously associated regions of "hyperactivity" to a level similar to that of controls. This is consistent with our previous work showing a decrease in occipital activation with TMS results in a decrease of frontal activity, thereby indicating connections between ventral regions and the frontal lobe (Rafique et al., 2014). Notably, the patient displayed greater activity post-TMS in the inferotemporal and parietal lobes when viewing images of objects and scenes respectively, demonstrating a redistribution of activity most likely regarding object and attention processing. This case provides evidence of an infarct resulting in excitatory discharges at the border of the lesioned area, which stimulate neighbouring areas, and thus results in abnormal visual perception. We causally demonstrate that repetitive TMS provides a valuable method of modulating hallucinations from occipital injury or infarct.

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53.4053 Visual representations in the absence of visual awareness

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"Perceptual disappearance" refers to a group of phenomena in which physically presented visual stimuli are perceived as invisible. This dissociation between the physical world and the perceptual experience suggests that visibility is not simply governed by object properties, but can be altered with changes in the internal states. Here we attempt to specify the information available on visual stimuli during perceptual disappearance by examining interactions between the visible and the perceptually invisible. Observers preformed the Motion Induced Blindness task (MIB; Bonneh, Cooperman, & Sagi, 2001), wherein a target (1.5□ eccentricity) perceptually disappears when superimposed onto rotating background (10x10 '+' patterns, 0.7□ width, 1.4□ spacing). A 'Cue' was presented next to the target upon observers' report of perceptual disappearance. Target and cue were presented together for a limited interval (200, 300, 400ms) before the target was physically erased, permitting an estimation of the time required for perceptual reappearance. Observers were asked to report target reappearance. The presentation of a cue resulted in increased proportions of reappearances. Reappearances were relatively slow and required the target presence for 300-400ms since cue presentation. For a Gabor target (σ=0.12□, λ=0.17□, 100% contrast), the proportion of reappearances was higher with a collinear Gabor 'Cue' relative to an orthogonal cue (0.80 vs 0.37; spontaneous=0.53) and with a proximal cue (0.53□) relative to a more distant cue (1.2□) (0.77 vs 0.50; spontaneous=0.30). For an isosceles-triangle target (0.49□), reappearance rate increased in the presence of proximal triangular cues (0.8) relative to square or circular cues (0.5), irrespective of the triangular cue shape and size. This suggests dependence of reappearances on local features similarity between target and cue. Taken together our findings show preserved information about the location and features of the unaware target. This may imply that some visual processes sensitive to feature-similarity operate across the boundary of awareness.

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53.4054 Real-world regularities facilitate visual awareness of objects under continuous flash suppression

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Our stable visual awareness of the world is thought to reflect the transient dominance of neural assemblies representing the conscious percept over competing assemblies representing other aspects of the visual input. These competitive dynamics can be tracked using continuous flash suppression (CFS), in which high-contrast patterns flashed into one eye can suppress the perception of stimuli presented to the other eye for several seconds. Recent work indicates that the competitive strength of a stimulus in overcoming CFS is influenced by contextual regularities in the visual input. For example, stimuli that can be perceptually grouped based on illusory contours have a competitive advantage in gaining access to awareness under CFS. Here, we show that higher-level regularities that arise from the relative positioning of natural objects in the visual environment also modulate visual awareness. In two experiments, suppression times under CFS were shorter for pairs of objects that were positioned according to real-world spatial regularities (e.g. a lamp above a table) relative to the same object pairs shown in irregular configurations (e.g. a table above a lamp). This advantage for regular object pairs was specific to upright stimuli and abolished by stimulus inversion, meaning that it did not reflect low-level differences between regular and irregular pairs. Further controls ruled out that the relative position of individual objects could explain the effect. Thus, pairs of objects that are arranged according to real-world regularities have a competitive advantage in gaining access to awareness. These findings suggest that long-term memory representations of the typical spatial configuration of objects in the environment shape the contents of conscious perception.

53.4055 Construction of and adaptation to 3D perspectives in the absence of awareness

Shinho Cho[1] (choxx305@umn.edu), Sheng He[1]; [1]Department of Psychology, University of Minnesota

The human visual system can construct the 3D perspective of an object based on simple 2D contours. This process is presumably an essential part of the visuomotor control that allows for appropriate interaction with object. Here we investigated whether the construction of 3D objects from 2D line drawings could occur in the absence of awareness. Observers adapted to a Necker cube rendered unambiguous with occlusion cue, and then were presented with an ambiguous Necker cube and reported the perceived perspective of the test cube. In each trial, the unambiguous adapting cube was presented monocularly for 2 seconds either alone (visible) or with Continuous Flash Suppression (CFS) noise in the other eye (invisible). Nor surprisingly, the visible unambiguous Necker cube induced a clear adaptation aftereffect in that observers were about 20% more likely to perceive the test Necker cube in the opposite perspective compared to the adapting cube. This adaptation aftereffect was very robust and was observed even when the test cube was different in size from the adapting cube, presented at different retinal location, or presented in the different eye. Interestingly, a perspective adaptation aftereffect was obtained even when the adapting cube was invisible, and the aftereffect from the invisible adapter could also be observed with different relative size of the cubes, but the aftereffect disappeared when test cube was presented at a different retinal location from the adapter. In contrast to the visible adapter, an invisible adapter induced a priming effect when the test cube was presented in the opposite eye. Results from this study suggest that the visual system can construct 3D perspective in the absence of awareness of the retinal image. These results are consistent with the observations, for example in blindsight patients, that appropriate visuomotor action could be executed independent of explicit visual awareness.

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53.4056 **Contextual processing modulates hemispheric differences in visual perceptual selection** Elise Piazza[1] (elise.piazza@gmail.com), Karen Wong[2], Michael Silver[2,3]; [1]Vision Science Graduate Program, University of California, Berkeley, [2]School of Optometry, University of California, Berkeley, [3]Helen Wills Neuroscience Institute, University of California, Berkeley

The right hemisphere processes low spatial frequencies (SFs) more efficiently than the left hemisphere, which preferentially processes high SFs. We employed binocular rivalry to determine how these hemispheric differences in spatial frequency processing influence visual perceptual selection from multiple SFs that are simultaneously present in the environment. Participants viewed a pair of rivalrous orthogonal gratings with different SFs, presented either to the left or right of central fixation, and they continuously reported which grating they perceived. At the onset of the rivalry pair, the low SF grating was perceptually selected (perceived) more often when it was presented in the left hemifield (right hemisphere) compared to the right hemifield (left hemisphere), whereas the high SF grating showed the opposite pattern of results. In a subsequent experiment, we found that this hemispheric asymmetry is based on relative, rather than absolute, frequency processing. For example, a medium SF grating, when rivaling with a high SF grating, was more likely to be perceptually selected when the rivalry pair was presented in the left, compared to the right, visual hemifield. However, this same medium SF grating, when it was paired in rivalry with a low SF grating, was more likely to be perceptually selected in the right, compared to the left, visual hemifield. Thus, the visual system's classification of a given SF as "low" or "high" (and therefore, which hemisphere preferentially processes that SF) depends on the other SFs that are present in the environment at any given time, demonstrating an influence of top-down, contextual processing on hemispheric differences in visual perceptual selection and conscious representations of space.

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53.4057 **Interocular grouping of negative afterimages after binocular rivalry** Min Bao[1] (baom@psych.ac.cn), Bo Dong[1]; [1]Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, Beijing, P.R. China

Afterimage (AI) formation is based on both retinal mechanisms and perception (Gilroy & Blake, 2005; Shimojo et al., 2001). Here we propose an amended view that AI can be formed independent of perception. Stimuli in each eye were a centrally presented 2 by 2 array of grating squares (1 cycle/deg). Each element subtended 3°. In one eye, gratings in two diagonal quadrants were vertical, while those in the other quadrants were horizontal. The orientations of the corresponding elements in the other eye were orthogonal. Complete interocular grouping might produce coherent percepts of single large vertical or horizontal gratings. While for incomplete grouping, one could perceive two types of partially integrated patterns. Otherwise, the monocular stimuli were perceived. Both during and after each induction period (55s), 10 subjects reported their percepts according to the 4 types. Surprisingly, although all types were perceived with close probability during induction (22.5% ~ 27.3%), subjects reported seeing the AIs of coherent patterns much more frequently (57.3%). Alternating presentation of the two inducers binocularly failed to reproduce this effect (N = 9). To ensure the observed effect was specific to AIs, we measured it with varied inducing contrasts [.04 .08 .16 .35 1]. For all the contrast conditions, the predominance for the coherent percepts was significantly higher ($N = 20$, $p < .01$) during the AI period (70.6%) than during the induction (< 38.6%). Because of micro eyemovements, AIs might be rendered blurry like low-pass filtered stimuli. So we filtered the inducers with a low-pass filter (< 0.5 cpd retained), but still observed similar effects (N = 16, coherent percepts: 74.5% (AIs) vs. < 41.9% (inducers)). These findings suggest that AI formation after binocular rivalry adaptation is strongly dominated by the mechanisms that favor coherent percepts, while during induction such effects could be largely corrected by monocular feed-forward signals.

53.4058 **Probing binocular rivalry: Suppressed-eye probes draw attention to the object in the suppressed-eye** Brian Metzger[1,2] (bmetzge2@illinois.edu), Xinhui Hu[1,2], Diane Beck[1,2]; [1]Psychology, University of Illinois, Urbana-Champaign, [2]Beckman Institute for Advanced Science and Technology

Binocular rivalry occurs when incompatible images are presented simultaneously but separately to each eye. Perceptual dominance reverses over time such that one image temporarily dominates perception, while the other image is suppressed. Prior research has shown that presenting brief probes to the suppressed eye can cause a rapid switch in perceptual dominance. Previously we have shown that these switches are likely mediated by a reallocation of attention to either the suppressed eye or the suppressed object (Metzger et al., VSS 2014). Here we ask whether the probe is drawing attention to the object or the eye by placing the probe either on or off the object. Rivalry was induced using oval-shaped faces and textures. Probes were presented with equal probability on top of, or outside of, suppressed or dominant objects. Eccentricity of the probe was matched across conditions. We replicate previous results showing that suppressed-eye probes accelerate reversals relative to dominant-eye probes; median dominance durations were 2034 ms. for suppressed-eye probes and 2445 ms. for dominant-eye probes. Critically, however, suppressed-eye probes presented on the object produce significantly faster reversals (median = 1866 ms.) than suppressed-eye probes presented off the object (median = 2197 ms.), suggesting that drawing attention to the suppressed object is more important than drawing attention to the suppressed eye. Coupled with our earlier data we conclude that reversals are more likely to occur (i.e. reversal rates increase) when suppressed-eye probes draw attention to the suppressed object.

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53.4059 **Inversion effect and hemifield asymmetry independently affect how faces break through interocular suppression** Jessica Goold[1] (jessica.e.goold.gr@dartmouth.edu), Ming Meng[1]; [1]Psychological and Brain Sciences, Dartmouth College

How the two hemispheres of the brain work together in order to create a conscious percept of the world is a fundamental question in neuroscience. It has been shown that the two hemispheres have different response functions to face stimuli (e.g., Rossion et al., 2000; Meng et al., 2012; Rangarajan et al., 2014). However, it is not clear whether lateralization of face-selective representations or different response functions to visual configurations underlie such hemispheric asymmetry. Inversion is known to impair the configural representation of faces (Yin, 1969) and lead to delayed break through times during interocular suppression of visual awareness (Jiang, Costello, & He, 2007). To investigate if the hemispheric asymmetry of face processing relies on conscious experience of configural representations, we designed an experiment using continuous flash suppression to examine breakthrough times of upright and inverted faces and houses at different positions in the visual field. Using a stereoscope, flashing Mondrian patches consisting of circles and squares were presented to the participants' dominant eye at ~10Hz while the stimuli were presented to the non-dominant eye. Upright faces reliably broke through suppression, replicating previous findings. More interestingly, faces presented to the right hemifield broke through suppression faster than faces in the left hemifield, independently of the inversion effect. For comparisons, no asymmetry was found between the top and bottom visual hemifields and no significant effects of inversion or hemifield were found for houses. These results suggest that the face inversion effect may occur at a preconscious level and independently of the lateralization of face-selectiveness, providing important clues for understanding how the brain is organized to process faces and how the two hemispheres may be specialized for visual representations.

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53.4060 **Consistent Individual Differences in Suppression Breaking Speed in Continuous Flash Suppression.** Asael Sklar[1] (Asaelsk@gmail.com), Ran Hassin[1,2,3]; [1]Psychology Department, The Hebrew University of Jerusalem, [2]Cognitive Science Department, The Hebrew University of Jerusalem, [3]Center for the Study of Rationality, The Hebrew University of Jerusalem

Identifying consistent individual differences in central constructs such as intelligence or working memory is one of the psychology's greatest contributions. Here, we report a new trait affecting the contents of our conscious-

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ness. In Experiment 1 fourteen participants were presented with emotional faces (sad, happy and neutral) in a breaking suppression Continuous Flash Suppression task (bCFS). Participants' suppression breaking speed (SBS) was strongly correlated between the different facial emotions (r=0.93, p< 0.001; r=0.96, p< 0.001; and r=0.94, p< 0.001; for happy-sad, happy-neutral and sad-neutral respectively). Importantly, there was also a strong correlation between the eyes, r=0.92, p< 0.001, indicating that eye-specific individual differences cannot account for the differences in SBS. In Experiment 2, twenty four participants first completed a categorization task in which they categorized stimuli as houses or faces, and then completed a bCFS task with stimuli from the same categories. In both tasks either houses or faces were more frequent (80% of trials), varied between participants. The correlation between frequent and infrequent stimuli's SBS was high, r=o.86, p< 0.001, and remained high when RTs to frequent and infrequent stimuli in the conscious categorization task were partialed out, $r_{partial}$=0.86, p< 0.001. In Experiment 3 we pushed the boundaries further, by examining whether individual differences in SBS are stable across time. Sixteen participants completed two bCFS tasks approximately fifteen minutes apart. SBS was highly correlated across time, r=0.82, p< 0.001, thus suggesting rare stability. SBS was highly stable in all experiments regardless of stimuli type, which eye was masked, participants' expectations, time, and a statistical control for average RT. We therefore conclude that SBS is a stable individual trait that affects one of the most important determinants of human behavior: our consciousness.

53.4061 **Absolute pitch impacts visual awareness of musical scores accompanied by auditory melodies during binocular rivalry** Sujin Kim[1] (preikestolen89@gmail.com), Minyoung Lee[1], Chai-Youn Kim[1]; [1]Department of Psychology, Korea University

Individuals with absolute pitch (AP) are able to identify or reproduce a given musical note without the benefit of a reference tone (Deutsch, 2013). They tend to utilize AP when matching visually presented musical scores with auditorily presented melodies, showing poor performance in recognizing a shifted tone in a transposed melody (Miyazaki and Rakowski, 2002). A previous work in our group showed that congruency between visual musical scores and auditory melodies modulated visual awareness of the musical scores during binocular rivalry (Lee et al., VSS 2014). In the present study, we further investigated whether visual awareness of musical scores accompanied by auditory transposed melodies is distinguishable from that of congruent audiovisual information for individuals with AP. Participants with the ability of reading musical scores were divided into two groups depending on the possession of AP. A sinusoidal vertical grating and one of six musical scores moving in the opposite directions were presented dichoptically. Each musical score was accompanied by congruent, incongruent, or congruent-transposed melody. Transposed melodies were either a semitone lower or higher than the noted melody. Participants tracked their rivalry perception by depressing one of two keys. Results replicated our previous work in that a visually presented musical score predominated over a competing rival stimulus when the melody congruent to that score is accompanied. However, only the AP group showed the difference in predominance of scores between the congruent and the congruent-transposed conditions. Specifically, a visual score tended to predominate less when accompanied by transposed auditory melody than when accompanied by congruent melody. The degree of reduced score predominance in the transposed condition didn't reach that in the incongruent condition. These results suggest that individuals with AP are sensitive to a slight offset of an auditory melody from visual musical scores, which impacts perceptual dynamics during binocular rivalry.

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53.4062 **Emotion Perception is Valence-Dependent during Binocular Rivalry** Nour Malek[1] (nour.malek@mail.mcgill.ca), Andy Gao[1], Daniel Messinger[2], Ridha Joober[3], Karim Tabbane[3], Julio Martinez-Trujillo[1]; [1]Cognitive Neurophysiology Laboratory, Department of Physiology, McGill University, Montreal, QC, CA, [2]Departments of Psychology, Pediatrics, and Electrical and Computer Engineering, University of Miami, Coral Gables, FL, USA, [3]Douglas Hospital Research Centre, Montreal, QC, CA

The perceptual strength of a facial expression is widely shaped by context. Binocular rivalry (BR) has proven to be a promising tool in studying face perception. It involves the alternation between two stimuli that are simultaneously, but monocularly, presented. BR is postulated to occur due to inhibitory interactions between neuronal populations tuned for the presented stimuli. Therefore, BR provides a reflection of perceptual strength, whereby shorter stimulus perception (dominance duration) signifies greater inhibition and weaker tuning. We previously demonstrated that, while there may be an interaction between the identity and emotion portrayed by face stimuli during BR, emotion has a stronger influence and thus holds greater perceptual strength. Moreover, positive emotions tend to dominate over negative ones. To assess whether perceptual strength is also dependent on the intensity of an emotion (valence), 3D natural-looking face identities of similar skin tone and gender were created in FaceGen Modeller to express five emotions (very happy, happy, neutral, sad, and very sad) and were set to rival as 29 human subjects reported which stimulus they perceived throughout a trial. Prior BR studies that investigated valence-dependence were confounded by stimuli discrepancies that highlight certain local facial features over others. Here, extreme emotions were portrayed through the use of Duchenne eye constrictions, which permitted control over feature-salience across stimuli. Subjects reported that extreme emotions were perceived for significantly greater dominance durations than basic ones (p < 7.91x10-7, Kolmogorov-Smirnov [KS]). Furthermore, when the same stimuli were inverted and rivaled, all dominance durations were rendered insignificantly different from one another (p > 0.11, KS). This verifies that the observed significance using Duchenne characteristics was not driven by the local feature—eye wrinkles, but rather by the global emotion portrayed. Overall, the more intense an emotion, the greater its perceptual strength and possibly the higher its processing priority during BR.

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Attention: Selection and modulation

Tuesday, May 19, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.4063 **Receptive field complexity in primate prefrontal cortex area 8A varies as a function of neuronal type** Kelly Bullock[1] (kelly.bullock@mail.mcgill.ca), Florian Pieper[2], Adam Sachs[3], Julio Martinez-Trujillo[4]; [1]Department of Physiology, McGill University, Montreal, Canada, [2]Institute for Neuro- & Pathophysiology, University Medical Center Hamberg-Eppendorf (UKE),Hamburg, Germany, [3]Department of Surgery, University of Ottowa, The Ottowa Hospital Research Institute, Ottowa, Canada, [4]Department of Physiology and Pharmacology, Western University, London, Canada

The prefrontal cortex, particularly the dorsolateral area 8A, is thought to play a role in transforming visual signals into goal-directed behavior. Neurons within this area exhibit visual, motor, and visuomotor responses during oculomotor tasks. We have recently described two types of neurons within the area that have receptive fields (RFs) located in the contralateral and ipsilateral visual hemifields relative to the recorded hemisphere. Whether these neurons show variation in the complexity of their RF remains unclear. Here we recoded the responses of 81 neurons in area 8A of a Macaca fascicularis while the animal made visually-guided saccades to a peripheral sine-wave grating stimulus positioned at one of 40 possible locations (8 equidistant directions arranged along 5 concentric circles). To characterize the visual and motor RFs, we integrated the average firing rate at each location over a 200-millisecond time window during stimulus presentation (visual field) and prior to saccade onset (motor field). 28 percent of neurons showed visual and motor responses. 48 neurons had contralateral-preferring and 27 ipsilateral-preferring visual receptive fields. We observed that visual and motor field size ranged from narrow, directed 'hotspots' to large, diffuse spots spanning both hemifields. Furthermore, we found that a higher proportion of contralateral cells exhibited very small or no shift from visual to motor field center, while ipsilateral cells often displayed greater disparity between their motor and visual field centers. Finally, comparison of the number of peaks in the RFs of ipsilateral and contralateral neurons revealed that motor fields of ipsilateral neurons had more peaks than those of contralateral neurons (p< 0.05, Wilcoxon rank-sum). These findings show that ipsilateral neurons have more complex motor field properties compared to contralateral ones, implying different roles for these neuronal types in the transformation of visual information into gaze commands within area 8A.

53.4064 **Sustained spatial attention excludes external noise and narrows the perceptual template** Yukai Zhao[1] (yukai.zhao@usc.edu), Zhong-Lin Lu[2], Barbara Dosher[3]; [1]Neuroscience Graduate Program, University of Southern California, CA 90089, USA, [2]Laboratory of Brain Processes (LOBES), Department of Psychology, the Ohio State University, [3]Memory, Attention and Perception Laboratory (MAPL), Department of Cognitive Sciences and Institute of Mathematical Behavioral Sciences, University of California, Irvine

The mechanism of attention is one of the central topics in psychology, neurophysiology, and functional imaging. However, neurophysiology experiments often require an animal to maintain attention to one location (sustained attention1), while human behavioral studies often direct subjects to attend to different locations in every trial (transient attention2). It has been difficult to integrate the two levels of investigation. To facilitate integration, we conducted a human behavioral study3 based on a paradigm in a neurophysiology experiment1. Four synchronized RSVP streams of Gabors were presented in each trial. Each stream consisted of 10 distractors, all oriented at 45˚ clockwise, and one potential target, either +11˚ or -11˚ from 45˚, that occurred between the 3rd and the 9th temporal positions simultaneously. Subjects were instructed to maintain fixation (monitored by an eye-tracker) and attend to one location in each block of 70 trials. A central report cue, presented 150 ms after target presentation and consistent with the block cue 62.5% of the time, directed subjects to report the orientation of the target in the cued location. In the invalid condition, the report cue pointed to one of the other three locations with equal probability. Full psychometric functions were measured at 4-5 external noise levels. Block cuing improved performance in high external noise conditions for three out of four subjects and increased asymptotic performance across all noise levels in one of them. The other subject showed only increased asymptotic performance. The data were fit with the elaborated perceptual template model4 ($r2=0.9529$). On average, sustained attention excluded 17% of external noise, and narrowed the perceptual template by 16%, but did not enhance the stimulus. The results are consist with behavioral studies on transient attention2,5. (1.Cohen & Maunsell, 2009; 2. Dosher & Lu, 2000; 3. Zhao et.al., 2013; 4. Jeon et.al., 2009; 5. Hetley et.al., 2014)

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53.4065 Generalizability of implicit spatial learning depends on task difficulty

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Implicit learning allows humans to exploit visual regularities without explicit awareness. For such a mechanism to provide maximal utility, it should be neither too stimulus-specific nor over-generalized. Some previous studies report task-general learning, while others report task-specific learning, and it is unknown why these results differ. What determines the generalizability of implicit spatial learning? Here, we manipulated task difficulty as a novel test of this question. We employed a probability cueing manipulation, in which search targets are more frequently presented in one "rich" quadrant of the display than in the remaining "sparse" quadrants. Previous work has shown observers to gradually bias their spatial attention toward the rich quadrant, yielding faster responses to targets in that quadrant. In this study, during an initial training phase, easy and difficult visual search trials were intermixed, and each had their own rich quadrant. Specifically, targets appeared more often in one quadrant on easy trials ("easy rich quadrant") and in another quadrant on difficult trials ("difficult rich quadrant"). During the test phase, we transferred the observers to an intermediate difficulty search task, in which targets appeared equally frequently in each quadrant. We found the bias toward the easy rich quadrant not only on easy trials but also on difficult trials, whereas the bias toward the difficult rich quadrant appeared only on difficult trials. Moreover, the bias toward the easy rich quadrant – but not the difficult rich quadrant – generalized to the intermediate difficulty trials during test. Further experiments showed that the failure to generalize from the difficult task was not due to either weak probability cueing (Experiment 2) or interference between the two simultaneous rich quadrants (Experiment 3). These findings accord well with learning theories that predict asymmetric generalization based on task difficulty and extend those theories to the domain of implicit spatial learning.

53.4066 Univariate frontoparietal BOLD does not track the magnitude of attentional modulations in visual cortex

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Directing attention to a region of visual space facilitates the processing of relevant sensory information, resulting in increased neural and BOLD activity in areas of the brain that process this sensory information. This process is thought to be mediated by a frontoparietal "attentional control" network that biases processing in visual cortex. Electrical microstimulation of frontal area FEF in macaques selectively enhances responses in area V4, and also leads to improved behavior (Moore, Fallah 2001, 2004; Armstrong, Moore 2007). If frontoparietal regions such as the FEF are responsible for the differential modulations in early visual cortex across time, then the magnitude of frontoparietal activity should track the magnitude of attentional modulations in early visual cortex on a trial-by-trial basis. Here, we attempted to test this hypothesis using fMRI. Participants directed spatial attention to either the left or right visual field on each trial while performing a demanding spatial attention task. Consistent with previous data, we found that frontoparietal responses were high when early visual responses were high across trials (i.e. an overall yoking between frontoparietal and occipital regions). In addition, visual areas in the hemisphere contralateral to the attended stimulus showed reliably larger BOLD responses compared to areas in the ipsilateral hemisphere. We compared the magnitude of frontoparietal activity and the differential activity in visual areas contra and ipsilateral to the attended stimulus. However, we found no evidence that the overall magnitude of responses in frontoparietal regions track the magnitude of differential attentional responses in early visual cortex. These findings indicate that the univariate magnitude in frontoparietal ROIs is not related to the magnitude of attention effects in visual cortex, at least as measured with the BOLD signal.

53.4067 Attentional Orienting Expectations Broaden and Constrain the Window of Spatial Selection

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Individuals adjust preparatory attentional control settings according to environmental statistical regularities such that the behavioral cost in response time associated with shifting attention is reduced when shifting is likely (Sali, Anderson, & Yantis, under review). This learned flexibility may reflect a readiness to update the spatial locus of attention. Alternatively, the spread of attention may be variable such that when a shift of attention is anticipated, the region of space encompassed by attentional selection broadens. We, therefore, investigated whether the breadth of selection varied based on block-by-block changes in the likelihood of shifting attention. Participants held and shifted attention between two rapid serial visual presentation (RSVP) streams of alphanumeric characters in response to visual cues and made speeded parity judgments for target stimuli appearing in the cued stream. Three distractor streams flanked each of the two task-relevant streams. We manipulated the frequency of attention shift and hold cues across blocks of 40 trials each. To test whether these changes in cue frequency modulated the breadth of attentional selection, we varied the response congruency of stimuli appearing in the three distractor RSVP streams surrounding the to-be-attended location. Consistent with previous studies, the behavioral cost in RT associated with shifting attention was smallest for blocks in which shifting was most frequent. When examining shift trials alone, there was a significant interaction of block type and flanker congruency. Participants were slower for incongruent shift trials than for congruent shift trials only in blocks with frequent shift cues. A similar trend existed such that the congruency effect for hold trials was larger when holding was frequent. Our results suggest that increased likelihood of shifting attention is associated with increases in the breadth of attentional selection to include the to-be-attended spatial location, not simply a faster shift at the time of the cue.

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53.4068 Predictive spatial cues reduce competition between items in crowded visual displays: Evidence from ERPs

Joel Robitaille[1] (jrobitaille089@gmail.com), Holly Lockhart[1], Stephen Emrich[1]; [1]Department of Psychology, Brock University

Findings from a recent EEG study by Anderson et al. (2014) support the idea that crowded visual displays prevent individuation of a target and results in the substitution of features from the distractors during target processing. An alternative explanation for this phenomenon, also known as binding errors, suggests that this misattribution may be the result of active competition between the items during encoding. In order to test this possibility, the introduction of a spatial cue may alleviate the active competition present between target and nearby distractors. In the present study, we replicated part of Anderson et al. (2014), but introduced a predictive spatial cue. Participants were required to report the orientation of a radial target among diametrical distractors presented in the periphery. Performance was compared between trials with far or near flankers as well as with the presence of either a single predictive cue or three non-predictive spatial cues. Preliminary behavioural results show an overall decrease in target accuracy in the trials during which the single spatial cue is presented, supporting the idea that competition can be reduced by a predictive attentional cue. ERP results revealed two effects: First, the N2pc was evident only in the near flanker condition when the cue was absent, suggesting that spatial cues alleviated the competition between targets and flankers. Second, the uncued conditions produced a greater amplitude

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in the lateralized P1 component relative to the cued conditions, possibly suggesting that this competition may be resolved in early sensory processing. The results suggest a potential mechanism by which attentional biases can reduce competition between targets and distractors during encoding.

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53.4069 Space Depends On Time: Informational Asymmetries in Visual and Auditory Short-Term Memory

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Sensory modalities vary in adeptness for spatial and temporal information domains (Welch & Warren, 1980). Recent work suggests that attention and short-term memory (STM) recruit this variability (Michalka et al., submitted). Here, we investigate the relationships among visual and auditory modalities, and spatial and temporal STM. We developed stimuli comprising short sequences of visual events (instantaneous image changes) or auditory events (50ms complex tones). Each event within a sequence had a unique spatial location and a unique inter-event interval. These stimuli were used in a STM change-detection task. On each trial, two successive sequences were presented; a change could occur among the locations, the intervals, both, or neither. Subjects attended to either space (the sequence of locations), or time (the sequence of inter-event intervals), and reported whether the patterns of locations or intervals were identical. Each subject completed blocks of unimodal (both sequences presented in the same modality) and crossmodal (sequence 1 visual and sequence 2 auditory, or vice versa) trials for both tasks. We found a strong modality appropriateness effect, with best temporal performance on unimodal auditory trials, and best spatial performance on unimodal visual trials. The order of modalities on crossmodal trials mattered for space (benefit for visual sequence 1) but not for time, supporting a domain recruitment account of spatial STM. We also investigated cross-domain interactions by measuring whether instability of spatial location affected change detection for intervals, or vice versa. Changes in timing from sequence 1 to sequence 2 substantially impaired change detection for locations, while changes in locations did not impair change detection for intervals. These results suggest that spatial and temporal STM are asymmetrically related, such that timing information facilitates monitoring a series of locations, but spatial knowledge is unnecessary when monitoring a series of intervals.

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53.4070 Modulation of intracranial field potential responses in the human large-scale attention network during a spatial attention task

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Spatial attention is mediated through a large-scale network that includes occipital, temporal, parietal and frontal cortical regions. While the network architecture has been well characterized using neuroimaging methods, less is known about the temporal dynamics in local regions and across the network. Here, we explored the modulatory effects of spatial attention throughout this cortical network by analyzing intracranial field potentials recorded from 538 ECoG electrodes implanted in 6 epilepsy patients. We examined the effects of attention using a variant of the Eriksen flanker task, where subjects were cued by an exogenous stimulus to the spatial location of an upcoming target stimulus which, after a variable delay period, was presented embedded in a circular array of shapes. Subjects had to differentiate between barrel or bowtie target stimuli flanked either by congruent or incongruent shapes. Using our probabilistic atlas of the human visual system, we localized the recorded ECoG signals to topographically organized brain areas and linked them to functional brain imaging data from normal subjects. We found spatially constrained visual response fields in 175 electrodes, as indicated by differential cue-related activity, obtained from both induced broadband power and evoked potentials. We examined response modulation from those electrodes during the delay period of the task when subjects either attended to or away from the response field. Further, we related these results to changes in the BOLD signal measured in normal subjects performing the same task. We found that covert spatial attention affected evoked event-related potentials and induced low frequency (4-20Hz) and broadband high gamma (50-200Hz) power differentially along the dorsal pathway through nodes of the fronto-parietal attention network, from V1 through intraparietal sulcus areas IPS0-IPS5 and the frontal eye fields.

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53.4071 Overt Retrospective Cues Elicit Location Specific Enhancement of Visual Working Memory

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Prior studies have shown that retrospective cues presented following the offset of an initial stimulus prevent degradation of items stored in visual working memory (VWM). Whether this protective effect occurs following overt rather than covert attentional shifts remains unknown. In the present study, we examined the effect of memory facilitation for two retrospective cue types; location cues (memory tested with target stimulus at an initially presented location) and saccade cues (revisiting the location of the initial stimulus through an overt attentional shift – a saccadic eye movement). Subjects performed a change-detection task involving an array of four peripherally presented geometric shapes, and either fixated centrally or made a saccade before memory was tested for a single target shape presented centrally or peripherally. Accuracy for change detection was recorded and subsequently converted to sensitivity scores and response criterion. Our results indicated a significant enhancement in both detection sensitivity and response times when the memory target occurred in the periphery and participants made a saccade to that same location. Task performance was reduced if no saccade was made or if the target was presented centrally. Interestingly, participants shifted from a conservative criterion when the memory target location matched the eye position to a liberal criterion when target position did not match the eye position. Taken together, our results suggest that making saccade eye movements to the location of a prior stimulus can produce a location specific facilitation of VWM and modulation of response criterion.

53.4072 High response conflict devaluates attractivenes

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We investigated whether strategies acquired in response to conflict frequency affect aesthetic evaluation of task-irrelevant stimuli, by employing a flanker task in which participants identified a target letter (“N” or “Z”) among flanker letters presented to the left or right side of the visual field. The target was flanked by two congruent (e.g., “NNNNN”) or incongruent (e.g., “ZZNZZ”) flankers on either side of the target; conflict frequency was manipulated in each visual field. The probability of trial congruency was higher in the low-conflict visual field; trial incongruency probability was higher in the high-conflict visual field. Aesthetic evaluation trials were inserted in parallel during every 16th flanker task trial, during which a pair of attractiveness-matched faces appeared side-by-side; participants decided which side of each face was more attractive (or unattractive, depending on the instruction). The flanker effect, in which reaction times for incongruent trials were longer than they were for congruent trials, was modulated by conflict frequency in each visual field. Specifically, the flanker effect in the low conflict visual field was greater than in the high conflict visual field. Furthermore, participants indicated that faces presented in the low conflict visual field were more attractive than were those presented in the high conflict visual field relative to their counterpart. A similar pattern of results was obtained during an aesthetic judgment task of meaningless patterns: block-wise conflict adaptation affected apparently task-irrelevant aesthetic judgments, as well as extent of cognitive control of conflicting responses, such that the aesthetic value of stimuli presented at spatial locations containing high response conflicts was reduced.

53.4073 Rapid parallel allocation of attention to multiple objects

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Serial models of visual search postulate a unitary focus of spatial attention that moves sequentially between candidate target objects at different locations. This implies that the allocation of attention to a new object will be preceded by the de-allocation of attention from its previous location. In contrast, alternative parallel models assume that focal attention can operate simultaneously at multiple target locations. In recent ERP stud-

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ies, we employed the N2pc component as an on-line electrophysiological marker of attentional target selection to show that when two colour-defined target objects appear at different locations in rapid succession (with stimulus onset asynchronies between 10 and 100 ms), two parallel foci of attention are established, each with its independent time course (Eimer & Grubert, 2014; Grubert & Eimer, 2014). We will discuss this recent evidence for rapid parallel allocation of attention to multiple objects, and present new findings from a series of studies that explored the nature of this fast and flexible attentional control mechanism. These new results demonstrate that rapid parallel selection is not restricted to conditions where two colour-defined targets are presented sequentially. Multiple parallel attentional foci are also activated when two targets are presented simultaneously, when target objects are defined by other feature dimensions than colour, and even in search tasks where more than two targets are presented in rapid succession at different locations. We also show that attentional control processes are sensitive to temporal sequence information that is inaccessible to conscious report. These findings demonstrate the dynamic nature and flexibility of attentional selectivity in time and space.

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53.4074 **The Attentional "Zoom-Lens" is Already Developed in 8-Month-Old Infants**

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The spatial attention mechanisms of orienting and zooming collaborate to properly select relevant visual information from a noisy environment and plan eyes movements. Despite the orienting ability has been extensively studied in infancy, the zooming mechanism –i.e. the ability to distribute the attentional resources to a small or large portion of the visual field – has never been tested before. The aim of the present study was to evaluate the attentional zooming abilities in 8-month-old infants. Saccadic latencies (SLs) were measured at the onset of a visual target displayed at two eccentricities. The size of the more eccentric target was adjusted in order to counteract the effect of cortical magnification. Before the target display, attentional resources were automatically focused (zoom-in) or spread (zoom-out) by using a small or large cue, respectively. Two different cue-target intervals were also employed to measure the time-course of this attentional mechanism. Results showed that infants' SLs varied as a function of the cue size presenting a clear time-course. Our results demonstrated that infants can rapidly adjust the attentional focus size during a pre-saccadic temporal window. These findings are extremely important to understand the developing cognition and could result in being an early marker for neurodevelopmental disorders associated with attentional zooming dysfunction, such as autism and dyslexia.

53.4075 **Attention immaturity in late adolescence: Conflict adaptation with value associated stimuli**

Daniel Dodgson[1] (dbd337@bham.ac.uk), Jane Raymond[1]; [1]School of Psychology, University of Birmingham

Speeded responding to targets in the presence of flanking distractors is slower when targets and distractors activate incongruent versus congruent responses. This slowing can be reduced when the preceding trial is also incongruent, an effect called conflict adaptation (CA). CA indexes a transient modification of attention selection strategy based on immediate prior experience. It is large when cognitive control is reactive to current events and smaller when control is tightly goal-driven (proactive), despite changing stimulus demands. Here, we measured CA in adolescents (~17 yrs) and adults (~29 yrs) to investigate late childhood development of cognitive control. Considering that cognitive control is thought to be more reactive than proactive in teens, we predicted larger CA in this group. Teens are also thought to be hyper-reactive to reward associations, suggesting that reward associated incongruent distractors should be highly distracting for this group even when CA is used to limit distractor effects. To investigate, we had all participants (adults and teens) undergo value association learning (wherein abstract symbols reliably predicted monetary wins, losses or nothing) and then used the value-associated stimuli in a conventional flanker task to measure CA. When distractors were associated with neither winning nor losing money, CA was significantly ($p < .05$) larger for adolescents than for adults (and was observed for both groups). For adults, value-associated distractors had no effect on the magnitude of CA, whereas for adolescents, large distractor interference (slowing) was evident when flankers were win or loss associated. This slowing was unaffected by response conflict in the previous trial (causing CA effects to collapse). These results show that the motivational salience of current stimuli and the consequences of recently experienced stimuli are especially effective at rapidly influencing attention in teenagers. These data support the wider view that cognitive control is still developing in late childhood.

Acknowledgement: ESRC UK

53.4076 **Correlation between the effects of attention and response normalization in prefrontal area 8A neurons is cell type dependent.**

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Many visual neurons lower their response rates to a stimulus in the receptive field when other stimuli are added inside or outside their receptive field. This phenomenon has been proposed to be the result of a canonical normalization mechanism that acts across multiple brain areas and has been reported to correlate with visual attentional response modulation in extrastriate visual neurons. We recorded neural activity in prefrontal area 8A, an area associated with selective visual attention, of two macaca fascicularis using chronically implanted multielectrode arrays during two task conditions. In one condition, the animals were presented with four identical grating stimuli, each positioned in one quadrant of the visual field while fixating on a central dot. In the second condition, one grating was initially presented followed by the onset of the remaining three stimuli. The position of the first grating (the target) varied between trials. Animals had to make a saccade to the target when that grating changed orientation. The majority of our visually-tuned single units showed a lower response when four stimuli were presented relative to the sum of individual responses to each single stimulus (mean normalization index = 0.72). These units also showed a strong attentional modulation (mean attentional index = 0.41). Importantly, units with stronger normalization showed the strongest attentional modulation ($r=0.19$; $p< 0.05$). We further classified attention-tuned units depending on the hemifield which showed the strongest visual response relative to the recording site. Ipsilateral neurons showed negative correlations between normalization and attention when the animals switched attention whereas contralateral neurons showed positive correlations. Finally, spike-count correlations were higher between ipsilateral than between contralateral neurons. These results demonstrate that in PFC circuitry, normalization and attention are linked, and that neurons here may perform different computations during attention allocation depending on their spatial tuning.

53.4077 **Feature binding and eye movements: Object identity is bound to retinotopic location regardless of stimulus complexity**

Anna Shafer-Skelton[1,2] (annashaferskelton@gmail.com), Colin Kupitz[1,2], Adeel Tausif[1,2], Julie Golomb[1,2]; [1]Department of Psychology, The Ohio State University, [2]Center for Cognitive and Brain Sciences, The Ohio State University

Despite frequent eye movements that rapidly shift the locations of objects on our retinas, our visual system creates a stable perception of the world. To do this, it must convert eye-centered (retinotopic) input to world-centered (spatiotopic) percepts. Intuitively, the most stable way for objects to be incorporated into these percepts is for their features to be bound directly to spatiotopic locations. We might expect that low-level features are bound to retinotopic locations, but what about features of more complex stimuli? Recently, Golomb et al. (2014 JEP:G) showed that object location is not only automatically attended but fundamentally bound to identity representations. The "spatial congruency bias" reveals that even when location is irrelevant to the task, two shapes are more likely to be judged as the same when they are presented in the same location. Importantly, this bias is exclusively driven by location. Here, we tested the coordinate system of the bias across eye movements for two different types of complex stimuli (novel objects in one experiment, faces in another). On each trial, subjects saw two stimuli and had to judge whether they were the same or different identity. The second stimulus could appear in the same screen location as the first ("spatiotopic location"), the same location relative to fixation ("retinotopic location"), or one of two control locations. For both shapes and faces, participants were more likely to judge identity as the same if stimuli were presented in the same retinotopic location, but not if they were presented in the same spatiotopic location. These results suggest that object identity is still bound to retinotopic location after an eye movement, even for complex stimuli. These findings carry important implications for feature binding and remapping across eye movements.

53.4078 **The spatio-temporal distribution of attention within a face during identification** Wei Chen[1,2] (emmachen_219@163.com), Carl Gaspar[1,2]; [1]Center for Cognition and Brain Disorders, Hangzhou Normal University, China, [2]Zhejiang Key Laboratory for Research in Assessment of Cognitive Impairments

Whole objects, like faces, can strongly attract visual attention. However, little is known about how spatial attention is distributed across the face. During 10AFC identification, we presented a small probe pattern at random locations 106ms after each target-face display. Probe patterns were small squares consisting of high-contrast black and white strips. On the premise that detection speed for probes is enhanced by local attention on the face, probe reaction times should reveal how attention is distributed across the face, in both space and time. We used 3 target-face durations. Face identification accuracy, above-chance for the lowest duration, improved with duration for all 4 subjects. The main data are maps of speed, 1/log(RT), across 3 face durations, for 4 subjects. Each map is based on 60 locations, arranged in an elliptical fashion around fixation (the average center of contrast energy across all faces). Using bootstrap percentile tests, we identified probe locations whose speed was significantly above the spatio-temporal average; these locations show us where attention is. At 12ms, attention is weak and spatially uniform; while at 106ms and 200ms, attention is biased to bottom and right parts of the face from the viewers' perspective. Our results seem surprising given that eye movements (Butler et al, 2005; Peterson & Eckstein, 2012) and classification images (Sekuler et al, 2004) suggest biases toward the top and left. However, the distribution of attention across the face does not necessarily have to match the distribution of extracted information, or fixations. For example, attention might be required to use weak information, less visible regions of the face, or to plan the next fixation. We are currently exploring these possibilities.

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Attention: Search and features

Tuesday, May 19, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.4079 **Effects of perceptual load in visual search in immersive virtual reality** Bettina Olk[1] (b.olk@jacobs-university.de), David Zielinski[2], Regis Kopper[2]; [1]Jacobs University Bremen, [2]Duke University

Research using computerized displays of simple stimuli has identified perceptual load as a critical factor for modulating distraction. Distraction is stronger when perceptual load is low than when it is high. Typically, participants determine which of two targets, e.g., letters, is present in a search array composed of other letters and perceptual load of the displays is varied. In the present experiment we made contact with the literature but increased ecological validity by assessing distraction in immersive Virtual Reality (VR), in which life-sized stimuli can be displayed in realistic settings, without losing the advantage of controlling conditions. Participants searched for a target (soda or yoghurt) among other daily objects on the countertop in a virtual kitchen. The search array was accompanied by a congruent or incongruent flanker. Perceptual load was manipulated. As expected, participants responded slower with incongruent flankers (flanker effect) and with high load (load effect), confirming that our materials and set up in the VR environment were suitable to elicit the basic effects. Contrary to our expectations based on the load theory of attention the flanker effect was not modulated by load. This finding may suggest that perceptual load may play a smaller role in attention and search in everyday situations than one would assume based on previous work. Obviously, virtual scenarios are more complex than the stimuli used and the conditions run in previous studies. Further, it is possible that daily, very familiar objects may be harder to ignore or be prioritized for processing also under high perceptual load. We discuss factors that may dilute or negate effects of perceptual load in a more ecologically valid situation and outline suggestions for further research. We suggest that VR offers an exciting interdisciplinary approach that may challenge our beliefs based on traditional laboratory research.

Acknowledgement: German Academic Exchange Service DAAD

53.4080 **Working Memory Deficits in Dynamic Sport Athletes with a History of Concussion Revealed by A Visual-Auditory Dual-Task Paradigm** Anthony Tapper[1] (atapper@uwaterloo.ca), Ewa Niechwiej-Szwedo[1], David Gonzalez[1], Eric Roy[1]; [1]Department of Kinesiology, University of Waterloo

Processing and integrating multiple sensory inputs simultaneously plays a vital role in an athlete's ability to plan and execute appropriate actions in dynamic environments. Previous research has shown that concussions affect an athlete's processing capacity and ability to process multiple sensory inputs simultaneously. Few studies to date have considered the impact of previous concussions on information processing of visual and auditory input. It is important to understand information processing capacity in dynamic sports because athletes must divide their attention between visual and auditory stimuli and hold that information in memory to guide actions. We developed a study to examine processing capacity by using a visuospatial working memory test to exhaust attentional resources. We hypothesize that athletes with a history of concussion will have more difficulty allocating attentional resources to each task and thus, will perform significantly worse on a visual-auditory test. Participants were varsity hockey players (n=28; 15 females) 17 of whom had suffered at least one concussion. They completed 2 tasks: a visual working memory task (Corsi block test [CBT]) and an auditory task (tone discrimination). The computerized CBT was an 8-target serial recall test that involved encoding and recalling the location of targets in the order of presentation. The auditory task involved discriminating high (1000 Hz) and low (375 Hz) tones using a computer mouse. Each task was completed individually and then simultaneously with primary focus on the visual task. The main dependent measure was the auditory task cost associated with the dual-task performance. We found that auditory cost was significantly higher in participants with a history of concussion. These results indicate that athletes with a history of concussion have more difficulty with processing multiple sensory inputs simultaneously. This evidence suggests that a history of concussion may produce long-term effects that make an athlete susceptible to further injury.

Acknowledgement: Propel Centre for Population Health Impact (University of Waterloo)

53.4081 **Acute aerobic exercise modulates feature selectivity in human visual cortex** Tom Bullock[1,2] (bullock@psych.ucsb.edu), James Elliott[1,2], John Serences[3,4], Barry Giesbrecht[1,2]; [1]Department of Psychological and Brain Sciences, University of California, Santa Barbara, [2]Institute for Collaborative Biotechnologies, University of California, Santa Barbara, [3]Department of Psychology, University of California, San Diego, [4]Neuroscience Graduate Program, University of California, San Diego

Multiple cognitive functions can be modulated by acute bouts of aerobic physical exercise (Chang et al. 2012). Behavioral changes during exercise are likely accompanied by fluctuations in patterns of neural activity, but a comprehensive understanding of these effects remains elusive. For example, it is unclear whether exercise induced changes in cognition reflect non-specific effects on task performance, or whether they are specific to the task that is being performed while engaged in physical activity. We investigated this issue by testing whether acute exercise causes an additive, non-specific shift in feature-based attentional selectivity, or if it causes a multiplicative gain in selectivity. We used electroencephalography (EEG, 64 electrodes) and a gaze-contingent task that enabled orientation-selective profiles to be estimated from steady-state evoked potential (SSVEP) responses (Garcia, Srinivasan & Serences, 2013). For each trial, participants (n=3) fixated at the center of a flickering (15 Hz) circular grating presented at one of nine different orientations and monitored for a brief duration clockwise or counter-clockwise shift, and then indicated the direction of the shift at the end of the trial. Participants completed the task at rest while seated on a stationary exercise bike (mean heart rate (HR) = 68 BPM), during low intensity cycling exercise (mean HR = 103.3 BPM, mean rating of perceived exertion (RPE) = 8) and during high intensity cycling exercise (mean HR = 151.7, mean RPE = 13). The feature-selective response functions estimated from the EEG data revealed enhanced peak amplitude during low intensity (mean = .41 μV, SEM = .04 μV), and high intensity exercise (mean = .42, SEM = .05 μV) when compared to rest (mean = .29 μV, SEM = .04 μV). These findings suggest that acute bouts of aerobic exercise modulate visual cortical responses and that these modulations can be manifested as a multiplicative gain on estimated feature-selective response profiles.

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53.4082 **Implied action affordance facilitates visual search** Michael Gomez[1] (michaelgomez@unr.edu), Jacqueline Snow[1]; [1]Department of Psychology, University of Nevada, Reno

Tuesday AM

Although numerous studies have explored the influence of object affordances on perception, it is usually the case that only one or two items are depicted and the affordance-related stimuli differ markedly from low-affordance exemplars. Here we examined whether visual search for stimuli that imply action is superior to non-affordance-related images using more cluttered visual arrays where the stimuli are closely matched for color, luminance, and contrast. The search displays contained greyscale objects that implied action, or 'reconfigured' versions of the same stimuli that did not imply action. Search performance was examined in Experiment 1 using door levers, and in Experiment 2 using forks. Reconfigured stimuli were created by digitally rotating one component of the functional end of the object (i.e., the door lever fulcrum / fork prongs) into a spatial configuration that interfered with implied functionality. The stimuli were presented briefly in a 2 x 2 grid. In half of the trials, the stimuli were identical (target absent trials); in the remaining trials one item (the target) was presented with the handle in a reversed left/right orientation from the remaining 'distractors' (target present trials) in the grid. Right-handed observers were asked to make a speeded target present / absent decision. In Experiment 1, intact door lever targets were detected faster than their reconfigured counterparts. In Experiment 2, target detection accuracy was more accurate for intact fork targets than their reconfigured counterparts. In both experiments, observers were faster to detect oddball targets in which the 'functional' or 'reconfigured' end was oriented towards the right than the left, and this effect was strongest for intact over reconfigured stimulus arrays. Taken together, our findings demonstrate that target search is facilitated for objects that imply action than those that do not, and that search is most efficient when an object's functional end is rightward-oriented.

53.4083 Visual foraging with fingers and with eyes reveals challenges for current theories of visual attention Árni Kristjansson[1] (ak@hi.is), Ómar Jóhannesson[1], Andrey Chetverikov[2], Irene Smith[1], Ian Thornton[3]; [1]Faculty of Psychology, University of Iceland, [2]Faculty of Psychology, Saint-Petersburg State University, [3]Department of Cognitive Science, Faculty of Media and Knowledge Sciences, University of Malta

A popular model of the function of visual attentional involves visual search where a single target is to be found among multiple distractors. A more realistic model may, however, arguably involve search for multiple targets of various types in the same search environment, since our goals at any one time may not necessarily be so narrow as to involve a single target. Here we present results from a novel paradigm involving foraging for different target types according to varying constraints. We test such foraging both with a finger-foraging paradigm where observers must tap a pre-designated number of items and an analogous eye-gaze foraging task where observers cancel the items by fixating on them for 100 ms. Supporting previous reports we find a dramatic difference between feature and conjunction foraging for a majority of observers. A notable subset of observers has little trouble switching between different target types during foraging, however, even in a difficult foraging task where observes must forage for two targets among distractors that are defined by conjunctions of features. There a significant correspondence between eye and finger foraging. The observers that have little trouble switching between different target types during finger-foraging, also tend to have little trouble switching during gaze-foraging. This finding establishes an important connection between eye-gaze and finger-tapping, most likely reflecting the close correspondence between eye and hand coordination and visual attention. Finally, the fact that some observers can switch between different target types with relative ease raises challenges for many current theoretical accounts of vision and attention.

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53.4084 Selection in Flanker Tasks is Governed by Identities and Not by Locations Ricardo Max[1] (ricardom@post.tau.ac.il), Yehoshua Tsal[1]; [1]Department of Psychology, Tel Aviv University

Distractor processing in flanker tasks has been widely attributed to inherent flaws of the attentional apparatus. We challenge three central premises behind this claim: (a) Early perceptual processing capacity is critically limited and lacks resolution for fully identifying stimuli. Therefore, (b) in order to attain target selection, the system deploys processing resources according to stimuli locations; the relevant (central) location is continually processed, whereas irrelevant (flanking) locations become suppressed. (c) Distractors are processed because attentional mechanisms fail to constrain processing exclusively within the target's location. The mutations paradigm provides behavioral measurements of the specific time window during which distractors must appear in order to delay responses. A central target is flanked by two identical distractors. In each trial, while the target remains unchanged, both distractors mutate once, either from incongruent to neutral, vice versa, or from neutral to neutral (control). Mutation time is random within the initial 200 ms after onset. Results from six experiments consistently showed: (a) Distractors' identities were processed as early as 8 ms after onset, which indicates that early perceptual capacity is not limited as believed. (b) Flanking distractors became robustly suppressed as early as 25 ms, indicating a sharp focus of the attentional window exclusively upon the target. (c) When neutral distractors were presented during the initial 30 ms, distractors' locations became swiftly and irrevocably suppressed. Yet, when a distractor was incongruent within the initial 30 ms, its location continued to be processed and its identity increasingly delayed responses for as long as presented. This indicates not only that identities were recognized before locations were discerned, but also that distractors were suppressed according to their initial identity (and not according to their locations). We propose that the flanker effect is strongly mediated by identity-based selection rather than solely caused by inefficient selection of target location.

53.4085 Attentional cartography: Mapping the distribution of attention across time and space Eric Taylor[1] (j.eric.t.taylor@gmail.com), David Chan[1], Patrick Bennett[2], Jay Pratt[1]; [1]University of Toronto, [2]McMaster University

Decades of research have shown that the covert orienting of attention follows a reliable pattern of facilitation then inhibition following a peripheral cue. In this paradigm, observers view a peripheral cue followed by a target at the same or a different location. When the cue-target onset asynchrony (CTOA) is < 200 ms, the cue facilitates target detection at the cued location. However, as the CTOA increases, target detection is inhibited at the cued location. Although this result is well-established, the literature lacks a high resolution spatiotemporal map of this pattern. We conducted a large-scale investigation into charting the spatiotemporal distribution of covert orienting. In addition, we also addressed the inconsistent use of placeholder stimuli in spatial cueing tasks. Attention has a well-known predilection for object contours, so it is problematic that spatial cueing tasks sometimes use placeholder stimuli for cued locations, which should presumably alter the spread of facilitation and attention – and sometimes do not. To remedy this ambiguity, we systematically manipulated the presence of placeholder stimuli at the cue locations. Eighty participants detected targets at 121 possible locations 100 ms, 200 ms, 400 ms, or 800 ms following an uninformative peripheral cue with or without placeholders (see Figure 1A). With placeholders, the classic pattern of early facilitation and late inhibition was observed for targets appearing within the placeholders, and the spread of inhibition is severely limited to within the placeholders (see Figures 1B, 2). Without placeholders, we observed inhibition shortly after cue presentation, upsetting the famously reliable effect of facilitation following a cue. Moreover, inhibition spread from the cued location, unlike when placeholders are present. These findings constitute the most detailed spatiotemporal map of attentional orienting ever recorded, and force a reconsideration of what has become the "classic" distribution of attentional orienting following a peripheral cue.

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53.4086 The Effects of Blur on Selective Visual Attention Jared Peterson[1] (jaredpeterson@k-state.edu), Greg Erickson[1], Alicia Johnson[1], Jeff Dendurent[1], Lester Loschky[1]; [1]Psychological Sciences, Arts and Sciences, Kansas State University

Dual task evidence suggests that visual blur is processed preattentively (Loschky et al., 2014). Interestingly, blur might be the first preattentive feature found to repel attention. Several experiments tested both of these hypotheses, using an L and T visual search task, and manipulating the presence of blur versus clarity. A pilot study found a level of blur that was clearly perceptible, but did not affect response times or accuracy compared to clear letters, thus confirming that both blurred and clear letters were equally legible. Experiment 1 compared RT for T targets with either all or no letters blurred, or the target or a single distractor as a blurred or clear singleton. Results suggested that blur did not repel visual attention, as shown by blurred singleton targets not having significantly longer RTs than the all-blurred and all-clear conditions. However, clarity seemed to capture attention—clear singleton targets had the fastest RTs, and clear singleton distractors near the target produced the longest RTs. Experiment 2 aimed to increase the effects of the blur manipulation by varying set size, increasing letter eccentricity, and increasing task difficulty by making L distractors appear more T-like (Jiang & Chun, 2001). With set size = 8, the results were consistent with blur not repelling visual attention (blurred singleton target = all-blurred & all-clear), while the clear singleton targets had the shortest RTs, consistent with clarity capture. Surprisingly, however, when there was

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less attentional demand (set size = 4), both clear and blurred singleton targets showed the shortest RTs, although capture by blur must be replicated. These visual search findings provide converging evidence to eye-tracking studies showing that when freely viewing scenes, observers typically attend to clear regions before blurred regions (Enns & MacDonald, 2012; Kahn, Dinet, & Konik, 2011; Loschky & McConkie, 2002; Smith & Tadmor, 2012).

53.4087 The role of cue processing in advancing the onset of inhibition of return

Andrew Rodriguez[1] (eat24foods@csu.fullerton.edu), Brittney Hernandez[1], Eriko Self[1]; [1]Department of Psychology, California State University, Fullerton

The appearance of inhibition of return (IOR), a phenomenon where invalid trials produce faster reaction times than valid trials, is delayed in target discrimination tasks at SOA of 700 ms compared to target localization tasks where it appears at SOA of 300 ms (Posner & Cohen, 1984; Lupiáñez, Milan, Tornay, Madrid, & Tudela, 1997). Our goal was to see whether deeper processing of the cue can accelerate the onset of IOR in target discrimination tasks (Gabay, Charras, Funes, Chica, & Henik, 2012), predicting that the cue processing will accelerate IOR's appearance at SOA of 100 ms. In our study, two white hollow squares (2.5o each side) were presented to the right and left of the fixation cross (retinal eccentricity of 6.84°). One of the two squares changed color (to red or green) which served as the non-predictive cue. Following SOAs of 100, 300, 600, or 1000 ms, the target (blue or yellow circle) appeared inside one of the two hollow squares. Participants performed identical target discrimination task with additional task about the cue: one which did not require any processing of the cue, a second which required identifying the cue's color, and the third which required identifying the cue's location. The results showed IOR at the SOA of 100 ms in the cue color discrimination condition, however, IOR was not observed at any of the SOAs in the cue localization condition. IOR was also observed at the SOAs of 100 and 600 ms in the no cue task condition. Although the findings show IOR at the SOA of 100 ms for the cue color discrimination condition as hypothesized, the no cue processing condition produced IOR at earlier SOAs than what is normally observed, possibly indicating that factors other than processing of the cue affect the onset of IOR.

53.4088 Statistical processing of partly occluded sets

Tatiana Aloi Emmanouil[1] (tatiana.emmanouil@baruch.cuny.edu), Jaeeun Lee[2]; [1]Baruch College and the Graduate Center of the City University of New York, [2]Baruch College of the City University of New York

The visual environment contains sets of objects with similar properties, such as the pebbles on the beach or the cars on the highway. Even though the objects in these sets exceed the capacity of attention, people can accurately encode their average properties, such as average size or speed. Studies thus far suggest that statistical summaries are computed effortlessly and automatically, however the exact stage at which statistical processing occurs remains unclear. In this study, we investigated whether averaging occurs before or after objects are perceptually completed. Participants viewed sets of circles that appeared either in front of or partly behind horizontal bars and they were asked to judge their average size. Estimates of the mean were similar for occluded and unoccluded sets, suggesting that objects were amodally completed before they were averaged. The results suggest that statistical processing is informed by complex computations that occur at later stages of visual processing.

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3D Perception: Space

Tuesday, May 19, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.4089 Claustrophobic Fear and Compression of Visual Space

Samuel Hunley[1] (shunley@emory.edu), Eugene Park[1], Matthew Longo[2], Stella Lourenco[1]; [1]Psychology Department, Emory University, United States, [2]Department of Psychological Sciences, Birkbeck, University of London, United Kingdom

Psychologists have long noted perceptual distortions associated with fear (e.g., Baddeley, 1972; Keinan, 1987). More recently, researchers have reported that participants high in acrophobic fear (i.e., fear of heights) show greater overestimation of vertical extents compared to participants low in acrophobic fear (e.g., Teachman et al. 2008; Stefanucci & Proffitt, 2009). In our study, we examined individual differences in trait claustrophobic fear (i.e., fear of enclosed or restrictive situations) in relation to horizontal distance perception. In Experiment 1, participants estimated a single horizontal extent using multiple means of estimation. Afterwards, participants completed the claustrophobia questionnaire (CLQ; Radomsky et al., 2001) and other questionnaires to control for general fear (i.e., acrophobia) and anxiety (i.e., agoraphobia). Participants' consistently underestimated egocentric distance when using verbal report, $t(39) = -2.01$, $p < .05$. Furthermore, a multiple regression analysis revealed that the degree of underestimation was predicted by claustrophobic fear ($b = -.61$, $t = -3.09$, $p = .004$; total $R2 = .239$), even when accounting for general fear ($b = .024$, $t = 0.14$ $p > .8$) and anxiety ($b = .309$, $t = 1.74$, $p > .09$). In Experiment 2, participants estimated multiple distances using visual matching. We fit power functions to these judgments to explicitly model compression of visual space. Higher reported claustrophobic fear predicted greater compression of visual space (i.e., smaller power function exponents; $b = -.518$, $t = -3.02$, $p = .006$; total $R2 = .206$), even when accounting for general fear ($b = .007$, $t = 0.08$, $p > .9$) and anxiety ($b = .184$, $t = 1.38$, $p > .2$). Taken together, these findings suggest that higher claustrophobic fear is associated with an exaggeration of a normative bias in horizontal distance perception—namely, the compression of visual space.

Acknowledgement: Emory University

53.4090 Monocular visual perception of target displacements relative to a slanted surface specified by a regular array

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In the general case, the recovery of a 3D scene from its 2D projection is indeterminate. Adding constraints typical of normal environments sometimes, however, allows unique solutions to be determined. This study is concerned with how monocular visual perception resolves the ambiguities in the 3D position of a target object in the presence of an extended background surface. Computer-generated images, shown in a wide-angle rear-projection display, produced a compelling perceptual impression of a 3D scene in which a regular array of widely-spaced square tiles formed a flat vertical plane slanted, around a vertical axis, relative to the frontal plane. On each trial, a target tile could be displaced from its regular array position, either left or right along the surface of the array plane, or perpendicularly to the plane, either in front of or behind it. Observers made two, three-alternative, forced-choice judgments: (1) whether the target was perceived to be to the left, right, or in the center of its regular position in the array and (2) whether the target was perceived to be in front of, behind, or on the array plane. Lateral and perpendicular displacements relative to the slanted array plane both produced changes in the size and shape of the projected target image as well as shifts in its lateral position. Nevertheless, the distinct combinations of these projective transformations, produced by the two types of displacement, were in principle sufficient to mathematically disambiguate them under the constraint that the target tile remained physically identical to the other tiles in the array. Observers' perceptual judgments, however, showed systematic errors suggesting that the perceived lateral and perpendicular target displacements interacted perceptually in ways inconsistent with this constraint and biased by the implied surface induced by the array of tiles.

53.4091 Perceptual Consequences of Curved Screens

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When looking at a picture from the center of projection (CoP), the image on the retina is identical to the retinal image produced by the original scene. But pictures are usually not viewed from the CoP, so the retinal image differs from what would have occurred when viewing the original scene. Nonetheless, pictures seen from the wrong place continue to look largely veridical. Vishwanath et al. (2005) showed that the visual system compensates for off-to-the-side viewing by estimating the orientation of the picture surface at each point of interest (based on binocular disparity and frame perspective) and uses this estimate to in effect adjust the dimensions of the retinal image. Interestingly, when the eye is actually at the CoP, this compensation mechanism creates visible distortions in eccentric regions of the picture; the distortions are most obvious in pictures with large fields of view. We examined whether these wide-angle distortions can be reduced by (1) curving the projection plane used to create images, and (2) curving the display screen. Curving the projection plane decreases its slant from the CoP thereby reducing the stretching of the image of a depicted object, which should reduce perceived distortion. By curving the screen, the local slant of the display surface is minimized, which should also reduce distortion. We tested these predictions by measuring perceptual distortions on flat and curved (curvature radius = 418 cm) screens from 30 different viewing angles ranging from 0-50° and 6 viewing distances. We found that the local slant of the display surface was the sole predictor of perceptual distortions: i.e., distortions were reduced when pictures were presented on the curved screen. We derive a set of software and hardware guidelines to create natural-looking images based on focal length, projection plane curvature, and screen curvature.

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53.4092 Ordered Planes in Stereo-transparency

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After many weeks of practice, subjects can report the number of clearly-separable transparent depth planes from 2 to 6, in briefly-presented (400ms) stereo displays of 96 randomly-located x's. They report the number from 7 to 10 with decreasing but still above chance accuracy (VSS 2010). Jittering the disparity differences between planes and jittering the number of elements in each plane, to remove spurious cues, reduced the range by only 1, so we have concluded that subjects can learn to see 6 or more transparent depth planes in parallel (i.e., without scanning or vergence movements across the displays). But how organized is the information in these depth planes? We have one finding. When given a constant number (6) of planes, subjects can enumerate how many of them contain +'s when the rest contain x's, and subjects can report which particular plane, from 1 through 6, contains +'s, when all the rest contain x's. We conclude that experienced subjects can learn to see, in one glimpse, a 'depth frame' comprising transparent depth planes with known features in a known order.

53.4093 Depth Perception of Augmented Reality Information in an Automotive Contact Analog Head-Up Display

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In an automotive contact analog head-up display (cHUD), virtual information can be presented in augmented reality manner in the driver's primary field of view, minimizing mental transformation effort for the driver. Whether virtual information in the cHUD is really perceived at the correct location in the environment depends on several factors such as the technological specifications of the cHUD, the design of the virtual information or environmental conditions. One possibility to realize a cHUD is to implement an upright virtual image in a distance at which human depth perception is supposed to rely on monocular depth cues only (> 6m). So far it has not been investigated whether this technology succeeds at conveying the correct spatial impression of the virtual information to the driver. In the current study, we investigated whether depth perception of lying navigation arrows in a cHUD with a fixed virtual image distance of 10m was influenced by (a) whether the arrow was overlaid on the road surface or superimposed on a leading vehicle and by (b) whether it was shaded/ desaturated with increasing distance or not. Arrows were randomly presented for 1sec at suggested distances of 20, 25, 30, 35, and 40m. Participants had to match the virtual arrows in the cHUD to distance markers in front of the car. Superimposition led to a significant increase in errors compared to the projection onto the street surface but did not affect reaction times. Increasing distance led to significantly increased reaction times but fewer errors (speed-accuracy tradeoff). The impact of superimposition on error rates was significantly more pronounced in nearer distances. Shading did not have an effect on error rates or reaction times. The results have important implications for the further development of automotive cHUD technology and related design concepts.

53.4094 Efficient coding provides a better account of systematic biases in locomotor space perception than does action ability

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Quantitative predictions of egocentric distance and geographical slant perception may be derived from dense coding (scale expansion) in angular variables (Durgin & Li, 2011). In particular, distance/height matching tasks can be accounted for by measured biases in perceived direction (elevation) relative to the horizon (Li et al., 2011). However, substantial interest has accumulated for studies arguing that perception is affected by physiological factors such as BMI and age. We used a cross-sectional methodology to look at space perception across the adult lifespan (ages 18-72). We examined performance in several distance, height, and slant tasks including estimation and perceptual matching. We also measured factors concerning specialized knowledge (golfers and skiers know more about distance and slope estimation, respectively), physiology (age, BMI), and personality (e.g., Agreeableness) that might influence performance. Participants (N=106) included college students (N=58), but also non-student members of the nearby community (N=48). Consistent with coding efficiency theory, slant, distance and height estimates closely accord with the angular expansion account: Distances were underestimated (0.72 of actual distance); height was overestimated (1.11 of actual height) and egocentric distance-height matching performance (mean ratio: 1.53) accorded well with the ratio between estimate ratios (i.e., 1.54). Contrary to the action-ability hypothesis, participants defined as obese by CDC guidelines (mean BMI = 35.2) tended to underestimate distance more than those defined as normal. Slant overestimates were consistent with scale expansion, but were also affected reliably both by knowledge and by age. Although obese adults tended to give higher slant estimates, the reliable effect of age on slant estimation was opposite to the predictions of action ability (older adults gave lower slant estimates). Whereas some aspects of the slant results could be used to support an action-ability account, the data as a whole contradict the action-ability account. The data quantitatively support the coding efficiency account.

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53.4095 Modelling observers' errors in pointing to an unseen target

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Observers make large, systematic errors when they point to an unseen target (VSS 2014). Here, we report modelling of these errors. In the experiment (reported VSS 2014), participants in a real or virtual environment viewed a set of 4 target boxes from one location and then walked behind a set of screens with the targets obscured from view. They were then told which 'pointing zone' to go to and there they pointed to the location of the remembered targets. Participants' head and hand were tracked throughout to allow actual and true pointing directions to be compared. Pointing errors depended not only on the layout of the targets and the pointing zone but also the orientation of the obscuring screen. Models based only on a distorted initial representation of the target layout or on cumulative errors in walking (odometry) cannot account for this effect of screen orientation. The most successful model emerged from allowing the layout of the boxes to vary freely according to an affine distortion in a screen-dependent coordinate frame (6 free parameters). This model shifted all the target boxes to lie almost in a single plane parallel to and significantly behind the obscuring screen. The same model accounted well for other data gathered with four different screen orientations. Any model that assumes the configuration of the target boxes is planar will predict that the ordering of pointing to different boxes (e.g. yellow box is to the left of the blue box) will remain constant independent of pointing zone; this is a characteristic error that participants make. Current theories based on a particular, fixed distortion of visual space cannot explain these pointing data. The heuristics participants use differ systematically and significantly from 3D geometric calculations, even with a distorted representation of visual space.

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53.4096 Aging and the visual perception of exocentric distance

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The ability of 18 younger and older adults to visually perceive exocentric distances was evaluated in Experiment 1. The observers judged the extent of fronto-parallel and in-depth spatial intervals at a variety of viewing distances from 50 cm to 164.3 cm. Most of the observers perceived in-depth intervals to be significantly smaller than fronto-parallel intervals, a finding that is consistent with previous studies. While none of the individual observers' judgments of exocentric distance were accurate, the judgments of the older observers were significantly more accurate than those of the younger observers. The precision of the observers' judgments across repeated trials, however, was not affected by age. The purpose of Experiment 2 was to examine potential longitudinal changes in the ability to perceive spatial extents across a period of 20.5 years. Two of the authors, whose abilities to perceive spatial extents were thoroughly evaluated in 1994, were re-evaluated in 2014. These observers demonstrated a significant improvement in accuracy for the fronto-parallel intervals from 1994 to 2014. The results of both experiments show that increases in age can produce significant improvements in the visual ability to perceive the magnitude of exocentric distances.

53.4097 The interaction between relative, familiar object size and binocular vision cues when perceiving stereoscopic 3D content

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Stereoscopic 3D television can suffer from a "puppet theater effect", where figures are perceived as unnaturally small. This does not normally affect 2D television, perhaps because viewers interpret the image as being produced by a correctly-sized object viewed from a suitably far distance, whereas the additional binocular cues to distance rule out this interpretation in S3D displays. In this study, we examined the interaction between binocular disparity and perceived size. Viewers were shown a picture of a standard credit card - a familiar everyday object with a definite size – presented on a S3D TV screen with varying physical size and binocular disparity. They reported whether it appeared smaller or larger than a real card. The viewing distance was 50, 100 or 200cm. The credit card was presented in the middle of the screen either on a black background (absolute disparity condition), or on a textured background (relative disparity condition). If a "familiar size" cue dominated, viewers would always perceive the image as being credit-card-sized, so the percentage of "bigger" judgments would not depend on image size or disparity. Alternatively, viewers might base their answers on the size of the physical image on the screen, if they were able to detect this. Thirdly, viewers might combine the binocular information about the distance of the virtual card with the angular subtense of the image, and base their answers on the implied size of the virtual card. Our results indicate that viewers use a mixture of the last two strategies. At all 3 viewing distances, they do take disparity into account, especially when this is more precise (relative disparity condition). However, they are also influenced by the physical size of the image on the screen. We present a mathematical model of how viewers combine size and disparity in this task.

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53.4098 **Two eyes are identical to one: Three-dimensional motor tracking of visual targets** Kathryn Bonnen[1,2] (kathryn.bonnen@utexas.edu), Alexander Huk[1,2,3], Lawrence Cormack[1,2,3]; [1]Institute for Neuroscience, The University of Texas at Austin, [2]Center for Perceptual Systems, The University of Texas at Austin, [3]Department of Psychology, The University of Texas at Austin

The threshold for detecting stereoscopic motion is notably higher than that for detecting the equivalent fronto-parallel motion. Thus, for small excursions, an apparently stationary line can easily be seen as moving by simply closing one eye – two eyes being less sensitive than one (Tyler, 1971). Here, we used a 3D tracking paradigm to examine motion perception with a continuous motor task. Observers used a cursor to track a target as it moved in a 3D Gaussian random walk. In the main experiment, each eye saw a veridical 2D projection of a square target and cursor moving in 3D. A Leap Motion controller was used to move the cursor by simply pointing at the target location. The controller was calibrated such that there was a one-to-one mapping between finger movement and simulated cursor movement. Tracking data were analyzed by computing the cross-correlograms (CCGs) between the target and cursor velocities for each of the three cardinal motion directions, and assessing the lag, peak correlation, and width of the CCGs. Responses to the depth component of the motion were markedly weaker and more sluggish than responses to the fronto-parallel directions. Further experiments revealed that these depth responses were identical when either only horizontal disparity information was available or when a disparity-only target was viewed monocularly. Our primary finding was that depth tracking is worse than fronto-parallel tracking, but this was simply due to the much smaller amplitudes of projected fronto-parallel motion that motion-in-depth produces. We did not find evidence for the stereo-motion suppression observed with traditional psychophysics, nor did we find a need to invoke a specific disparity processing mechanism. Rather, continuous tracking behavior is parsimoniously explained by reliance on the 2D projections of 3D motion.

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53.4099 **Detection of unusual shadows is faster in scenes with weaker 3D cues** Brent Carpenter[1] (brentcblue@gmail.com), Cheryl Olman[1], Daniel Kersten[1]; [1]Psychology, University of Minnesota

In the process of ascertaining the properties of objects, the illuminant is often discounted and shadow information is lost. When searching for oddly angled shadows in search arrays, observers are faster for inverted displays than for upright displays (Rensink and Cavanagh, 2004). Faster search in inverted displays is presumably because observers do not have to use attention to retrieve discarded shadow information, since the scene inversion interrupts the usual process of discounting shadows. However, previous studies have typically used simplified stimuli with flat shadow-casting objects presented against a background surface lacking strong depth cues. The present study compared search times under conditions in scenes with rich vs. impoverished 3D cues, and with right-side up vs. inverted presentation. The 3D-rich condition provided linear perspective cues to depth, realistic shadows, and 3D-shaded casting objects. The impoverished scenes lacked shading, the shadow casting objects appeared flat, and the only cues to depth were caster image size and cast shadows. Search arrays contained 2, 6 or 10 casters. On 50% of the trials one shadow was cast at an angle 30 degrees away from the illuminant direction indicated by the rest of the lighting cues in the scene. Detection times with impoverished scenes were significantly faster. Further, when all surfaces lacked shading, observers' search efficiencies were independent of set size. Inversion of the search arrays did not affect observer's time to find the distractor in either the rich or impoverished 3D scenes. Our results suggest that the level of 3D detail in a scene has a larger impact on search times than the global manipulation of inversion.

53.4100 **Judgments of Distance to Elevated Targets With and Without a Visible Ground Contact** Daniel Gajewski[1] (gajewsk1@gwu.edu), John Philbeck[1, 2], Sandra Mihelič[1]; [1]Department of Psychology, The George Washington University, [2]School of Psychology, University of Wollongong

Angular declination (AD) is a reliable cue to egocentric distance when targets are floor-level and within the intermediate distance range; elevated objects can be localized based on where their supporting structures contact the ground. In the real world, humans must locate objects supported by surfaces (tables, countertops, etc.) when the ground contact is obscured or not salient. Can knowledge of height above the ground be used in conjunction with target AD when the ground contact of the support is not visible? Here, observers walked without vision to previewed targets that were vertically-oriented boards resting on the ground, 71 cm high and 2.5-5m distant. One end was yellow; the rest was color-matched to the blue-gray carpet. Targets were oriented with the yellow end up or down, and the viewing duration was either short (< 20 ms, sufficient to detect only the yellow end of the object) or long (100 ms, sufficient to detect both ends). Thus, in the up position, the short viewing duration prohibited detection of the ground contact. Observers were informed the object extended to the height of a typical table and were shown real-world examples in advance. Response sensitivity was similarly high in all conditions (slopes near 1). In Experiment 1, the viewing duration was always short, and underestimation was greater in the yellow-down condition (-17%) relative to yellow-up (-1%). In Experiment 2, the targets were always yellow end up, and underestimation was greater when viewing was long (-24%) relative to short (-14%). Several accounts for the bias differences will be considered, but there was no indication that a visible ground contact is crucial. The findings indicate an ability to utilize knowledge of object height to localize objects, but the change in bias across viewing durations suggests a preference to use the ground contact when it becomes visible.

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53.4101 **Reorientation in three-dimensional space: is distance the key?** Sami Yousif[1] (sryousi@emory.edu), Vlad Ayzenberg[1], Stella Lourenco[1]; [1]Emory University

Successful navigation depends on one's ability to use different visuospatial cues both to maintain a sense of orientation and to recover from disorientation. Although researchers debate the extent to which organisms integrate geometry (e.g., distance/length) with features (e.g., color), there is general consensus that even human children use geometry when reorienting in an enclosed three-dimensional environment (Cheng & Newcombe, 2005). Yet questions remain about which geometric properties support navigational processes such as reorientation. One recent proposal is that geometric properties are neurally dissociable (Spelke, Lee, & Izard, 2010) such that children reorient by relying on distance (i.e., spatial extent from the self to a boundary), not properties of the space itself (e.g., relative wall length; Lee, Sovrano, & Spelke, 2012). However, existing work confounds individual geometric properties (distance/length) with the global shape of the surrounding space. Here we address the impact of this confound. As in previous research, we used fragmented spaces to isolate distance and length. In Experiment 1, distance was available in a rectangular layout whereas length was available in a square layout. Children (M_{age} = 3.7 years) were better at reorienting using distance than length ($p < .05$) and were only above chance at localizing a target when using distance ($p < .05$), replicating Lee and colleagues. In Experiment 2, we dissociated distance/length from global shape by adding appendages to the ends of the walls and preventing perceptual completion. Children (M_{age} = 3.9 years) were now above chance at using length ($p < .05$) to localize a target, with no difference between length and distance conditions ($p > .3$). These findings demonstrate that human children are capable of using different geometric properties for the purpose of reorientation and suggest that a distance advantage, when it exists, may be a consequence of the overall shape of the environment.

Object Recognition: Mechanisms and models

Tuesday, May 19, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.4102 Decoding the emerging representation of degraded visual objects in the human brain.

Tijl Grootswagers[1,2] (tijl.grootswagers@students.mq.edu.au), Thomas Carlson[1,2]; [1]Perception in Action Research Centre, Department of Cognitive Sciences, Macquarie University, Sydney, NSW, Australia, [2]Centre for Cognition and its Disorders, Macquarie University, Sydney, NSW, Australia

Object recognition is fast and reliable, and works even when our eyes are focused elsewhere. The aim of our study was to examine how the visual system compensates for degraded inputs in object recognition by looking at the time course of the brain's processing of naturally degraded visual object stimuli. The study used a set of 48 images depicting real world objects (24 animate and 24 inanimate). In experiment 1, we degraded the images by varying the simulated focus, such that each image was equally recognizable. In experiment 2, we presented the intact and out-of-focus images to participants, while their brain activity was recorded using magnetoencephalography (MEG). In the scanner, participants were asked to categorize the objects as animate or inanimate as quickly and accurately as possible. We predicted a behavioural reaction time effect and accordingly observed degraded objects were recognized 22ms slower. Time resolved multivariate pattern analysis was used to decode category (animacy) membership, as well as object identity for all possible pairwise exemplar comparisons as a function of time. In the decoding analysis, we observed lower decoding performance for degraded images overall; and the decoding onset and peak for degraded stimuli were 15ms slower. We assessed several models to explain the behavioural reaction time difference, including distance-based models, which predict reaction times based on exemplar decodability, as well as time-based models, which use the decoding onset and peak. Our analysis shows that distance based models are better predictors. These findings suggest that the time decodable information emerges is less important for determining reaction time behaviour than the quality of the representation (decodability).

53.4103 Learning invariant object representations: asymmetric transfer of learning across line drawings and 3D cues

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View invariant object recognition requires binding multiple views of a single object while discriminating different objects from similar views. The capacity for invariant recognition likely arises in part through unsupervised learning, but it is unclear what visual information is used during learning, or what internal object representations are generated. In study 1, subjects were tested on their abilities to recognize novel 3-dimensional objects rotated in depth, before and after unsupervised learning when subjects saw the objects at a variety of angles. Objects were rendered in different visual formats: stereo, shape-from-shading, line drawings, and silhouettes, and trained/tested on the same format. Unsupervised learning produced significant recognition improvement in all conditions, but was substantially less effective for silhouettes than the other three formats ($p < 0.01$). A computational model of the ventral stream (Yamins, 2014) showed equal improvement across all formats in an intermediate V4-like stage, showing that the less-effective human learning for silhouettes cannot be attributed to a lack of visual information. However, a higher IT-like stage of the same model exhibited a learning curve pattern similar to that in humans. In study 2 we tested whether learning transfers across formats. Subjects participated in unsupervised learning of objects generated from shape-from-shading or line drawings and were tested on objects generated from the same or different cues. While subjects' performance significantly improved after learning in all conditions, testing performance was better for shape-from-shading than line drawings irrespective of the learning cue ($p < 0.02$). We replicated these findings in a separate study training and testing with stereoscopic or line drawings of objects. Together these findings indicate that although contours can enable learning invariant representations, structural cues are more effective. Furthermore, our results suggest that learning optimizes internal representations to improve recognition of real 3D objects rather than simply generating associations among trained views.

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53.4104 The effects of recurrent dynamics on ventral-stream representational geometry

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Visual processing involves feedforward and recurrent signals. Understanding which computations are performed in the feedforward sweep and which require recurrent processing has been challenging. We used fMRI and MEG to characterize the spatial and temporal components of human visual object representations. In the fMRI experiment, we used brief stimulus presentation (16.7ms) and a backward masking paradigm with short and long interstimulus intervals (ISI) to distinguish the contributions of feedforward and recurrent processing. In the short-ISI trials, the mask was presented 37ms after stimulus onset (ISI=20ms), interfering with recurrent processing. In the long-ISI trials, the mask appears only 1017ms after stimulus onset (ISI=1000ms), leaving time for recurrent processing. Representations of a set of animate/inanimate object photos were characterised by their representational dissimilarity matrices (RDMs). We observed no change of the representational geometry with recurrent processing in early visual cortex (EVC). In human inferior temporal (hIT) cortex, however, the representation was transformed as a result of recurrent processing. Long-ISI trials (enabling more extended recurrent processing) were associated with stronger clustering of artificial inanimate objects and more prominent human-body clusters. By contrast, human faces were more clustered in the short-ISI trials. We also compared the fMRI RDMs with RDM movies computed from MEG sensor patterns. The MEG-to-fMRI RDM correlations for the long-ISI fMRI data peaked later (126ms) than for the short-ISI fMRI data (75ms), suggesting that computations occurring at longer latencies after stimulus onset actually contribute to the representational geometry observed with fMRI in long-ISI trials. The MEG results further suggested that the categorical divisions observed in hIT (e.g. animate vs. inanimate) emerge dynamically, with the latency of categoricality peaks suggesting a role for recurrent processing. Our study demonstrates that object representations in hIT evolve with recurrent processing in a way that strengthens categorical divisions in the representational geometry.

53.4105 Semantic Unmasking Effect is Not Explained by Triggering of Memory

Alisabeth Ayars[1] (alisabetha@email.arizona.edu), Mary Peterson[1,2], Joseph Sanguinetti[1]; [1]Psychology Department, College of Science, University of Arizona, [2]Cognitive Science Program, College of Science, University of Arizona

Sanguinetti & Peterson (VSS, 2013) found that silhouettes semantically related to preceding masked words can "unmask" the words. Participants viewed masked words (50ms). 60ms later, a masked silhouette (Familiar or Novel) was displayed (175ms). Familiar silhouettes depicted a recognizable, nameable object. Novel silhouettes were unnamable objects. Familiar silhouettes were named by the masked words on half the trials (Match) and not on the rest (Mismatch). Participants indicated, on each trial, whether they saw a word. Participants saw more words on Familiar Match trials than other trials (40%vs.20%, $p < .05$). Participants also categorized the silhouettes (novel/familiar); accuracy = 77%. Sanguinetti & Peterson hypothesized that word presentation triggers a hypothesis of the word's presence that is disconfirmed by the mask, preventing its conscious awareness. The semantically-related silhouette unmasks the word because the semantic relation serves as confirmation of the word. An alternative explanation is that the word is perceived when presented but immediately forgotten or degraded due to the mask; conscious recognition of the Familiar silhouettes simply facilitates memory of the word. We present evidence against this alternative explanation. The memory explanation depends on conscious recognition of the Familiar silhouettes. We shortened the silhouette exposure to 70ms, reducing iterative processing of the silhouette, but not recognition. Participants saw fewer words on Familiar Match trials (22%, $p < .01$), suggesting that unmasking strength depends on silhouette duration; recognition is insufficient. A separate study showed the silhouettes were indeed recognizable with a 70ms exposure. The same display sequence was used except participants categorized the silhouettes (novel/familiar). Accuracy was 81%, equivalent to Sanguinetti & Peterson ($p > .05$). Our results show that the memory explanation is incorrect, and demonstrate

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that the unmasking effect requires a longer silhouette exposure, perhaps because longer exposures allow more iterative processing and therefore more access to the silhouette semantics necessary to unmask the word.

53.4106 **The Deep Model** Panqu Wang[1] (pawang@ucsd.edu), Garrison Cottrell[2]; [1]Department of Electrical and Computer Engineering, University of California, San Diego, [2]Department of Computer Science and Engineering, University of California, San Diego

"The Model" (a.k.a. "TM", Dailey and Cottrell, 1999) is a biologically-plausible neurocomputational model designed for face and object recognition. Developed over the last 25 years, TM has been successfully used to model many cognitive phenomena, such as facial expression perception (Dailey et al., 2002), recruitment of the FFA for other categories of expertise (Tong et al., 2008), and the experience moderation effect on the correlation between face and object recognition (Wang et al., 2014). However, as TM is a "shallow" model, it cannot develop rich feature representations needed for challenging computer vision tasks. Meanwhile, the recent deep convolutional neural network techniques produce state-of-the-art results for many computer vision benchmarks, but they have not been used in cognitive modeling. The deep architecture allows the network to develop rich high level features, which generalize really well to other novel visual tasks. However, the deep learning models use a fully supervised training approach, which seems implausible for early visual system. Here, "The Deep Model" (TDM) tries to bridge TM and deep learning models together to create a "gradually" supervised deep architecture which can be both biologically-plausible and perform well on computer vision tasks. We show that, by using the sparse PCA and RICA algorithms on natural image datasets, we can obtain center surround color-opponent receptive field that represent LGN cells, and Gabor-like filters that represent V1 simple cells. This suggests that the unsupervised learning approach is what is used in the development of the early visual system. We employ this insight to develop a gradually supervised deep neural network and test it on some standard computer vision and cognitive modeling tasks.

53.4107 **Orientation, Rotary Motion, and Congruency Effects: Models of Visual Object Identification** James Ryland[1] (james.w.ryland@gmail.com), Alice O'Toole[1], Richard Golden[1]; [1]The University of Texas at Dallas

We developed a computational model of object identification (HAT-F) that is consistent with the Transformational Framework of Recognition (TFR) (Graf, 2006) and tested it as a model of human object recognition. The HAT-F model combines convolution, coordinate adjustment, and multiple-view templates. The TFR proposes that a hybrid of coordinate adjustment and multiple-views could account for human recognition phenomena that static retinotopic theories fail to predict. To test this claim, we specifically examined the accord between human and HAT-F's object recognition performance: a) across novel orientations in the image plane, b) while rotating, and c) when preceded by unrelated primes in either congruent or incongruent orientations. In addition, we compared HAT-F against models consistent with invariant representation and multiple-view theories. We examined HAT-F's accuracy and reaction times when classifying learned objects (N = 150) from the Revised Snodgrass set in unlearned image orientations (Rossion, 2004). Consistent with human behavior (e.g. Lawson, 2003), HAT-F's accuracy varied according to a W-shaped curve over orientation (R2 = 0.9491); reaction time varied according to an inverse W-shaped curve (R2 = 0.9215). The multiple-view and invariant representation models displayed accuracy curves uncharacteristic of human object recognition behavior. The qualitative difference between accuracy curves for the three approaches was statistically reliable, $F(22, 3278) = 61.85$, $MS_e = 0.054$, $p < 1x10^{-15}$. Additionally, HAT-F was more accurate at recognizing objects preceded by primes in congruent orientations, $F(1, 99) = 49.86$, $MS_e = 0.163$, $p < 2.31x10^{-10}$ and at recognizing objects rotating towards an upright orientation, $F(1, 149) = 22.39$, $MS_e = 0.0788$, $p < 5.13x10^{-06}$. Both effects match human behavior (e.g. Graf, 2005; Jolicoeur, 1992). These results indicate that a combination of convolution, transformation, and multiple-view models can account for planar orientation effects, rotary motion effects, and orientation congruency effects, partially validating the TFR's claim.

Acknowledgement: None

53.4108 **Computational similarities between visual and auditory cortex studied with convolutional neural networks, fMRI, and electrophysiology** Alexander Kell[1,2] (alexkell@mit.edu), Daniel Yamins[1,2,3], Sam Norman-Haignere[2,3], Darren Seibert[2,3], Ha Hong[2,3,4], Jim DiCarlo[2,3], Josh McDermott[2]; [1]These authors contributed equally, [2]Brain & Cognitive Sciences, MIT, [3]McGovern Institute for Brain Research, MIT, [4]Harvard-MIT Dviision of Health Sciences and Technology

Visual and auditory cortex both support impressively robust invariant recognition abilities, but operate on distinct classes of signals. To what extent are similar computations used across modalities? We examined this question by comparing state-of-the-art computational models to neural data from visual and auditory cortex. Using recent "deep learning" techniques, we built two hierarchical convolutional neural networks: an auditory network optimized to recognize words from spectrograms, and a visual network optimized to categorize objects from images. Each network performed as well as humans on the difficult recognition task on which it was trained. Independently, we measured neural responses to (i) a broad set of natural sounds in human auditory cortex (using fMRI); and (ii) diverse naturalistic images in macaque V4 and IT (using multi-array electrophysiology). We then computed the responses of each network to these same sounds and images, and used cross-validated linear regression to determine how well each layer of each model predicted the measured neural responses. Each network predicted the cortical responses in its modality well, explaining substantially more variance than alternative leading models. Moreover, for each modality, lower layers of the network better predicted primary cortical responses, while higher layers better predicted non-primary cortical responses, suggestive of hierarchical functional organization. Our key finding is that both the visual network and the auditory network predicted auditory cortical responses equally well in primary auditory cortex and in some nearby non-primary regions (including regions implicated in pitch perception). In contrast, in areas more distant from primary auditory cortex, the auditory network predicted responses substantially better than the visual network. Our findings suggest that early stages of sensory cortex could instantiate similar computations across modalities, potentially providing input to subsequent stages of processing that are modality-specific. We are currently analyzing the auditory network's prediction of visual cortical responses.

Acknowledgement: DOE Computational Science Graduate Fellowship to AK. NVIDIA GPU Donation both to AK and JHM and to DY, HH, and JD. McDonnell Scholar Award to JHM.

53.4109 **Supposing that crowding is compulsory grouping suggests a remarkably simple model for object recognition** Denis Pelli[1] (denis.pelli@nyu.edu), Sarah Rosen[1]; [1]Psychology Dept., NYU

Grouping and crowding have each received much study, but, because they can be avoided, they have seemed marginal to the mystery of how people recognize objects. We begin by showing that the same image parameters that promote grouping also promote crowding. Joining grouping and crowding theories suggests a unified account in which grouping and crowding are two aspects of the classification underlying all object recognition. In this unified account, recognition of a simple object, like a letter, is mediated by a single combining field driving a simple classifier that can only recognize one thing at a time. It follows that the human observer has a vast array of combining fields, one for each size and retinal location, and is usually free to use whichever best matches the target. For simplicity, we suppose they are all similar, differing only in position and size. As eccentricity increases, the smallest available combining field size increases, presumably because fewer neurons are available. Crowding arises when the smallest available combining field is too large to isolate the target object from adjacent objects, as a simple classifier cannot recognize two things at once. To test the notion that the same classifiers underlie both crowding and grouping, we show that the efficiency of identification by a single isolated combining field in the periphery is practically the same as the efficiency of unrestricted central vision of the same target. We conclude that the same unit for object recognition underlies both (optional) grouping and crowding, which is compulsory grouping. Critical spacing marks the boundary between optional and compulsory.

Acknowledgement: NIH grant EY04432

53.4110 **Mixing hierarchical edge detection and medial axis models of object perception** Daniel Leeds[1,2] (dleeds@fordham.edu), Michael Tarr[2,3]; [1]Department of Computer and Information Science, Fordham University, [2]Center for the Neural Basis of Cognition, Carnegie Mellon University, [3]Department of Psychology, Carnegie Mellon University

The nature of the visual representations underlying object perception in the brain is poorly understood. Past studies often have focused on the ability of one of two representational approaches to properly model biological object vision. Hierarchical edge models – pooling selected local edge information across space – have been used to help account for human

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neuroimaging data in response to photographs of 60 real-world objects (Leeds 2013). In contrast, medial axis models have been used successfully to probe mid- and high-level featural selectivities of single neurons in the cortical object perception pathway (Hung 2012). Both approaches, however, leave significant levels of unexplained variance in the neural data. To better model cortical object representations, we fit a weighted-sum mixture of models from the hierarchical and medial axis approaches – SIFT (Lowe 2004) and Shock Graph (Siddiqi 1999) – to neural data. We used fMRI to compare single and mixed-model responses with voxel population searchlight responses to a set of 60 object pictures. Representational distance matrices (Kriegeskorte 2008) were computed for each model combination and each voxel population, to serve as the basis of model-neural comparison. We found that weighted mixtures of the hierarchical and medial axis models exhibited varied results: from insignificant improvements (in lateral occipital cortex) to modest improvements (a 13% increased correlation in fusiform cortex) over either individual model in accounting for cortical representations in the brain regions associated with object vision. The fitted combination of the two models used weights of roughly consistent ratio across regions and subjects, reflective of the ratio of typical interobject distance values produced by the two model metrics. Each of the two models thus appears to account for a subset of the representational strategies realized in the human brain, in what is a sometimes mutually complementary and sometimes mutually equivalent manner.

53.4111 **Backward masking vs. common onset masking using two different types of face mask** Marwan Daar[1] (mdaar@yorku.ca), Hugh Wilson[2]; [1]Centre for Vision Research, York University

Previous research has shown that the shape of a backward masking function depends upon a number of factors, including the structural properties of the mask, and the relative contrast between target and mask. In our study, we compared backward masking functions between a full face mask and a head outline mask. In both cases, the target was a full face. In the full face mask condition, the target was half the contrast of the mask, and in the head outline mask condition the target and mask contrasts were equal. We found that the full face mask produced peak masking at a lower SOA (stimulus onset asynchrony) compared to the head outline mask, a finding that can be readily explained with several models of masking. We then compared the effect of these two masks in a common onset trailing masking paradigm. Notably, while the full face mask showed a steady increase in masking as a function of trail duration, and saturated at 100 ms, the head outline mask showed a markedly lower amount of masking compared to the full face mask, with some observers showing recovery from masking at longer trail durations. A three way repeated measures ANOVA revealed an interaction between mask type (full face, head outline) and masking paradigm (backwards, trailing) ($p = 0.023$). We explain these findings by integrating the idea of parvocellular and magnocellular pathways with object updating models.

53.4112 **Shared noise variability facilitates discrimination of natural images in V4 population** Shaobo Guan[1] (Shaobo_Guan@brown.edu), Ruobing Xia[1], David Sheinberg[1]; [1]Department of Neuroscience, Brown University

The visual system is usually simplied as a hierarchical feed-forward filtering system containing independently functioning neurons. However, interactions among visual neurons exist in neural population. The pairwise shared noise variability of spike counts, or noise correlation, is an easily accessible and potentially powerful measure of such interactions. About the role of noise correlation in a population code, the literature includes multiple, often conflicting, perspectives. This is partly due to how noise correlation is experimentally quantified (Cohen & Kohn, 2011), and partly to how its impact is evaluated. In the present study, we attempted to address these discrepancies and to more objectively assess noise correlation and its role in visual coding. We used a 32-channel semi-chronic microdrive array to record spiking activity from the foveal region of macaque area V4 in a passive viewing task. Our study differed from previous investigations in three primary respects: 1) We used complex natural images as visual stimuli, instead of artificial patterns with limited variability, to better approximate naturalistic visual experience; 2) we quantified noise correlation independently for each stimulus rather than using the mean correlation, so as to preserve the stimulus modulation of correlation that is informative for coding (Ponce-Alvarez, Thiele, Albright, Stoner, & Deco, 2013); 3) we evaluated the coding performance using the likelihood ratio of a multi-variant gaussian model, a decoder approach that provides advantages over direct estimation of information given limited data (Moreno-Bote et al., 2014). Our preliminary results suggest that the pattern of noise correlation improves discrimination of natural stimuli, providing the first evidence of synergistic processing with neurons exhibiting shared noise variability.

53.4113 **Perceiving the lifelikeness of crowds: summary statistical representations of abstract visual dimensions** Allison Yamanashi Leib[1] (ayleib@gmail.com), Anna Kosovicheva[1], David Whitney[1]; [1]University of California Berkeley

Observers can extract the overall "gist" of a scene in the form of summary statistical information about visual features or objects that have explicit dimensionality (e.g., average orientation, size, facial identity or emotion). However, our rich perception of scenes seems to encompass more than this, suggesting that individuals can extract ensemble information from perceptual impressions that are not immediately specified by the visual features in the image. Here we tested whether observers perceive lifelikeness—how "alive" a groups of static, random objects is. In a pre-test, we asked 20 observers to rate the perceived animacy of 150 individual static objects. There was high agreement between observers, and these pre-test ratings were used to generate crowds of random objects containing varying degrees of animacy. In Experiment 1, 20 new observers rated the average animacy of groups of up to 6 objects displayed simultaneously for 1 second. We regressed each observer's ratings against the predicted crowd ratings generated by the independent observers in the pre-test, and obtained highly significant correlations. These results indicate that observers perceived average animacy, and that overall animacy is predictable from the individual objects comprising the crowd. We replicated these results in Experiment 2, in which participants rated the average animacy of a group of random objects, sequentially displayed for 50 ms each, showing that observers can extract ensemble information about animacy within a fraction of a second. Sub-sampling control conditions confirmed that participants integrated multiple objects into their ensemble percept. Our results demonstrate that ensemble perception is not restricted to features or dimensions that are explicitly available in the image. Instead, ensemble percepts can operate over abstract visual interpretations, providing a link between summary statistical representations of basic visual features and the rich perceptual experience that observers report.

3D Perception

Tuesday, May 19, 2:30 - 4:15 pm
Talk Session, Talk Room 1
Moderator: Johannes Burge

54.11, *2:30 pm* **Intact implicit representation of object 3D structure in object agnosia** Erez Freud[1,2] (erezfreud@gmail.com), Tzvi Ganel[1,2], Galia Avidan[1,2], Marlene Behrmann[3,4]; [1]Department of Psychology, Ben-Gurion University of the Negev, [2]Zlotowski Center fo Neuroscience, Ben-Gurion University of the Negev, [3]Department of Psychology,Carnegie Mellon University, Pittsburgh, PA, [4]Center for the Neural Basis of Cognition,Carnegie Mellon University, Pittsburgh, PA

The representation of object 3D structure in the human brain is fundamental for the recognition and visuomotor control of objects. Accordingly, multiple cortical regions along the dorsal and ventral visual streams have been shown to exhibit sensitivity to object structure. To examine the contribution of regions in the ventral stream to processing object 3D structure, we tested five patients with focal damage in the right ventral visual cortex. In a series of behavioral experiments, in which spatially possible and impossible objects were presented, the patients exhibited reduced explicit classifications of 3D structure compared to matched healthy and brain-damaged controls. Interestingly, however, evidence of implicit sensitivity to object 3D structure was revealed by superior performance for possible compared to impossible objects in tasks that did not require explicit classifications of object possibility. A corresponding pattern was also observed in an fMRI experiment in which participants passively viewed possible and impossible objects. Whereas in the matched controls, all object-selective regions showed sensitivity to object possibility, with greater response for impossible than possible objects, in the patients, only a subset of these regions showed such pattern of activity. An additional functional connectivity analysis showed an overall reduced connectivity between object-selective ROIs among the patients, with marked abnormality in the connections to the right inferior temporal sulcus. Taken together, the results suggest that, despite the central role of the right ventral stream in representing 3D structure, a degraded representation of object structure that suffices for some tasks (implicit) but not others (explicit) can still be derived even after damage to this region. This representation may be subserved by the distributed fashion in which 3D structure is represented in the human brain.

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54.12, *2:45 pm* **Naturalistic Depth Perception** Brian McCann[1,2] (brian.c.mccann@utexas.edu), Mary Hayhoe[1], Wilson Geisler[1]; [1]Center for Perceptual Systems, University of Texas at Austin, [2]Texas Advanced Computing Center, University of Texas at Austin

Making inferences about the 3-dimensional spatial structure of natural scenes is a critical visual function. While spatial discrimination both in depth and on the image plane has been well characterized for simple stimuli, little is known about our ability to discriminate depth in natural scenes, particularly at far distances. To begin filling in this gap we: (i) developed a database of 80 stereoscopic images paired with the corresponding measured distance information, (ii) used these scenes as psychophysical stimuli and measured near-far discrimination acuity in 4 observers as a function of distance and the visual angle separating the targets, (iii) made additional measurements under patched-eye (monocular) viewing conditions to evaluate the importance of binocular vision in depth discrimination as a function of viewing geometries. We find that binocular thresholds are roughly a constant Weber fraction of the distance for distances ranging from 4 to 28 meters. Further, measured thresholds were around 1% for small separations, and increased to 4% for stimuli separated by 10 deg. Thus, the ability to discriminate depth in natural scenes is very good out to considerable distances. To investigate the basis of this discrimination ability, monocular thresholds were measured. We found that monocular thresholds were elevated for distances less than 15 meters, but were comparable to binocular thresholds for greater distances. Accurate depth perception depends on combining (fusing) multiple sources of sensory information. Thus binocular thresholds probably involve fusing separate monocular and disparity-derived estimates. Under the assumption of Gaussian distributed independent estimates, Bayes rule provides a simple reliability-weighted summation model of cue combination. Using disparity threshold measurements by Blakemore (1970), and the current monocular thresholds, parameter-free predictions were generated for the current binocular thresholds. These predictions largely matched the data, suggesting that the disparity and monocular cues are separable and combined optimally in natural scenes.

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54.13, *3:00 pm* **Optimal estimates of distance and direction are mutually inconsistent** Peter Scarfe[1] (p.scarfe@reading.ac.uk), Andrew Glennerster[2]; [1]Department of Psychology, University of Reading

Purpose: We used judgements of distance and direction to examine whether observers combine cues to construct a single unified representation of the environment as they move within it. Methods: Observers moved in a virtual reality simulation of a room with brick-textured walls and a checkerboard-textured floor. Upon entering a view-zone to the left of the room, a red sphere appeared 1.6m in front of the observer (Interval-1). Observers judged the position of the sphere and pressed a button triggering a half-second inter-stimulus-interval. Unknown to the observers, when the room reappeared (Interval-2) it had uniformly scaled in size around their cyclopean point. Experiment 1: observers walked rightward across the room, entering a second view-zone, upon which a second red sphere appeared in front of view-zone one. Observers judged whether the visual direction of the sphere in Interval-2 was to the left or right of the sphere in Interval-1. Experiment 2: observers remained in view-zone one, and a second ball appeared in front of them. They judged whether this ball was closer or further from them than the ball in Interval-1. In both experiments, we measured thresholds for "texture-based" cues (those unaffected by room expansion e.g. texture) and "physical-based" cues (those that could signal metric object position e.g. stereo and motion parallax) in isolation and used these to predict performance in a "combined-cues" condition where both cues varied. Results: For both distance and direction, observers combined cues "optimally", such that performance in the combined-cues condition was well predicted by the single cue sensitivities. However, these "optimal" estimates were mutually inconsistent due to (1) differential weighting of physical- and texture-based cues and (2) different biases in the judgements made in the two tasks. Conclusion: In our experiment optimal cue combination was incompatible with observers constructing a single unified representation of the environment.

Acknowledgement: EPSRC

54.14, *3:15 pm* **The binocular energy model and V1 neurons signal disparity in half-matched stereograms** Sid Henriksen[1,2] (s.henriksen@ncl.ac.uk), Bruce Cumming[1], Jenny Read[2]; [1]Laboratory of Sensorimotor Research, National Eye Institute, NIH, [2]Institute of Neuroscience, Newcastle University

Depth perception from binocular disparity depends upon correctly matching image features seen by the left and right eyes. A local cross-correlation between left and right images, similar to the operation of the binocular energy model, is a good candidate mechanism. Recently, Doi et al. (2011, 2013, 2014) showed that human observers can detect depth in "half-matched" stereograms containing equal numbers of correlated and anti-correlated dots. These stimuli have a binocular correlation of 0 for all disparities, leading Doi et al. to argue that a correlation computation cannot explain human performance. However, these stimuli do contain local fluctuations in correlation. We explore whether it is possible account for these responses with the binocular energy model, and have begun testing the predictions in disparity-selective neurons from V1. In half-matched stereograms the standard binocular energy model responds equally to all disparities. Simply adding an expansive nonlinearity on the output of a model complex cell renders it disparity selective. At the preferred disparity, local fluctuations in correlation produce a greater variance in the output of an energy model, compared to a non-preferred disparity. When passed through the nonlinearity, this greater variance results in a greater mean. The strength of disparity selectivity decreases with dot density (low density produces greater fluctuations). We examined this in disparity selective neurons in monkey V1. In neurons showing attenuated responses to anticorrelated stimuli, we find robust disparity selectivity at low dot densities. At high dot densities disparity selectivity is much weaker, but remains significant. A single computation – the binocular energy model followed by an output nonlinearity, can explain depth perception in both correlated and "half-

matched" random dot stereograms. A key property of this simple model, that disparity selectivity depends on dot density (only in half-matched stereograms), is true in appropriately selected disparity selective V1 neurons.

Acknowledgement: Wellcome Trust, National Institutes of Health

54.15, *3:30 pm* **Estimation of 3D surface shape from line drawings: a Bayesian model** Seha Kim[1,2] (sehakim@rutgers.edu), Manish Singh[1,2], Jacob Feldman[1,2]; [1]Department of Psychology, Rutgers University-New Brunswick, [2]Rutgers University Center for Cognitive Science

Human observers can interpret line drawings as well-defined 3D surfaces, despite the absence of local cues to depth such as shading and texture. In our previous work (VSS2013, VSS2014), we found that human depth interpretation in the interior of line drawings is probabilistic, in that the degree of certainty in judgments of relative depth varies in complex ways based on local and global aspects of contour geometry. Here we propose a principled Bayesian framework in which to understand human visual estimates of relative depth in line drawings. We assume a generative model in which 3D shapes are "inflated" from stochastic skeletons with circular cross-sections and then orthographically projected to create line drawings; this model defines a likelihood function for surface normals. The model then estimates the posterior distribution of surface normals at each point on a given line drawing. These posteriors are integrated to yield the probability that any given point on the surface lies closer to the viewer than any other point. This theoretical probability is combined with human biases for depth perception: (1) a fronto-parallel bias leading to an underestimation of slant, and (2) a lower-region bias, so that lower points in the image tend to be interpreted as closer. We compared the probability derived from this model to subjects' judgments of relative surface depth at two probe points from the experiment, and found good agreement between model and data. In addition, we examined the "receptive field" size of the model to quantify the degree of locality of the cues that influenced subjects' judgments. The model establishes a theoretical framework in which surface depth in line drawings can be understood as probabilistic inference based on contour structure, and in which the relative contribution of local and global aspects of contour geometry can be quantified.

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54.16, *3:45 pm* **Priors on surface shape, reflectance, and illuminance that overcome the generalized bas-relief ambiguity in shape from shading** Richard Murray[1] (rfm@yorku.ca); [1]Department of Psychology and Centre for Vision Research, York University

Perception of surface shape and reflectance is a difficult problem because it is underconstrained. The generalized bas-relief (GBR) ambiguity is potentially a powerful tool for probing how human vision solves this problem, as it mathematically describes an important special case of the problem of ambiguity. The GBR ambiguity shows how we can make drastic changes in the shape, reflectance, and illumination conditions of an object without changing its retinal image at all, and so it describes a fundamental obstacle to perception of shape and reflectance from shading. What statistical knowledge about real-world surfaces would help a visual system to overcome the GBR ambiguity? Do we need detailed knowledge about the statistics of real-world surfaces, or is general knowledge that mostly avoids pathological interpretations enough? Method. I examined the statistics of surface properties in digital representations of 1000 natural and man-made objects. I histogrammed local changes in orientation, reflectance, and illuminance, and also their pairwise joint distributions. I tested which of these statistical models of real-world surfaces selected the correct 3D interpretation of 2D images of objects, out of a wide range of GBR transformations of the objects. Results. Local reflectance changes tended to be small, and this simple prior was effective at selecting correct 3D interpretations of 2D images. Local orientation changes were also small, but this prior usually did not select correct 3D interpretations. Significantly, a simple prior stating that local changes in reflectance and illuminance are uncorrelated also worked very well in selecting correct 3D interpretations. Conclusion. Local statistical information about real-world surfaces can be useful in recovering 3D shape from 2D images, and general knowledge that mostly just avoids pathological interpretations can also work surprisingly well. I will also discuss psychophysical experiments that test whether these priors guide human perception of shape and reflectance from shading.

Acknowledgement: NSERC, CFI

54.17, *4:00 pm* **3D Object Recognition in Honeybees** Annette Werner[1] (annette.werner@uni-tuebingen.de), Wolfgang Stürzl[2], Johannes Zanker[3]; [1]Institute for Ophthalmic Research, University of Tuebingen, Germany, [2] Institute of Robotics and Mechatronics, German Aerospace Center, Germany, [3]Department of Psychology, Royal Holloway University of London, UK

Bees are one of the best studied animal models for vision and show an amazing complexity of visual performances, given their tiny brains. The recognition of 3D objects is an important and challenging visual task for bees as it is for humans, but like most insects bees lack sufficient stereo vision; how, then, do bees master 3D object recognition? To find out, we trained individual free flying honeybees to collect sugar water from small three-dimensional objects and tested their discrimination. We show that bees successfully encode the three-dimensional form of these objects, whereby they employ an active strategy to uncover the depth profiles. Analysing the bees' flight tracks revealed specific combinations of flight maneuvers (translations and in-plane rotations). We modelled the generated optic flow patterns and found that their flight maneuvers allows the bees to extract detailed depth cues from amplitude and direction of the image shift. The robustness and simplicity of this strategy offers an efficient solution for 3D- object-recognition without stereo vision, and could be employed by other flying insects, or mobile robots.

Acknowledgement: Bernstein Centre for Computantional Neuroscience, Tübingen Centre for Integrative Neurosciences Tübingen

Visual Search

Tuesday, May 19, 2:30 - 4:15 pm
Talk Session, Talk Room 2
Moderator: Justin Ericson

54.21, *2:30 pm* **Guided Search 5.0: Meeting the challenge of hybrid search and multiple-target foraging** Jeremy Wolfe[1,2] (wolfe@search.bwh.harvard.edu), Matthew Cain[4], Krista Ehinger[1,5], Trafton Drew[3]; [1]Visual Attention Lab, Brigham & Womens' Hospital, Boston, MA, [2]Depts. of Radiology and Ophthalmology, Harvard Medical School, [3]Dept. of Psychology, University of Utah, [4]US Army Natick Soldier Research, Development, & Engineering Center, [5]Dept of Ophthalmology, Harvard Medical School

The most recent Guided Search model (GS4, Wolfe, 2007) combines serial and parallel processes. Parallel guidance by "preattentive" features prioritizes items for serial selection. Items are selected every ~50 msec, starting a diffusion process that decides if the item is target or distractor. Each diffusion process takes ~300 msec/item. Thus, several items apparently undergo identification in parallel. New extended search paradigms involving multiple possible targets and multiple actual targets in each display require modifications to GS and to other models that assume a single search template and that consider only simple present/absent trial structures. 1: In "Hybrid Search" tasks, observers search visual arrays for any of N distinct target items, held in memory. This is quite easy, even for memory sets of 100 unique objects (Wolfe, 2012). This suggests that selection of each visual item may start accumulation of information to each of N decision boundaries in parallel. Moreover large memory sets show that observers' "search templates" aren't limited to the current contents of working memory. 2: In foraging experiments, observers look for multiple instances of the same target (e.g., berry picking). Uncertainty about the number of targets requires new search termination rules. GS5 adopts these from Optimal Foraging Theory within a Bayesian framework in which observers are continually updating their estimates of target probability in the current display. 3: Finally, in "hybrid foraging" tasks, observers easily search visual arrays for multiple instances of N items held in memory. The speed with which items are collected suggests "multi-tasking" in which observers are simultaneously clicking on one target, storing locations of others, and searching for still more. We seem to require memory for locations of targets that have been identified but not collected. The GS5 architecture has implications for real-world extended search tasks such as radiology or satellite image analysis.

Acknowledgement: NEI EY017001, NGA HM0177-13-1-0001_P00001, ONR N000141010278, NSF CELEST

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54.22, *2:45 pm* **Visual search through a 3D volume: Studying novices in order to help radiologists** Avigael Aizenman[1] (aizenman.avi@gmail.com), Matthew Thompson [2,3], Krista Ehinger[1,2], Jeremy Wolfe[1,2]; [1]Brigham and Women's Hospital, [2]Harvard Medical School, [3]The University of Queensland

Modern radiology often involves search for abnormalities in 3D volumes of imagery (e.g. chest CT, breast tomosynthesis). Drew et al., (2013) used eye tracking to identify two different search strategies: "drillers" scroll quickly through depth while keeping their eye position relatively constant, while "scanners" examine each XY plane before scrolling more slowly in depth. To determine if one method is inherently superior, we developed an analog to radiologic search that can be performed by non-experts. Target "T's" and distractor "L's" were inserted into a 3D block of 1/f noise. Naive participants were given driller or scanner instructions. Observers marked T's they found with mouse clicks. XY eye-position was recorded at 1000 Hz and co-registered with slice/depth plane as the observers scrolled through the 3D volume. Scan paths indicate that observers were scanning or drilling as instructed. Results from 8 participants reading 21 simulated cases suggest that miss error rates were lower for drillers than for scanners. Search durations, however, were ~2X longer for drillers (186sec vs 98sec). This raises the obvious possibility of a speed-accuracy tradeoff that might be countered by further instruction. Drilling, overall, was associated with somewhat shorter fixations (270 msec vs 229 msec) and shorter distances travelled per unit of time by the eyes, consistent with the differences between drilling and scanning. More extensive testing of non-radiologists is required before recommendations could be made regarding best practice by experts.

Acknowledgement: NEI EY017001

54.23, *3:00 pm* **Long-term visual search: Examining trial-by-trial learning over extended visual search experiences** Justin Ericson[1] (justin.ericson@duke.edu), Adam Biggs[1], Jonathan Winkle[1], Christina Gancayco[1], Stephen Mitroff[1]; [1]Center for Cognitive Neuroscience, Duke University

Airport security personnel search for a large number of prohibited items that vary in size, shape, color, category-membership, and more. This highly varied search set creates challenges for search accuracy, including how searchers are trained in identifying a myriad of potential targets. This challenge has both practical and theoretical implications (i.e., determining how best to obtain high accuracy, and how large memory sets interact with visual search performance, respectively). Recent research on "hybrid visual and memory search" (e.g., Wolfe, 2012) has begun to address such issues, but many questions remain. The current study addressed a difficult problem for traditional laboratory-based research—how does trial-by-trial learning develop over time for a large number of target types? This issue, which we call "long-term visual search," is key for understanding how reoccurring information in retained in memory so that it can aid future searches. Through the use of "big data" from the mobile application Airport Scanner (Kedlin Co.), it is possible to address such previously intractable questions. Airport Scanner is a game where players serve as an airport security officers looking for prohibited items in simulated bags. The game has over 7 million downloads and provides a powerful tool for psychological research (Mitroff et al., 2014 JEP:HPP). Trial-by-trial learning for multiple different targets was addressed by analyzing data from 50,000 participants. Distinct learning curves for each specific target revealed that accuracy rises asymptotically across trials without deteriorating to initially low starting levels. Additionally, an investigation into the number of to-be-searched-for target items indicated that performance accuracy remained high even as the memorized set size increased. The results suggest that items stored in memory generate their own item-specific template that is reinforced from repeated exposures. These findings offer insight into how novices develop into experts at target detection over the course of training.

54.24, *3:15 pm* **Foveal vision loss interferes with visual search guidance by learned spatial contexts in contextual cueing** Stefan Pollmann[1,2] (stefan.pollmann@ovgu.de), Franziska Geringswald[1]; [1]Department of Experimental Psychology, Otto-von-Guericke-University, Magdeburg, Germany, [2]Center for Behavioral Brain Sciences, Magdeburg, Germany

Visual search is guided by past experience of regularities in our visual environment. In the contextual cueing paradigm, incidental learning of repeated distractor configurations improves search times and eye movement parameters. Both in patients with age-related macular degeneration who suffer from foveal vision loss and in young normal-sighted observers with gaze-contingent central scotoma simulation contextual cueing was severely reduced (Geringswald et al., Front Hum Neurosci 2012, J Vis 2014). Previous work has shown that not the learning of spatial contexts but rather the utilization of previously learned context for efficient search guidance depends on visuospatial working-memory (Manginelli et al., Att Percept Psychophys 2013; Vickery et al., J Exp Psychol Hum Perc Perform 2010). Therefore, increased working memory demands due to top-down controlled visual search in the presence of foveal vision loss could lead to reduced contextual cueing. To test this hypothesis, we let normal-sighted observers search with simulated foveal scotoma during a learning phase but without scotoma in a subsequent transfer phase. Contextual cueing was absent during learning, but reinstated in the transfer phase. This indicated that context learning occured in the presence of foveal vision loss, but learning could not be utilized for more efficient search while the scotoma was present. However, in a further experiment, after few hours of search training with central scotoma simulation, contextual cueing was reinstated during scotomatous search, indicating that contextual cueing can be regained when the exploration of the environment becomes more automatic. Thus, foveal vision loss leads to inefficient use of implicitly learned contextual cues for the guidance of visual search. Automatization of search with a simulated scotoma leads to reinstatement of contextual cueing in normal-sighted observers. This may show a promising way for training programs in patients with foveal vision loss.

Acknowledgement: DFG grants PO 548/8-1 and PO 548/14-1

54.25, *3:30 pm* **Visualizing trumps vision when training attention** Robert Reinhart[1] (robert.reinhart@vanderbilt.edu), Laura McClenahan[1], Geoffrey Woodman[1]; [1]Department of Psychology, Center for Integrative and Cognitive Neuroscience, Vanderbilt Vision Research Center, Vanderbilt University, Nashville, Tennessee 37240, USA

There is a strong belief among individuals in scientific, medical, and lay industries (e.g., surgeons, educators, athletes, musicians, and psychiatrists) that imagery can help us improve performance in variety of tasks and situations. The theories that seek to motivate potentially beneficial effects of imagining propose that imagery improves processes late in the stream of information processing. For example, the leading hypotheses propose imagery trains stimulus-response mapping or even simply improves motor control. The present study examined the untested hypothesis that imagery can improve the operation of visual attention, allowing for more efficient selection of task-relevant objects in a visual scene. We designed a task in which we could pit instances of imagery against instances of practicing the same task with visual input. We found that subjects were faster even after a single instance of imagining searching for a target in a visual search array, compared to when they had actually practiced the task with visual input. Recordings of brain activity demonstrate that the electrophysiological measure of focusing attention on the potential target items increased in lockstep with the speeding of subjects' behavioral responses to the target objects. These neural data demonstrate that imagery training improves the focusing of attention better than practicing the same task with visual input. Using a variant of the paradigm we developed we show that imagery can also induce greater interference than simple task practice, demonstrating the downside of this potent training technique. Next, we replicated the findings and provide a more precise parametric manipulation of the amount of imagined practice to completely characterize the nature of this new phenomenon. Finally, we determine the source of the superiority of imagery over vision. We show that imagining performing the task is superior to actual practice due to memory representations of the task-irrelevant items accumulating during actual practice.

54.26, *3:45 pm* **Creating shortcuts in the visual hierarchy: improving saccadic reaction time and accuracy with RSVP training** Jacob Martin[1] (jacobgmartin@gmail.com), Maximilian Riesenhuber[2], Simon Thorpe[1]; [1]CNRS Center for Brain and Cognition (CerCo), [2]Georgetown University Medical Center, Department of Neuroscience

Humans can initiate ultrafast saccades towards face as early as 100ms post-stimulus onset (Crouzet & Thorpe, 2010, J Vis). However,other object classes, such as cars or animals, have slower mean saccadic reaction times and lower overall saccadic accuracy in comparison to faces. Based on the theory of Spike Timing Dependent Plasticity, which predicts that local input statistics can drive the learning of representations in the visual hierarchy, we hypothesized that an RSVP-based training paradigm, in which a large number of different stimuli could be presented per unit of time, might lead to stimulus-driven plasticity in lower visual areas which would improve saccadic speed and accuracy towards the trained object class. To test this hypothesis, subjects were shown 12hz RSVP streams of cluttered images containing randomly embedded 2° cars at 8 different positions, each at 9° eccentricity. Following 10 minutes of RSVP training,

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saccade latencies to car targets showed a strong and selective decrease, from a mean of 216ms pre-training to a mean of 167ms post-training (p< 0.005). This speed-up in car localization was not the result of a speed-accuracy tradeoff, as accuracy on car detection likewise increased (from 55% to 66%). We also simultaneously recorded EEG while the subject performed the localization task, and found that post-training, target location for cars could be predicted starting at 81ms after stimulus onset. These results suggest that it is possible to rapidly train neural representations in early visual areas which effectuate shortcuts in the visual hierarchy.

Acknowledgement: Funded by ERC Advanced Grant N° 323711 (M4) and ANR-NSF NEI R01EY024161,

54.27, *4:00 pm* The rise and fall of hybrid visual and memory search

Todd Horowitz[1] (todd.horowitz@nih.gov); [1]Basic Biobehavioral and Psychological Sciences Branch, Behavioral Research Program, National Cancer Institute

In hybrid search, observers search through arrays of visually presented items for any of a set of targets held in memory; think of looking on a store shelf for items on your grocery list, searching luggage x-rays for potential banned items, or chest x-rays for signs of cancer. As the size of the memory sets used in hybrid search increased, descriptions of the RT by set size function moved from linear (Shiffrin & Schneider, 1977) to logarithmic (Wolfe, 2012). In order to study hybrid search at larger set sizes, with greater resolution, and as a function of expertise, I utilized the Airport Scanner (Kedlin Co., www.airportscannergame.com) dataset (see Mitroff and Biggs 2014). Airport Scanner is a game for mobile devices, which simulates searching through baggage x-rays for threats under time constraints. Players move through five ranks as they acquire game expertise, from "Trainee" to "Elite". Critically, new items are added to the list of potential threats as the game progresses. Eliminating trainees to reduce potential learning effects, I analyzed only trials (bags) with a single target. This left 3,491,664 trials from 18,595 players. Memory set size(potential threats) ranged from 3 to 155 items. Visual set size had no influence on performance. For set sizes from 6-12, the logarithmic relationship held. However, across the full range of set sizes, at all expertise levels, reaction time was best described as a quadratic, rather than logarithmic, function of set size. For the low expertise groups, the curve opened upward, while at high expertise, it opened downward. These data suggest that encoding and retrieval strategies in hybrid search change in a complex fashion as the size of the memory set increases, and as observers gain more expertise with the task. Models developed for small set sizes may not generalize to realistically large set sizes.

Visual Memory: Neural mechanisms

Tuesday, May 19, 5:15 - 7:15 pm

Talk Session, Talk Room 1

Moderator: Nicholas Turk-Browne

55.11, *5:15 pm* Neural represenations of category information in viual short-term memory

Bobby Stojanoski[1,2] (bobby.stojanoski@gmail.com), Rhodri Cusack[1,2,3]; [1]Brain and Mind Institute, University of Western Ontario, [2]Department of Psychology, University of Western Ontario, [3]Medical Biophysics, University of Western Ontario

The neural code underlying the representation of complex natural objects in visual-short term memory (VSTM) is poorly understood. Recent findings have highlighted the role of key brain regions underlying VSTM processing, but many of these studies have relied on simple low-level features such as colour. The current study employed functional Magnetic Resonance Imaging (fMRI) and multi-voxel pattern analysis (MVPA) to examine the underlying neural representations of maintaining animate (e.g. animals) and inanimate (e.g. tools) objects in VSTM. To isolate low-level features from semantics, we implemented a novel diffeomorphic warping algorithm to generate versions of each image that varied in their degree of distortion. "High" warp images contained the same basic visual features as "low" warp images but contained no semantic information. Participants performed a whole report task in which they were asked to identify a probe (held in VSTM for 1 to 10 seconds) from a set of 15 distractors aligned along the contour of a wheel that parametrically deviated from the remembered item. Behaviourally, we found that images containing semantic information ("low" warp) were remembered more precisely than images with only low-level properties ("high" warp) irrespective of semantic category. Univariate fMRI analysis revealed stronger bilateral activity in anterior visual areas when maintaining objects containing semantic information ("low" warp condition) in VSTM. Additionally, animate objects evoked more activation in these areas than inanimate objects. Similarly, MVPA also showed differences related to warping level and animacy. Specifically, the pattern of activity during VSTM in parietal cortex was significantly different between "high" and "low" warped images, with differences in the pattern of activity in temporal cortex for remembering animate vs. inanimate objects in both warping conditions. Our results demonstrate that distinct cortical areas are recruited for maintaining semantic and low-level information about complex natural objects in VSTM.

55.12, *5:30 pm* Theta Oscillations Track the Content of Representations Retrieved from Long Term Memory

David Sutterer[1] (sutterer@uoregon.edu), David Anderson[1], John Serences[2], Edward Vogel[1], Edward Awh[1]; [1]University of Oregon, [2]University of California - San Diego

Recent work has demonstrated that it is possible to reconstruct orientation selective channel tuning functions (CTFs) during the encoding and delay period of a working memory (WM) task using a forward encoding model and electroencephalography (EEG). Specifically these CTFs can be derived from the distribution of alpha-band (8-12hz) activity across the scalp (Anderson et al. 2014), providing a high temporal resolution measure of the content and quality of WM representations. The goal of the present work was to determine whether we could employ a similar approach to track the content of representations retrieved from long term memory (LTM). Subjects (n = 24) learned randomly assigned colors for a collection of 120 unique shapes, with the color selected from a continuous 360 degree space. Twenty four hours after the initial learning session, subjects were presented with shape cues and asked to retrieve the associated color while EEG was recorded. We found that robust color-selective CTFs could be obtained from the distribution of evoked theta-band (4-7 hz) activity during the first 400 ms following the onset of the shape cue. We replicated this pattern of results with a spatial LTM task identical to the color task save that subjects learned and reported the position of 120 unique shapes from 360 degrees of space around a circle (n = 26). Together these results reveal that the content of representations retrieved from LTM is tracked by phasic activity in the theta-frequency band, and that this pattern of results generalizes across visual features. These findings dovetail with the longstanding consensus that low frequency activity in the theta band is integral to LTM function, and they provide a powerful new method for measuring the temporal dynamics of LTM retrieval.

55.13, *5:45 pm* Electrophysiology reveals distinct neural mechanisms for lateralized and spatially global visual working memory representations.

Keisuke Fukuda[1] (keisuke.fukuda@vanderbilt.edu), Min-Suk Kang[2], Geoffrey Woodman[1]; [1]Department of Psychological Sciences, Vanderbilt University, [2]Department of Psychology, Sungkyunkwan University

Visual working memory (VWM) allows us to actively maintain a limited amount of information. To study the neural basis of its limited capacity, electrophysiological studies have traditionally employed a task in which participants remember items presented in a cued hemifield, while ignoring the items in the other hemifield. Such studies have successfully identified lateralized neural correlates of VWM capacity by measuring a sustained negativity over the contralateral hemisphere to the cued hemifield relative to the ipsilateral hemisphere (e.g., the contralateral delay activity, or the CDA, Vogel & Machizawa, 2004). Another line of work measured lateralized alpha power modulations and proposed that these oscillations may underlie the CDA and measure this same lateralized VWM representation (Sauseng et al, 2009; Mazehari & Jensen, 2008). However, recent fMRI studies have reported that VWM representations can be decoded not only from the contralateral hemisphere, but also from ipsilateral hemisphere (Ester, Serences, & Awh, 2011; Pratte & Tong, 2014). To test whether this spatially global spread of the VWM representations can be measured electrophysiologically, we ran two experiments in which we independently manipulated the number of targets and distractors. We found that irrespective of the number of distractors, the CDA tracked the number of items held in VWM, thus indexing the contralateral VWM representations. In contrast, the parieto-occipital alpha power over both hemispheres tracked the number of items held in VWM, thus indexing the spatially global VWM representations. These findings are consistent with the previous fMRI findings indicating the existence of spatially global VWM representations. In addition, our findings suggest the event-related potentials and alpha-band oscillations index different neural mechanisms that appear to map onto lateralized and spatially global representations, respectively.

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55.14, *6:00 pm* **Visual working memory representations are distributed throughout human cortex.** Edward Ester[1] (eester@ucsd.edu), Thomas Sprague[1,2], John Serences[1,2]; [1]Department of Psychology, University of California, San Diego, [2]Neurosciences Graduate Program, University of California, San Diego

Visual working memory (WM) enables the representation and manipulation of fleeting visual information. Invasive neurophysiological recordings and human neuroimaging studies have revealed sustained increases in neural activity (e.g., single- and multiunit firing rates) and/or activation (e.g., the amplitude of the blood-oxygenation-level-dependent response) within a network of prefrontal, parietal, and inferotemporal cortical regions during WM storage, but it is unclear whether these responses encode memoranda or instead reflect top down signals that coordinate storage in posterior sensory areas. To examine these alternatives, we asked participants to remember and recall the precise orientation of a lateralized grating after a 10 second blank delay. Using fMRI and an orientation encoding model, we were able to reconstruct spatially global representations of a remembered – but not a forgotten – orientation within multiple subregions of retinotopically organized visual and inferior parietal cortex (e.g., Ester et al., VSS 2014). Next, we used this method to explore putative representations of the remembered orientation across regions of frontal, parietal, and temporal cortex (identified using general linear model-based localizers and/or a roving searchlight analysis). We obtained robust representations of a remembered – but not a forgotten – orientation across a distributed network of frontal and parietal cortical regions, including (but not limited to) bilateral inferior and superior parietal lobule (IPL), bilateral medial and inferior frontal gyri (IFG), bilateral cingulate cortex, and bilateral inferior temporal gyri (ITG). Moreover, trial-by-trial fluctuations in the relative "quality" of reconstructions observed in visual cortex as well as a set of left-lateralized frontoparietal and temporal ROIs (e.g., MFG, ITG) were robustly correlated with fluctuations in memory performance. These results suggest that WM representations are encoded and represented by a diffuse network of posterior sensory and anterior multimodal cortical areas.

55.15, *6:15 pm* **Recovery of degraded information in visuospatial working memory representations in occipital, parietal and frontal cortex** Thomas Sprague[1] (tsprague@ucsd.edu), Edward Ester[2], John Serences[1,2]; [1]Neurosciences Graduate Program, UC San Diego, [2]Department of Psychology, UC San Diego

Working memory (WM) is a core cognitive function that enables the maintenance of information no longer present in the environment for guidance of behavior. When more information must be maintained, recall precision is impaired (e.g., Bays & Husain, 2008). Using a multivariate image reconstruction technique (Sprague & Serences, 2013), we recently demonstrated that item representations carried by fMRI activation patterns degrade with increasing memory load (Sprague, Ester & Serences, 2014). However, it is not clear if degraded item representations are permanently corrupted due to rapid degradation at encoding, or whether multiple representations mutually suppress each other during retention. If the latter were true, removing an item from WM midway through a long delay interval would resuscitate the fidelity of a degraded representation. To evaluate this possibility, we required participants to precisely maintain either one or two spatial positions in WM during a long delay interval (16 s). On half of trials when two items were maintained, participants were post-cued 8 s into the delay about which item would be queried at the end of the trial with 100% validity, so that they could "drop" the irrelevant item from WM. Though WM recall precision was behaviorally impaired with increasing set size, when a second item was dropped recall performance recovered to that when a single item was maintained. We computed spatial reconstructions using activation patterns from both the first and second half of the WM delay interval. After one item had been dropped from WM, we observed robust recovery of the remaining target representation over the dropped target representation. Together, these results suggest that multiple simultaneous representations can mutually inhibit each others' fidelity (Franconeri et al, 2013). When one of several items is removed from WM, the normalization drive is reduced, allowing the remaining item representation to rebound in fidelity.

Acknowledgement: NSF GRFP (TS), NIMH R01-MH092345 (JS), James McDonnell Foundation (JS)

55.16, *6:30 pm* **Hippocampal representations of attentional state predict the formation of visual memories** Mariam Aly[1] (aly@princeton.edu), Nicholas B. Turk-Browne[1,2]; [1]Princeton Neuroscience Institute, Princeton University, [2]Department of Psychology, Princeton University

Attention does not only modulate what we see, but also what we remember about an experience. Despite this connection in behavior, little is known about how attention influences the formation of memories in the brain. Using high-resolution fMRI, we investigated the hypothesis that attentional states are represented in the hippocampus — a brain region necessary for long-term memory — and that the quality of these representations during encoding influences whether the attended information is later remembered. The study consisted of three phases. In Phase 1, observers performed an attention task in which, on every trial, they were presented with an image consisting of a room with a painting and then searched through a stream of four other images. The search target was specified by a cue at the beginning of the trial: either a painting from the same artist (art state) or a room with the same layout (room state). We then used all trials of each attentional state to identify an average pattern of activity within each hippocampal subfield that corresponded to the representation of that state. Phase 2 used an incidental encoding design: observers performed a 1-back task with trial-unique images (rooms with art), attending to the art in one block and the room layouts in the other. Memory for the attended feature of each image (art or room) was tested in Phase 3. We predicted that when observers correctly remembered a feature (e.g., spatial layout), it was because their hippocampus was more strongly in an attentional state that prioritized that feature (e.g., room state) during encoding. This was measured by correlating trial-by-trial activity patterns from Phase 2 with the state representations from Phase 1. Our predictions were confirmed in the CA2/3 subfield of the hippocampus. Together, these results offer a mechanistic window into how attention enhances memory.

Acknowledgement: NIH R01 EY021755

55.17, *6:45 pm* **Reprioritization of features of multi-dimensional objects stored in visual working memory** Young Eun Park[1,2] (youngeun.park@vanderbilt.edu), Jocelyn Sy[1,2], Frank Tong[1,2]; [1]Psychology Department, Vanderbilt University, [2]Vanderbilt Vision Research Center

A prevalent view of working memory is that visual information is actively maintained in the form of perceptually integrated objects. Such a reliance on object-based representations would lead one to expect that after an object is fully encoded into working memory, all features of that object would need to be maintained as a coherent unit. Here, we evaluated the predictions of this object-based account by testing whether observers can prioritize specific features of an object, after that object is fully encoded in working memory. On each trial, participants were presented with two sample gratings that varied in color and orientation (700 ms), followed by a mask array (100 ms) after a 200-ms interval. Both features were equally relevant at this encoding stage. Critically, at 500 ms into the retention period, participants either received a feature cue that indicated with 80% validity which feature dimension was most likely to be subsequently probed, or a neutral cue that provided no information, requiring maintenance of all the encoded features. Following the cue onset, participants maintained the features for a variable duration (2-4s) until they were asked to report either color or orientation of one of the items by adjusting the feature appearance of a probe stimulus. We used a mixture model (Zhang & Luck, 2008) to separately estimate the number and precision of successfully remembered features. Compared with the neutral cue, the feature cue led to improved memory precision for the cued feature, as well as a rapid increase of memory failure for the uncued feature. Our results demonstrate that working memory resources can be redeployed across features of objects during maintenance, conferring enhanced precision and temporal stability to the prioritized features.

Acknowledgement: NSF grant BCS-1228526

55.18, *7:00 pm* **Neural coding of object knowledge reflects the co-occurrence statistics of the environment** Amy Price[1] (amyroseprice@gmail.com), Michael Bonner[1], Jonathan Peelle[2], Murray Grossman[1]; [1]Center for Cognitive Neuroscience, University of Pennsylvania, [2]Department of Otolaryngology, Washington University in St. Louis, St. Louis, MO

Our knowledge of objects reflects the statistics of the visual environment. From our experiences in the world, we store information about categories of objects and the features that define them. One important statistical property of objects is the co-occurrence of their constituent features. For example, the round shape of an apple co-occurs frequently with the color red, but not the color blue. Here we examine the neural mechanisms that encode such feature co-occurrence statistics at the interface of perception and memory. In an fMRI experiment, subjects viewed images of colored objects while performing an unrelated scrambled-object detection task. The stimuli included exemplars from three different categories: apples, leaves, and roses. To create stimuli that sampled a range of co-occurrence statistics, each exem-

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plar image had its color systematically manipulated to be red, pink, yellow, green, or blue (Fig.1A). We quantified co-occurrence frequencies of color-object combinations (e.g., "yellow apple") in a large lexical corpus. A separate norming study demonstrated that this metric was strongly correlated with subjective ratings of color-object typicality. Importantly, the co-occurrence of object and color information is independent of the frequencies of each feature alone. We tested the hypothesis that feature co-occurrence information is encoded in semantic memory regions and automatically retrieved during object perception. Using representational similarity analysis, we identified regions where response patterns were similar for category exemplars with similar co-occurrence statistics (Fig.2B). We expected that the angular gyrus would encode combinatorial information given its proposed role in semantic integration. Indeed, we found that this region and the anterior fusiform cortex encode high-level feature co-occurrence statistics, while early visual cortex, lateral-occipital complex, and inferior-temporal cortex did not. These results suggest that regions at the interface of vision and semantic memory encode combinatorial information that underlies real-world knowledge of objects and is independent of coding for individual features.

Perceptual Organization

Tuesday, May 19, 5:15 - 7:15 pm
Talk Session, Talk Room 2
Moderator: Steven Dakin

55.21, *5:15 pm* Dissociations and associations between shape and category representations in the two visual pathways.

Stefania Bracci[1] (stefanie.bracci@gmail.com), Hans Op de Beeck[1]; [1]Laboratory of Biological Psychology, KU Leuven, Belgium

Accumulating evidence suggests that both visual pathways encode object structural properties (e.g., shape) as well as semantic representations (e.g., categories). In theory, the two codes could coexist in one representation reflecting both visual and semantic information. However, in practice, the recent literature is filling with reports that try to prove one by disproving the other. We present an event-related fMRI study that explicitly dissociates shape from category with a two-factorial design, allowing us to investigate the independent contribution of the two factors as well as their interactions. In 14 participants, we measured responses to 54 images comprising 6 semantic categories (minerals, animals, fruits/vegetables, musical instruments, sport items, tools) and 9 shape types. Our analyses included 15 regions of interest (ROIs) that altogether covered a large cortical area comprising both visual pathways. To investigate how information about object shape and category is distributed throughout the ventral and dorsal stream, dissimilarity matrices derived from similarity judgments acquired on both dimensions were compared with neural dissimilarity matrices derived from ROIs' multi-voxel activity patterns. Results revealed an independent contribution from each dimension in both visual pathways, with a transition from shape-preferring ROIs to category-preferring ROIs along the posterior-to-anterior anatomical axis. Interestingly, although both ventral and dorsal areas encoded object category, the nature of their representations largely differed; whereas the animate/inanimate division was primarily observed in ventral stream areas, dorsal stream areas distinguished objects based on their action-related properties. Furthermore, information content about shape evolved – from low-level (silhouette) shape to high-level (perceived) shape – from posterior to anterior areas, highlighting the same gradient along which category selectivity emerges. Our results show that representations of shape and category independently coexist and at the same time interact throughout the visual hierarchy, as such reconciling visual and semantic accounts of the functional organization in the visual system.

55.22, *5:30 pm* A canonical circuit for visual contextual integration explains induction effects across visual modalities

David Mély[1,2] (david_mely@brown.edu), Thomas Serre[1,2]; [1]Department of Cognitive, Linguistic and Psychological Sciences, Brown University, [2]Institute of Brain Science, Brown University

The perception of a stimulus is largely determined by its surrounding. Examples abound from color (Land and McCann, 1971) and motion induction (Anstis and Casco, 2006) to orientation tilt effects (O'Toole and Wenderoth, 1976). Many of these phenomena have been studied separately using monkey neurophysiology techniques. In these experiments, a center stimulus coincides with a cell's classical "center" receptive field (cRF), whose activity is modulated by an annular, extra-cRF "surround" stimulus. A large and disparate body of work in electrophysiology has shown the prevalence of such center-surround integration (CSI); however, we are still lacking a common unifying mechanism across visual modalities. Here, we present an extension of a popular cortical inhibition circuit, divisive normalization (Carandini and Heeger, 2011), which yields a computational model that is consistent with psychophysical data across visual modalities. We have found that a common characteristic of CSI across modalities is a shift in neural population responses induced by surround activity. Typical implementations of the divisive normalization model rely on gain control mechanisms from an 'untuned' suppressive pool of cells; that is, the identity of that pool is the same for every cell being suppressed. As such, the circuit cannot account for the selective shift in population response curves observed in contextual effects. In contrast, we show that the addition of a suppressive 'tuned' pool of cells which selectively inhibits different parts of a population response curve is sufficient to explain complex shifts in population tuning responses. Overall, our results suggest that a normalization circuit based on two forms of inhibition, gain control and selective suppression, captures shifts in population responses associated with center-surround integration and yields a model that is consistent with contextual phenomena across visual modalities.

55.23, *5:45 pm* Parametric responses to rotation symmetry in mid-level visual cortex

Peter Kohler[1] (pjkohler@stanford.edu), Alexandra Yakovleva[1], Alasdair Clarke[2], Yanxi Liu[3], Anthony Norcia[1]; [1]Department of Psychology, Stanford University, [2]School of Psychology, University of Aberdeen, [3]Department of Computer Science and Engineering, Penn State University

Symmetry is a fundamental principle of perceptual organization that contributes to multiple aspects of vision, running the gamut from judgments of aesthetics and mate selection, to shape processing and surface orientation. Crystallographic group theory categorizes all possible two-dimensional repetitive patterns into 17 wallpaper groups, as unique combinations of the four fundamental symmetries: mirror reflection, translation, rotation and glide reflection (Liu et al., 2010). We have developed an algorithm that can generate a near-infinite number of well-controlled exemplars belonging to each of the 17 wallpaper groups. Here, we focus on four wallpaper groups that all contain rotation symmetry exclusively – only differing in the maximum order of rotation symmetry found in each group. We use an fMRI block design that isolates the symmetry-specific BOLD response by alternating group exemplar images with matched control images. Using scalp EEG, we have previously shown that the neural responses to the groups increase linearly with maximum order of rotation symmetry (Kohler et al., VSS 2014), indicating that rotation is represented parametrically. Our fMRI experiment (n=12) localizes this parametric effect in several extra-striate areas of human visual cortex (V4, VO1, LOC), while other visual areas have little response to rotation symmetry (e.g. MT). Interestingly, the parametric response is also seen in V3, an area that has previously been found to have little or no response to mirror symmetry (Sasaki et al 2005). The fact that V1 and V2 do not show the effect suggests a functional distinction between V3 and earlier visual areas. Neurons in intermediate-level visual areas like V4 have complex and diverse response properties (Roe et al., 2012) that are difficult to characterize systematically (Gallant et al., 1996). These results present a novel, well-defined stimulus set, the wallpaper groups, that can drive V4 and other mid-level visual areas in a robust and systematic way.

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55.24, *6:00 pm* Differentiating Local and Global Processes in Amodal Completion Through Dot Localization

Susan Carrigan[1] (susancarrigan@ucla.edu), Evan Palmer[2], Philip Kellman[3]; [1]Psychology, Life Sciences, University of California, Los Angeles, [2]Psychology, Fairmount College of Liberal Arts and Sciences, Wichita State University, [3]Psychology, Life Sciences, University of California, Los Angeles

Competing theories of perception of partly occluded objects (amodal completion) have emphasized local contour interactions or global influences of symmetry and/or familiarity. These theories may reflect two different processes: a contour completion process and a more global recognition process. The two could be distinguished experimentally if only the former gives rise to precise boundary representations. Using a dot localization paradigm, we assigned participants to either a local or a global condition, which determined how the participant was instructed to complete objects with divergent local and global interpretations. On each trial, a small red dot was flashed on top of an occluder. Subjects reported whether the dot fell inside or outside of the occluded object's boundaries. Interleaved adaptive 2-up, 1-down staircases were used to estimate two points on the psychometric function: the point, in terms of pixels away from the boundary, where the probability was .707 that the dot would be seen as outside of the occluded object's boundaries (outer threshold), and the point where the probability was .707 that the dot would be seen as inside the occluded object's boundaries (inner threshold).

We examined imprecision, measured as the distance between these two thresholds. We also examined perceived location, defined as the mean of the inner and outer thresholds, as well as location error, measured as the absolute value of location. The results reveal that local contour interpolation produces precise and accurate representations of occluded contours, but completion according to mirror symmetry does not. This supports our hypothesis of two separate processes in contour completion: A low-level, local process completes contours according to local geometry and outputs a precise representation of interpolated contours; whereas a global recognition process outputs at least a decision regarding the likely shape of an object but does not produce precise representations of occluded contours.

55.25, *6:15 pm* **The shrunken finger illusion: Amodal volume completion can make your finger feel shorter** Vebjørn Ekroll[1] (vebjorn.ekroll@ppw.kuleuven.be), Bilge Sayim[1], Ruth van der Hallen[1], Johan Wagemans[1]; [1]Laboratory of Experimental Psychology, University of Leuven (KU Leuven)

When we look at a complete ball, only the front half of it is directly visible. Hence, a semi-spherical shell producing the same retinal image is easily mistaken for a complete ball. Given that the backside of a ball (or a corresponding semi-sphere) is hidden from direct view, it appears tempting to conceive of this kind of mistake as a rather mundane failure of cognitive guesswork. A more counter-intuitive hypothesis, however, which can be traced back to Michotte's early work on amodal completion is that the semi-spherical shell is completed into a full ball by processes of a genuinely perceptual nature. Here, we present an illusion of bodily self-awareness that lends strong support to the latter hypothesis. When a semi-spherical shell is put on the observer's own finger and viewed from above, the shell looks like a complete ball despite the availability of conflicting proprioceptive information from the finger in the shell. Instead, the finger is felt to be shortened, as if to make space for the illusory volume of the amodally completed ball. We quantified this illusion by asking observers to point to the felt location of their fingertip while balancing a semi-spherical shell on top of it. We found that the illusory shortening of the finger increases linearly with the radius of the shell, as would be expected if the illusory finger shortening depends on the amount of space necessary for amodal volume completion of the semi-sphere. On average, our measurements indicate that the illusory shortening of the finger corresponds to about 23 percent of the diameter of the shell, irrespective of its absolute size. These results provide strong evidence for the idea that our experience of the hidden backsides of objects is shaped by genuinely perceptual processes.

Acknowledgement: This work was supported by the Methusalem program by the Flemish Government (METH/08/02), awarded to JW. VE and BS are FWO Pegasus Marie Curie fellows.

55.26, *6:30 pm* **Can you simultaneously represent a figure as both an object and an open contour? Hybrid shape representations revealed by the "tap-the-shape" task** Chaz Firestone[1] (chaz.firestone@yale.edu), Brian Scholl[1]; [1]Department of Psychology, Yale University

Some figures are irresistibly seen as complete objects. Others are represented as mere collections of line segments. How does the visual system represent figures in between these extremes — say, when part of a figure strongly suggests a complete object, while another part strongly suggests an open contour? More generally, how do we represent figures that are ambiguous or underdetermined with regard to 'shapehood'? We explored these questions using the "tap-the-shape" task, which reveals the so-called "skeletons" (internal symmetry-defined geometric structures) that underlie human shape representation: when a subject is shown a shape on a touch-sensitive tablet computer and is instructed simply to tap the shape once anywhere they please, the aggregated taps from hundreds of observers collectively form that shape's skeleton (Firestone & Scholl, 2014, Psychological Science). Here we exploit this striking phenomenon to ask a more fundamental question: what is a shape in the first place? Across several experiments, we showed thousands of observers ambiguous or incomplete shapes, and asked them to tap "inside" those figures (with one tap and one shape per subject). Remarkably, ambiguous figures — e.g. a rectangle with one missing edge — were represented in a hybrid manner: touches near the 'inside' edge formed clear skeletal branches, while touches near the open edge devolved into noise. We also tested 'open' figures that were ambiguous between multiple complete interpretations. For example, a trapezoid missing its top edge — which can be seen as either a trapezoid or a triangle — was tapped as though it had both the shape skeleton of a triangle and the shape skeleton of a trapezoid. We discuss the significance of these apparent hybrid representations for theories of shape, and for use of the "tap-the-shape" method to study previously stubborn questions about visual representations.

55.27, *6:45 pm* **Predicting shape variations from single exemplars** Roland Fleming[1] (roland.w.fleming@psychol.uni-giessen.de); [1]Department of Experimental Psychology, University of Giessen

Different objects and materials—such as shoes, starfish or ice-cream—have distinctive shapes that we readily perceive and use to recognize and categorize them. But where do those shapes come from in the first place? Objects and materials end up with particular shapes due to some kind of generative process, such as manufacture, biological growth, aging and weathering, or self-organization in response to external forces. These generative processes specify the 'rules' and 'parameters' that shape things and stuff into specific forms. Here, I suggest that when we view novel shapes, we infer a (primitive) model of the underlying generative processes and that this model facilitates us in many tasks related to shape and material perception, including: (a) identifying physical properties (e.g., viscosity, elasticity, ductility); (b) predicting future states as the sample moves and interacts with other things; (c) judging similarity between different shapes and (d) predicting what other members of the same category might look like ('plausible variants'), even when you've only seen one or a few exemplars. Subjects were shown single exemplars of novel objects ('seed object') that were created by specific generative processes. They were then asked to rate the 'similarity' and 'plausibility' of other novel objects ('variants'). Some of the variants were created by parametric variations of the same generative process, while others were generated by a different process. Variants that were created by the same generative process as the seed were judged as more similar and more plausible variants of the seed object than variants that were equally similar in Euclidian terms but which were created by a different generative process. This suggests generative models play an important role in shape representation. A model based on identifying statistical regularities in the shape hints at how the visual system could infer generative models from single exemplars.

Acknowledgement: DFG funded SFB TRR-135

55.28, *7:00 pm* **Visual coding of natural contours leads to poor discrimination of object-shape around canonical views** Steven Dakin[1] (s.dakin@auckland.ac.nz), Rosilari Bellacosa Marotti[2]; [1]Optometry & Vision Science, University of Auckland, Auckland, New Zealand, [2]Department of General Psychology, University of Padua, Padua, Italy

Although progress has been made in understanding how we detect visual contours we know much less about how we encode their shape. Here we describe a psychophysical paradigm that does this by quantifying the perceptual similarity of complex contours: observers decided which of three outline contours (strings of Gabors derived from silhouettes of natural objects) was the "odd-man-out" (where one was derived from a subtly different 3D view of the same object). We estimated the minimum perceptible contour change (i.e. rotation-in-depth) for different starting views of a 3D hand-object. We report poorest discrimination of contours around canonical views ("characteristic" or "typical" object views); small rotations in non-canonical ("unusual") views tend to have more readily perceptible consequences leading to better performance. This finding extends to other objects, and is robust to random-scaling of contours, to randomization of local orientation structure, and even to replacement of oriented elements with non-oriented Gaussian blobs. We compared our results to predictions from a simple model of shape similarity using cross-correlation of silhouette-images.

Tuesday Afternoon Posters

Perceptual Learning: Higher-level processes and mechanisms

Tuesday, May 19, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

56.3001 **Perceptual Training and Competition for Representation in Visual Cortex** Paige Scalf[1] (paige.scalf@durham.ac.uk), Samantha Srivathsan Koushik[2], Autri Hafezi[2], Erica Wager[2], Jonathan Folstein[3]; [1]Department of Psychology, Durham University , [2]Department of Psychology, The University of Arizona , [3]Department of Psychology The Florida State University

When multiple stimuli simultaneously fall within the receptive fields of a common cell population, they compete fore representation via a series of mutually inhibitory interactions (e.g. Duncan & Desimone, 1995). Competition is reduced if the items form a single perceptual entity, either due to lower level perceptual grouping factors such as shape or color (McMains & Kastner, 2010) or higher level relationships such as actions affordance (e.g. Wager, Humphreys & Scalf, 2014). In this study, we investigate whether the relationships that reduce competition among multiple stimuli can be learned in a brief series of perceptual training sessions (~five sessions). Participants learned to name individuals groups of five peripherally presented stimulus items. We measured blood oxygen-level dependent BOLD activity evoked in visual cortex by the trained stimulus configuration and compared it with that evoked by the same stimuli presented in untrained configurations. Competition for representation was quantified by comparing signal evoked when stimuli were presented simultaneously (and were thus likely to compete for representation) with that evoked by stimuli that were presented sequentially (and were thus unlikely to compete for representation). Preliminary data indicate that stimuli compete less for representation when presented in trained than in untrained configurations. The relationships that allow multiple stimuli to be simultaneously represented can be acquired after relatively brief sequences of perceptual training.

Acknowledgement: Wolfson Resrach Institute for Health and Wellbeing

56.3002 **Perceptual learning for multiple features: Neural correlates of changes in RT-based measures of processing dependencies** Michael Wenger[1,2] (michael.j.wenger@ou.edu), Stephanie Rhoten[1]; [1]Psychology and Cellular & Behavioral Neurobiology, The University of Oklahoma, [2]Division of Nutritional Sciences, Cornell University

We previously (VSS 2014) reported EEG and behavioral data (response frequencies) supporting the hypothesis that that perceptual learning can be obtained with multiple features and that learning involves the development of non-independence at perceptual and decisional levels. This is consistent with evidence suggesting that multiple levels of processing and representation may be involved in perceptual learning. The present study explores these notions using EEG and response times (RTs), testing the hypothesis that learning of multi-feature patterns results in processing that is non-independent and parallel, as would be expected if the stimuli were learned as integral objects. Stimuli contained contrast-defined features, extracted from the 1865 drawing of the Cheshire Cat in Alice's Adventures in Wonderland. Participants began by performing a detection task implemented as a double-factorial paradigm (DFP), in which stimuli contained 0, 1, or 2 targets, at two levels of contrast, and were instructed to give a positive response if they judged the stimulus to have either 1 or 2 targets. They then practiced with all possible stimuli for 10-15 days, using an adaptive staircase procedure to track thresholds. Finally, they again performed the DFP detection task with stimuli presented at threshold and the two initial levels of contrast. EEG data were collected during both pre- and post-practice performance of the CID. Analysis of the RT data, at both the level of the mean and the distribution, suggested that the stimuli were initially processed serially, with practice resulting in a transition to dependent parallel processing and modulations of amplitudes of early ERP features, pre- and post-stimulus spectral power, and reductions in post-stimulus g-band power, selective to frontal electrodes. These results are consistent with the idea that perceptual learning of multi-feature patterns produces shifts in fundamental characteristics of processing consistent with the learning of an integral object.

56.3003 **Perceptual Learning on Simultaneity and Temporal Order Judgments** Nestor Matthews[1] (matthewsn@denison.edu), Leslie Welch[2], Rebecca Achtman[1]; [1]Department of Psychology, Denison University, [2]Cognitive & Linguistic Sciences, Brown University

Introduction: Prior research on bilateral-stream Rapid Serial Visual Presentation (RSVP) displays reveals that participants often perceive left visual field (LVF) targets significantly sooner than right visual field (RVF) targets (Matthews, Welch, Festa & Clement, 2013). The hastened perception of LVF targets occurs for temporal order judgments (TOJs) but not simultaneity judgments (SJs) on the same stimuli. This demonstrates task-specific neural events for time perception. Here, we investigated the extent to which task-specific neural events govern time discrimination by evaluating whether training differentially affects the precision of SJs and TOJs. Method: Twenty Denison University undergraduates viewed bilateral-stream RSVP displays containing two targets, one in each lateral hemifield, shown either simultaneously or at various asynchronies. Half the participants judged the targets' temporal order (TOJ task), and half judged whether the targets appeared simultaneously or not (SJ task). Retinal stimulation remained identical across the SJ and TOJ tasks. Each participant completed two daily training sessions. Collectively, the participants completed 24,000 trials (600 trials per day * 2 days * 10 participants per task * 2 tasks). We assessed temporal precision using standard signal detection procedures to determine d'. Results: On each task and each day, the precision of SJs and TOJs increased significantly with target-asynchrony magnitude (logarithmic trends, p's≤0.05), demonstrating significant stimulus-control over the participants' responses. At each target asynchrony, mean TOJ precision increased significantly (p's≤0.05) from day 1 to day 2. The practice-based improvement observed on TOJs significantly exceeded that observed on SJs (p's=3.04E-05), which exhibited non-significant precision decreases on day 2. Conclusion: In principle, precision on SJs and TOJs could depend on a shared computation, namely, the difference between two arrival times. Despite this, our perceptual learning data suggest a dissociation between the neural events mediating SJ and TOJ precision even when stimulation remains identical across tasks.

Acknowledgement: N/A

56.3004 **The neural correlates of medical expertise.** Liam Rourke[1] (lrourke@ualberta.ca), Verena Willenbockel[2], Leanna Cruickshank[3], Jim Tanaka[4]; [1]University of Alberta Department of Medicine, [2]University of Victoria, Visual Cognition Lab, [3]University of British Columbia, [4]University of Victoria, Visual Cognition Lab

Previous research using event-related potentials (ERPs) has shown that the N170 component is enhanced when experts categorize objects in their domain of expertise relative to when they categorize objects outside of their domain (Tanaka & Curran, 2001). Here, we replicated Tanaka and Curran's study on bird and dog experts with medical experts in reading electrocardiography (ECG) and chest X-ray (CXR) images. 16 physicians (8 cardiologists, 8 pulmonologists) participated in the ERP study. On a scale of 1 (zero expertise) to 9 (much expertise), cardiologists and pulmonologists rated their expertise with ECG images as 8.50 and 5.75, respectively, and with CXR images as 5.00 and 7.63, respectively. On each of 520 trials, participants viewed one of 7 ECG or CXR patterns. The pattern image was preceded by a correct or incorrect label either at the basic ("ECG", "CXR") or subordinate (e.g., "attrial flutter", "pneumonia") level. Participants were asked to indicate with a key press whether the label and diagnostic image matched or not. A mixed ANOVA on the accuracy data from both groups showed a significant interaction between stimulus type and expertise—participants were better at categorizing ECG than CXR images, particularly the Cardiologists ($F = 5.8$, $p < .05$). Closely reflecting the behavioural results, a mixed ANOVA on the N170 mean amplitudes from correct trials showed a significant interaction between stimulus type, expertise, and hemisphere. The N170 was larger to ECG than CXR images, especially for Cardiologists, and in the right hemisphere ($F = 6.97$, $p < .05$). In contrast, no significant effects were found for the P100. These findings indicate that the N170 amplitude not only reflects object expertise but can also be modulated by expertise in pattern recognition.

Acknowledgement: University Hospital Foundation, University of Alberta

See page 3 for Abstract Numbering System

56.3005 **No correlations between the magnitude of visual illusions**

Lukasz Grzeczkowski[1] (lukasz.grzeczkowski@epfl.ch), Aaron Clarke[1], Fred Mast[2], Michael Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, [2]Department of Psychology, University of Bern, Switzerland

In cognition, audition and somatosensation, performance correlates strongly between different tasks suggesting the existence of common factors. Surprisingly, this does not hold true for vision. For example, Vernier acuity and Gabor detection correlate very weakly (r2 = 0.003). Here, we show similar results for visual illusions. 143 participants, aged from 8 to 81 were tested for illusion magnitude using the method of adjustment in six visual illusions. Correlations of illusion strength were very low and mostly non-significant. For example, the correlation between the Ebbinghaus and the Ponzo illusion was r2 = 0.07, i.e., the two illusions have only 7% of variance in common. Results for males and females were similar. Our null results are supported by good test-retest reliability and a Bayesian analysis. Our results suggest that, contrary to cognition, audition and somatosensation, there is no general factor for vision.

56.3006 **Does donepezil improve visual stimuli detection and perceptivo-cognitive performance of heathy young adults ?**

Mira Chamoun[1] (mira.chamoun@umontreal.ca), Frédéric Huppé-Gourgues[1], Isabelle Legault[2], Pedro Rosa-Neto[3], Jocelyn Faubert[2], Elvire Vaucher[1]; [1]Laboratoire de neurobiologie de la cognition visuelle, Ecole d'optometrie Université de Montreal, [2]Laboratoire de psychophysique et de perception visuelle, Ecole d'optometrie Université de Montreal, [3]Laboratoire de neuroimagerie translationnelle (LNT), Institut Douglas Université McGill

Donepezil enhances the cholinergic synaptic transmission in the brain by inhibiting the enzyme that metabolizes acetylcholine in the synaptic cleft, thereby prolonging the action of this neurotransmitter. It has been demonstrated that chronic administration of donepezil increases perceptual learning. Our study examines the effect of acute administration of donepezil on first and second order visual stimuli detection on one hand and on perceptual-cognitive performance on the other hand. A double-blind, placebo controlled design was used to evaluate the effect of cholinergic enhancement - donepezil administration (5 mg, given per os) - on visual attention using two different attention tasks. 10 young healthy adults were enrolled in each group. The task was performed 3 hours after the donepezil (or placebo) intake to synchronize with the peak plasma concentration of the drug. We started by testing the first and second order visual detection for motion and direction using the Neurominder task (Habak & Faubert, 2000) before and after taking donepezil. Motion and direction identification thresholds for the first order and second order visual detection were identical before and after donepezil intake. The multifocal attention of the participant was tested by the multiple object tracking task (Legault and Faubert, 2012). During this perceptual-cognitive task, the observer is required to simultaneously track multiple moving items among distracters in a dynamic virtual reality environment. The task is repeated once a week during 5 weeks to test the effect of learning. The speed thresholds in the MOT task increased significantly in each session in the same range for both donepezil and control groups. Our results suggest that an acute 5mg dose of donepezil might not be sufficient to elicit perceptual-cognitive or visual detection performance improvement when given to healthy young subjects. Additional studies are needed to better define the involvement of acetylcholine enhancement on perceptual learning/attentional tasks.

Acknowledgement: CIHR (MOP-111003) and NSERC (238835-2011)

56.3007 **Target selective tilt-after effect during texture learning**

Hila Harris[1] (hila.harris@weizmann.ac.il), Noga Pinchuk-Yacobi[1], Dov Sagi[1]; [1]Department of Neurobiology/Brain Research, Weizmann Institute of Science, Rehovot, Israel

In texture learning, observers are presented with repeated stimulations, resulting in within–day threshold elevation, as well as between day threshold reductions. Within-day deteriorations were shown to be location and orientation specific (Mednick et. al., 2002; Ofen et al., 2007). Accordingly, the declined performance was suggested to reflect sensory adaptation. Here we test whether extensive training produces adaptation dependent tilt after-effects (TAE). Six observers were trained for 5 days on the texture discrimination task (Karni & Sagi, 1991), 800-1000 trials/day. The target (40ms) was composed of 3 lines of 22.5o orientation, stacked vertically or horizontally (2AFC task), embedded in a background of -22.5o lines. The target was followed by a variable blank interval and a mask (100ms). Multiple tests of perceived vertical (PV) were carried out prior and after each daily session to evaluate TAE at four locations, corresponding to: a target line, +22.5o on all trials (T_+); both target and background lines, balanced, either +22.5o or -22.5o (T_0); and the two background locations, near (B_N) and far from the target (B_F). Results showed learning across days, with within-day deterioration that varied across days. There was a significant TAE immediately following TDT training at both target's locations, at T_+ (-1.6°±0.3, mean±SEM; p< 0.01) and, more surprisingly, at T_0 (-0.8°±0.2; p=0.03) but not at background locations (B_N, 0.3°±0.3; B_F, 0.3°±0.1). The persistence of the TAE varied across days, as indicated by successive PV tests; decaying faster at location T_+ (p=0.02), while persisting longer at location T_0 (p=0.02). Here we show that texture training induces a localized target-selective TAE, which in return has a training-dependent component. The absence of background TAE and the target-biased TAE at the balanced location indicate that aftereffects are not determined by stimulus statistics, but rather by experience-dependent task-relevance. This supports mutual interactions between sensory adaptation and perceptual learning.

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56.3008 **Position-specific learning in a texture identification task**

Patrick Bennett[1] (bennett@mcmaster.ca), Ali Hashemi[1], Allison Sekuler[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Stimulus-specific perceptual learning (PL) often has been found in relatively simple tasks that require observers to discriminate stimuli that vary along a single dimension. Such learning has been interpreted as showing that training alters the response properties of mechanisms in early visual cortical areas. Stimulus-specific PL also has been found in situations that are arguably more complex, namely identification tasks using filtered random textures that varied on multiple dimensions: PL does not transfer to contrast-reversed versions of the training textures or to textures rotated by 180 deg [Hussain et al., J Vis, 2009, 9(4):20]. Such findings suggest that PL may alter the response properties of mechanisms in higher-level visual areas such as inferotemporal cortex. One potential criticism of the Hussain et al. findings is that stimulus specificity was assessed using transformations that altered the spatial distribution of the black and white blobs in the textures, and essentially created a new set of stimuli. According to this argument, PL in a texture identification task may generalize to textures presented in different spatial locations, without altering the spatial distributions of features. We tested this idea by measuring accuracy in a 1-of-5 texture identification task. Practice on Day 1 consisted of interleaved trials with two different sets of textures: one set was presented slightly above the fixation point and the other was presented below the fixation point. On Day 2, subjects continued the task either with stimuli in the same positions seen during Day 1 or with the top-bottom positions switched. We found evidence for both generalized and stimulus-specific learning: presenting textures in new positions on Day 2 caused accuracy to decrease significantly, but not to levels seen at the beginning of Day 1. Hence, a component of learning in this relatively complex texture identification task is stimulus specific.

Acknowledgement: NSERC and Canada Research Chairs

56.3009 **Multiple-object tracking training benefits display incomplete transfer across motion type and retinotopic location.**

Roger Strong[1] (rstrong@fas.harvard.edu), George Alvarez[1]; [1]Department of Psychology, Harvard University

Numerous "brain-training" companies have developed training paradigms for improving high-level attentional mechanisms, with the goal of extending performance gains from trained tasks to general cognitive functioning. For training benefits to transfer from trained to untrained tasks, the untrained tasks must utilize neural mechanisms modified during completion of the trained tasks (Ahissar & Hochstein, 2004). We examined whether training-induced benefits for multiple-object tracking (MOT), a task likely limited by high-level attentional processes (Cavanagh & Alvarez, 2005), generalize across different motion types (linear-moving dots vs. radially-spinning pinwheels) or different retinotopic locations (e.g., top-left vs. bottom-left visual quadrant). After obtaining baseline MOT speed thresholds for both motion types in two retinotopic locations, participants (N=16) completed six days of training on the dot-tracking task in one retinotopic location. Post-training speed thresholds for both motion types in both retinotopic locations were obtained in a final assessment and compared to baseline speeds. Despite shared high-level attentional mechanisms between tasks, training benefits failed to generalize completely from the trained MOT task (e.g., dots in the upper-left visual quadrant) to untrained MOT tasks, including 1) the trained MOT motion type in an untrained retinotopic location (t(15)=2.7, p=.017), 2) the untrained MOT motion type in the trained retinotopic location (t(15)=3.3, p=.005), and 3) the untrained MOT motion type in an untrained retinotopic location (t(15)=4.2, p=.001). Training on the pinwheel task (N=12, separate observers) resulted in the same magnitude of benefits for the trained task and the same pattern of results as training on the dot task. Thus, although attentional tracking is equally trainable for attending to linear-moving dots and radially-spinning pinwheels, improvements do not transfer completely between tasks or retinotopic locations. Combined, these results suggest that, rather than strictly improving general attentional mechanisms, training on attention-limited tasks alters the way such mechanisms select information from task-specific, low-level sensory areas.

Acknowledgement: NSF CAREER BCS-0953730 to G.A.A., DoD NDSEG Fellowship to R.W.S.

56.3010 **Specificity and transfer in perceptual learning of motion**

Ruyuan Zhang[1] (rzhang@mail.bcs.rochester.edu), Oh-Sang Kwon[1], Duje Tadin[1,2]; [1]Center for Visual Science & Dept. of Brain and Cognitive Sciences, University of Rochester, [2]Department of Ophthalmology, University of Rochester

Transfer of learning is a key characteristic of perceptual learning that is often used to reveal the underlying mechanisms. For instance, well-established feature and location specificity of perceptual learning highlight the importance of low-level feature and spatial tuning in learning. Here, we investigated the mechanisms governing the perceptual learning of motion by examining its transfer effects. Results reveal two distinct mechanisms that are selectively responsible for the learning process, which evidently depends on the contrast and size of learning stimuli. METHODS: Participants were instructed to identify motion direction of random texture patterns (6 °/s speed), which moved in one of four directions (up, down, left or right). In pre- and post-tests, participants' duration thresholds (i.e., minimum stimulus duration for participants to detect motion direction) were assessed at seven contrast levels (2% – 100%) and six stimulus radius levels (1° – 8°). During the 8 day training phase, one group of participants (N=5) were trained with small, low-contrast stimuli (radius drawn from Gaussian distribution: u=1.33°, σ=0.11°; contrast: u=2.85%, σ=0.5%) while another group of participants (N=6) were trained on large, high-contrast stimuli (radius: u=6°, σ=0.5°; contrast: μ=70%, σ=10%). RESULTS and DISCUSSION: Surprisingly, training effects on small, low-contrast stimuli generalized to large, high-contrast stimuli but not vice versa. Such dissociable transfer patterns suggest two distinct learning mechanisms. Training on small, low-contrast stimuli generally improves motion signal processing, which may account for the observed transfer of learning. On the other hand, we speculate, that training on large, high-contrast stimuli alters center-surround antagonism in motion processing, which is mainly specific for large, high-contrast stimuli (Tadin et al., 2003). We are currently working on a unified computational model to accommodate the two learning mechanisms observed in the data.

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56.3011 **Sleep rescues perceptual learning from interference**

Elizabeth McDevitt[1] (mcdevitt@ucr.edu), Mohammad Niknazar[1], Sara Mednick[1]; [1]Department of Psychology, University of California, Riverside

Daily living involves copious information processing that has the potential to "overload" the brain and result in memory loss (i.e., interference). Since we do not need to stabilize each waking experience with a nap before encountering the next, there must be a mechanism that allows the brain to rescue memories damaged by interference. Using a texture discrimination task with short training (120 trials/condition), we induced interference by testing back-to-back conditions in the same visual field before a consolidation period. Four consolidation groups were tested: active wake, quiet wake, non-rapid eye movement (NREM) naps, or NREM+REM naps. Wake produced perceptual learning (PL) in the no interference condition, likely due to the short training, and sleep was not correlated with performance. With interference, PL was abolished in all groups except REM naps. Sleep explained 22% of the variance in magnitude of PL, and minutes of slow wave sleep (SWS, p=.04) and REM (p=.009) were significant predictors of improvement. Performance was correlated with specific sleep features: a) the degree of temporal coupling between spindles and slow oscillations (0.5-1Hz) during Stage 2 (r=.30); b) SWS spindle density (#spindles/SWS_{min}) from the occipital site contralateral to the trained visual field (r=.54), but not spindle density from the ipsilateral site (r=.09); and c) REM density (#rapid eye movements/REM_{min}; r=.38). These results, for the first time, demonstrate a process by which the brain can rescue and consolidate memories damaged by interference, and that this process is mediated by specific brain states. Specifically, active wake is sufficient to support PL under conditions of no interference and short training, and REM sleep is critical for rescuing PL damaged by interference. When sleep is necessary for PL, retinotopically-specific sleep spindles, spindle-slow oscillation coupling, and REM density may play important roles.

Acknowledgement: NIH K01 MH080992

56.3012 **Sigma activity originated in the early visual cortex during sleep associated with visual perceptual learning**

Masako Tamaki[1] (tamaki@brown.edu), Aaron Berard[1], Takeo Watanabe[1], Yuka Sasaki[1]; [1]Department of Cognitive, Linguistic and Psychological Sciences, Brown University

A growing body of evidence indicates that sleep facilitates visual perceptual learning (VPL). However, how this facilitation occurs is controversial: researchers in the field are divided into two groups with two completely different views: use-dependent and learning-consolidation models. The use-dependent model assumes that sleep downscales overly increased synapses in the networks used during wakefulness, irrespective of whether learning is involved in the networks or not, and leads to the survival of only significant synapses. Downscaling is assumed to be involved in long-term depression related to slow-wave activity (SWA). The learning-consolidation model assumes that sleep affects the networks specifically related to learning by replaying activity patterns during training. The replay is assumed to be involved in long-term potentiation related to sigma activity. Although usage and learning components were not separated in previous studies, here we successfully dissociated the usage from learning components using an interference effect and tested which model is correct. There were two conditions. In a learning condition (n=12), participants were trained on one texture discrimination task (TDT), the learning of which is associated with response changes in the region of the early visual cortex that retinotopically corresponds to the trained visual field (trained region). In an interference condition (n=12), two different TDTs were serially trained so that learning should not occur due to mutual interference effects. The use-dependent model predicts increased SWA in the trained region during the post-training sleep in both conditions, whereas learning-consolidation model predicts sigma increase in the trained region during the post-training sleep only in the learning condition. Participants were trained with TDT before sleep and retested with TDT after sleep. Learning occurred only in the learning condition. EEG-source localization analysis indicated significant increase in sigma activity in the trained region during the post-training sleep. These results supports learning-consolidation model in VPL.

Acknowledgement: NIH R01MH091801

56.3013 **LImits of Expertise: Investigating the Role of Holistic Processing in Visual Discrimination and Recognition**

Cindy Bukach[1] (cbukach@richmond.edu), Jessie Peissig[2], Wesley Meredith[1], Sophia Minassian[1], Austen Winkler[1]; [1]Psychology, University of Richmond, [2]Psychology, California State University Fullerton

Category boundaries are dynamic and change with experience, and may be very different for experts than for novices, leading to unexpected failures of generalization that provide a unique window into the nature of neural plasticity. Bird watchers (n = 22) and age-matched novices (25) from the East Coast USA completed a recognition memory task (Vanderbilt Expertise Task/VET) and questionnaires assessing quantity and quality of experience. Participants also completed tasks of visual discrimination and holistic processing (Composite task) for birds from East and West Coast USA and Asia to assess generalization of expert skills. Although experts showed superior visual discrimination of birds overall, only Experts showed an other-region effect (ORE) for Asian birds. Quality of experience only marginally predicted expert performance on the VET (r = .39, p = .073), but was a strong predictor of expert visual discrimination of own region birds (r = .604, p = .003 and of the ORE for Asian birds (r =.486 p = .022). Both groups processed birds holistically, but groups showed opposite relationships between holistic processing and visual discrimination. The two measures were marginally positively correlated for Experts (r = .44, p = .077), but negatively correlated for novices (r =-.55, p = .010). Similarly, for experts, holistic ORE was positively correlated with visual discrimination ORE for West Coast birds (r = .53, p = .031), and negatively correlated with Novice visual discrimination ORE for Asian birds (r = -.52, p = .016). The nature of the holistic representation may differ for experts and novices, and/or that novices mistake the diagnostic value of the information they obtain. Taken together, the results of this study are consistent with the idea that individuating experience changes the structure of category representations, and that holistic processing plays a role in transfer of visual discrimination skills.

Acknowledgement: University of Richmond Faculty Research Committee University of Richmond Undergraduate Research Committee

Tuesday PM

See page 3 for Abstract Numbering System

56.3014 **Multidimensional-expertise space: Multidimensional scaling changes after expertise training with objects** Hillary Hadley[1] (hhadley@psych.umass.edu), Erik Arnold[1], James Tanaka[2], Tim Curran[3], Lisa Scott[1]; [1]Department of Psychological and Brain Sciences, University of Massachusetts, Amherst, [2]Department of Psychology, University of Victoria, [3]Department of Psychology and Neuroscience, University of Colorado Boulder

Perceptual experts are defined by their ability to make fast and accurate identifications of objects within their domain of expertise at specific levels of categorization (Tanaka & Taylor, 1991). Researchers have previously applied a multidimensional space (MDS) framework to better understand the psychological similarities of members of the same object or face category. For example, difficulties in recognizing other-race faces have been attributed to a more densely clustered MDS space of other-race versus own-race faces (e.g., Byatt & Rhodes, 2004; Papesh & Goldinger, 2010). Here, we used MDS analyses to examine whether 9 hours of expertise training with computer-generated objects influenced density of clustering and whether this differed for an untrained control group. Adults completed similarity ratings and training with two "families" of objects, one trained at a basic level (multiple exemplars of 10 species all labeled "Other") and one trained at a subordinate level (multiple exemplars of 10 species, labeled "A" through "J"). MDS plots were constructed based on dissimilarity ratings between object species before and after training. For the pre-training group, and for an untrained control group, MDS results show two distinct clusters of species that fall in line with the two family distinctions. After subordinate-level training, the density of clusters changed along two hypothesized dimensions, family membership and feature distinctiveness. In contrast, basic-level training only led to changes along the dimension of family membership. These results suggest that basic-level and subordinate-level expertise training leads to qualitatively different changes in the density and specificity of psychological object representations.

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56.3015 **Play Sports to Improve Visual Functions** Kelly Ha[1] (ktha@wichita.edu), Inga Sogaard[1], Logan Gisick[1], Rui Ni[1]; [1]Department of Psychology, Wichita State University

Previous research (Paul et al., 2011) found significant improvements in reaction time and movement in Ping-Pong players who went through visual training. While most research has focused on performance in sports, few studies have examined the effect of sports playing in improving visual functions. The current study aimed to address this question by training participants with Ping-Pong playing. In this study, 15 college students of ages 18-35 went through the multiple test and training sessions within a 2-week period. On Day one and four participants were measured on Ping-Pong play performance and visual functions, including processing speed, motion-in-depth perception, and divided attention. On Day two and three, participants were trained with one of the two playing tasks against a Ping-Pong robot for approximately one hour. For the Ping-Pong play sessions, a robot shot balls towards participants' side of the table in random direction, at three different speed levels with either left or right side spins. One training task involved catching and throwing back the Ping-Pong balls using one hand, while the other task involved intercepting the balls using a racket. Their scores of missed interceptions and failed returns were recorded. A four-way repeated-measures ANOVA was conducted to evaluate the effect of training on Ping-Pong play performance and visual functions. The results showed significant effects and interactions on play performance: Training, $F(1, 10) = 5.64$, $p < .05$; Speed, $F(2, 20) = 17.12$, $p < .001$; Training x Speed, $F(2, 20) = 5.51$, $p < .05$; And Training x Task x Spin x Speed, $F(2, 20) = 10.90$, $p < .001$. More importantly, significant improvement was found for the divided attention task after training, $F(1, 6) = 8.76$, $p < .05$. The results of the current study suggest that sports training not only improves play performance but also benefit visual functions.

Acknowledgement: Undergraduate Student Research Funds, Wichita State University

56.3016 **A reward-driven reweighting model of perceptual learning** Grigorios Sotiropoulos[1] (gsotirop@inf.ed.ac.uk), Aaron Seitz[2], Peggy Seriès[1]; [1]School of Informatics, University of Edinburgh, [2]Department of Psychology, University of California, Riverside

Perceptual learning (PL), the improvement of perceptual skills through practice, is known to be variably affected by the presence of external guidance, depending on the task. In various perceptual tasks, trial-by-trial feedback enhances learning and in some cases it is even necessary to induce learning. However, in some cases PL occurs just as well with block feedback or no feedback (Herzog and Fahle, 1997) or even without explicitly practicing a task (Seitz and Watanabe, 2003). A model of PL based on reweighting ("readout") of representations in early visual cortex (Liu et al, 2014) was recently proposed to explain previous psychophysical findings on the effect of different types of feedback (trial-by-trial, block, manipulated, uncorrelated and no feedback) on performance in a Vernier acuity task. This augmented Hebbian reweighting model (AHRM) accounted for the effectiveness of the trial-by-trial and block feedback and the ineffectiveness of the other types by means of a top-down bias control system employed to balance the response frequencies in the modelled binary decision task. However, an alternative mechanism that could explain the same data is to incorporate a variable learning rate mechanism whereby the learning rate is adjusted by the difference between expected performance and performance indicated by feedback. Here, we extended the AHRM model based on established reinforcement learning concepts and found that the model can account for the aforementioned psychophysical data in a natural way, under a wide range of parameter values. Our results are in accord with the research showing a role of reinforcement in perceptual learning and with other models that explore the role of performance gradient in PL. Furthermore, the extended model makes testable predictions that may help optimize future PL approaches.

Perception and Action: Reaching and grasping

Tuesday, May 19, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

56.3017 **Human cortical activity for visual processing is modulated by cued actions** Simona Monaco[1] (simona.monaco@gmail.com), John Crawford[2]; [1]Center for Mind/Brain Sciences, University of Trento, Italy, [2]Center for Vision Research, York University, Toronto, Canada

The neural activity for plan and execution of object directed actions is known to be modulated by object properties. It remains unknown whether the sensory processing of object properties is modulated by previously cued actions. We used a cue-separation task in a slow event-related fMRI design to investigate this question. In each trial, participants received two cues in two successive phases: an action cue (AC: auditory instruction to either 'Grasp' or 'Align' the hand with the visual cue) and a visual cue (VC: a 3D wooden rod illuminated for 250ms in two orientations). Each cue was followed by an 8 second delay in complete darkness. The second delay was followed by a go cue to execute the instructed movement toward the rod. The Align condition required participants to adjust the orientation of the hand according to the rod, while the Grasp condition required participants to position the digits according to the rod. We manipulated the order of cue presentation (AC:VC and VC:AC) as a control. Therefore, our design consisted of two action cues (Grasp and Align), two rod orientations (Horizontal and Vertical) and two cue orders (AC:VC and VC:AC). Fourteen right handed participants took part in this study. We hypothesized that action-cue dependant modulation of sensory activity during the delay following the visual cue would be reflected in different activity levels for the two action cues (Align and Grasp). We found that the calcarine sulcus, superior frontal sulcus (SFS), superior parietal occipital sulcus (SPOC), posterior intraparietal sulcus (pIPS) and anterior intraparietal sulcus (aIPS) showed higher activation for 'Align' than 'Grasp' cued action during the delay following visual presentation of the rod. These results suggest that the re-entrant feedback from the motor system influences visual processing even at early levels of cortical input.

Acknowledgement: Canadian Institutes of Health Research

56.3018 **Sequential Movements: When does Binocular Vision Facilitate Object Grasping and Placing** Dave Gonzalez[1] (daveg81@gmail.com), Ewa Niechwiej-Szwedo[1]; [1]Department of Kinesiology, University of Waterloo

Vision provides a rich source of spatial and temporal information about the environment and one's own actions, which is used to plan and execute upper limb movements. Previous research has shown that viewing with both eyes provides a greater advantage during the grasping phase in comparison to the reaching phase. However, most studies examined performance using a

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single reach-to-grasp movement. Since most of our daily activities involve sequential manipulation actions, it is important to examine hand-eye coordination during performance of these more complex actions. Therefore, we explored the role of binocular vision in a sequential task that involved precision grasping and placing a target onto a vertical needle. Six participants picked up and placed 6 beads (one at a time) onto a needle under binocular and monocular viewing conditions while eye and limb movements were recorded. The difficulty of the grasping task was manipulated by using 2 bead sizes and the kinematic analysis focused on 4 phases of the movement: approach to the bead, bead grasping, return to needle and bead placement on the needle. Therefore, our analysis allows us to delineate which component of the task (reaching for and grasping the bead vs transporting and placing the bead) benefits more from binocular vision. We found that binocular vision was most beneficial after the bead has been grasped. Movement times during the return and placement phase were significantly reduced during binocular viewing (0.6s, SE = .055s) in comparison to monocular viewing (left eye: 0.997s, SE = 0.106s; right eye: 1.136s, SE = 0.119s; p< 0.01). These results indicate that placing the bead onto a needle requires a higher level of precision and thus requires binocular visual input in comparison to the grasping phase. Further analysis will concentrate on quantifying the temporal relation between the hands and eyes during task execution.

Acknowledgement: Canadian National Institue for the Blind

56.3019 Expected utility maximization in motor decision-making: differences in representing probability through size vs. through distance David Aguilar-Lleyda[1,2] (aguilarlleyda@gmail.com), Elisabet Tubau[1,2], Joan López-Moliner[1,2]; [1]Institute for Brain, Cognition and Behaviour (IR3C), Universitat de Barcelona, Catalonia, [2]Departament de Psicologia Bàsica, Universitat de Barcelona, Catalonia

Humans are traditionally depicted as suboptimal decision-makers, since they often fail to maximize expected utility. However, recent studies claim people choose optimally in tasks called motor lotteries, where participants reach to different targets within a maximum time window in order to get a reward. A difference is that, while in classical tasks probability information is explicitly given, in motor tasks it is implicit in each participant's motor variability. Once this variability is known, a target can be designed to match a specific probability of being hit. This manipulation is normally implemented through size, but little has been done to explore other ways to represent probability in a motor task: for instance, through distance. Our experiment studied differences in expected utility maximization between these two ways of representing probabilities. In each of our two different conditions, trials consisted in the presentation of two targets, one with a lower probability to be hit but higher gain (risky) and another with higher probability and lower gain (safe). Participants decided to reach for one or another. In the size condition, both targets appeared at the same distance, but the risky was smaller. In the distance condition, both targets had equal size, but the risky was further away. Probabilities were manipulated to sample various expected gain differences between both targets. Results showed clear differences. Risk aversion was more present in the distance condition: participants tended to reach for the safe target even if the optimal choice was the risky target. In the size condition, participants were more sensitive to expected value differences: the more this difference favored the risky target, the more it was chosen. These differences may be interpreted as participants considering additional cost functions (e.g. biomechanical) in the distance condition not captured by the mere probability of hitting.

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56.3020 Grasping lacks depth constancy in both virtual and real environments Chiara Bozzacchi[1] (chiara.bozzacchi@iit.it), Robert Volcic[1], Fulvio Domini[1,2]; [1]Center for Neuroscience and Cognitive Systems@UniTN. Istituto Italiano di Tecnologia, Rovereto, Italy, [2]Department of Cognitive, Linguistic & Psychological Sciences, Brown University, RI, USA

The use of virtual reality setups allows sophisticated manipulations of visual and haptic feedback important for the study of grasping movements. On this respect, the absence of feedback is shown to induce different systematic biases in visuomotor tasks, such as underestimation of the target distance and, above all, lack of the target depth constancy. The latter is revealed by a decrease in grip aperture with target distance increase, thus resembling biases in perceptual estimates of relative depths. However, whether these findings are mostly caused by the use of virtual reality rather than by an intrinsic property of the visuomotor system is still an open and debated question. We addressed this issue by comparing grasping movements performed in three experimental conditions: lights-on (L), glow-in-the-dark (G) and virtual (V). In condition L, a natural grasping towards the object was performed with the lights on; in condition G, feedback of the hand and object were rendered covering the distal phalanges of thumb and index finger and the object with glowing material; in condition V, the visual feedback of the hand and object was virtually provided and only defined by binocular cues. A spherical object was located at four different distances (420, 450, 480, 510 mm) and 16 subjects performed 40 trials for each condition. Results indicate a difference between conditions related to the duration of the movement but, strikingly, they show a clear and strong effect of object distance on the grip aperture in all the conditions equally. Specifically, grip aperture gradually decreased with increasing object distance, therefore revealing a clear lack of depth constancy. These findings demonstrate that systematic biases in grasping actions are not a prerogative of virtual environments and that the visuomotor system is subject to the same biases affecting perceptual estimates.

56.3021 Sequential dependencies in grasping movements Robert Volcic[1] (robert.volcic@iit.it), Fulvio Domini[1,2]; [1]Center for Neuroscience and Cognitive Systems@UniTn, Istituto Italiano di Tecnologia, [2]Department of Cognitive, Linguistic & Psychological Sciences, Brown University

Responses to a stimulus reflect the properties of the given stimulus (direct effects). More often than not, however, the responses also depend on the previously presented stimulus (sequential effects). These sequential effects might reflect learning and calibration processes, or simply interference. Here, we investigate the direct and sequential effects in a task that involves grasping movements. To properly address this question, we build fully counterbalanced ordered sets of stimuli in which every stimulus type was equally likely to be preceded by any other stimulus type. These sets were based on the de Bruijn sequence of order 2, the shortest sequence of stimuli that ensures that all possible stimuli combinations of length 2 are presented. Subjects performed grasping movements in a virtual environment along the depth axis of a spherical object located at different distances. Both visual feedback of the hand (rendered virtual spheres representing the subject's thumb and index fingertips) and haptic feedback were provided. Despite the availability of these feedback and the fact that the subjects always grasped the same object, object distance had a direct effect on grip aperture profiles, resembling the lack of depth constancy found in perceptual tasks. Importantly, we found clear sequential effects, i.e., the preceding grasping action affected specific aspects of reach and grasp dynamics along the movement trajectory of the subsequent action. Systematic changes were found in early phases (wrist velocity) as well as in late phases of the movement (grip aperture). These findings draw attention to an important source of systematic movement variability and highlight the intricate role played by feedforward and feedback control mechanisms in planning and guiding grasping behavior, and possibly actions in general.

56.3022 Haptic feedback overrides visual size information during repeated grasping Carlo Campagnoli[1] (carlo_campagnoli@brown.edu), Evan Cesanek[1], Fulvio Domini[1,2]; [1]Department of Cognitive, Linguistic & Psychological Sciences, Brown University, [2]Center for Neuroscience and Cognitive Systems@UniTn, Italian Institute of Technology

Haptic feedback consists of the tactile and kinesthetic information available during physical interaction with surfaces and objects. When grasping an object, haptic information specifies object size and therefore may influence grasp kinematics over multiple grasps. In real-world grasping movements, the visual size of an object exactly corresponds to its haptically specified size, confounding the relative influences of these two modalities on grasp performance. As a result, accurate grasp performance in repeated grasping tasks may not be attributed entirely to veridical encoding of visual size. In these experiments, we independently controlled the visual and haptic information presented during repeated grasping of vertically-oriented rectangular bars. Visual bar sizes were presented using a computer display and an oblique mirror such that the bars appeared at eye height 40 cm in front of the seated observer. Haptic size information was provided by physical bars presented at the same 3D locations as the visual bars. Vision of the hand and physical arrangement was unavailable, making it impossible to notice size mismatches. In Experiment 1, three physical bars were grasped in a random order in three blocks of 30 grasps. In each block, the visual bars appeared smaller (-4 mm), larger (+4 mm), or equal in size to the physical bars. Maximum Grip Aperture scaling matched the physical size differences across all three blocks while we found no modulations due to visual size variation. To further investigate the time course of visuo-haptic integration, we ran a follow-up experiment looking at how MGA scaling develops over 14 repeated grasps at bars with seven different visuo-haptic combinations. Our results suggest that visual information is initially dominant in determining the size of the maximum grip aperture, but haptic information gradually overrides visual information in less than ten trials and enables physically accurate grasp performance.

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56.3023 Incorrect haptic feedback in 50% of trials is sufficient to bias grip aperture
Rachel Foster[1] (rachel.mary.foster@gmail.com), Annika Januszewski[1], Volker Franz[1]; [1]University of Hamburg

Grasping behavior is being tested increasingly often in virtual and mirror setups. In displays where the visual percept does not correspond to physical reality (e.g., distorted depth perception under limited cue conditions) an important methodological question is what and how much haptic feedback to provide. While grasping without haptic feedback has been shown to drift, both in position and aperture size (Bingham, Coats, & Mon-Williams, 2007, Neuropsychologia, 45, 288-294), grasping with terminal haptic feedback that does not correspond to the visual information has been shown to bias both reaching distance and maximum grip aperture (MGA) in the direction of the haptic feedback (Mon-Williams & Bingham, 2007, JEP:HPP, 33, 645-656; Coats, Bingham, & Mon-Williams, 2008, Experimental Brain Research, 189, 211-220). An ideal balance would be to find a level of haptic feedback that allows for natural grasping, while not biasing behavior. Because presenting correct haptic feedback on 50% of trials has been shown to produce normal grasping (Bingham et al., 2007), we therefore tested whether providing haptic feedback that differed from visual information by 5mm on 50% of trials would bias MGAs in the direction of the haptic feedback. We found that incorrect feedback on 50% of trials did appear to bias grasping (N=32). We additionally noticed that MGAs decreased over time even when correct haptic feedback was presented 100% of the time. We believe this may have been due to participants' initial uncertainty in the mirror setup, which decreased over time. Our findings underscore the difficulty of providing haptic feedback that does not bias the grasping response. Changes in the grip aperture found in the 100% correct haptic feedback condition also highlight a potential difficulty in defining baseline grasping behavior when using mirror setups.

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56.3024 Visuomotor strategies for grasping a rotating target.
Charlotte Leferink[1] (leferink@cc.umanitoba.ca), Hannah Stirton[1], Jonathan Marotta[1]; [1]Perception and Action Lab, Dept. of Psychology, University of Manitoba

When performing a visually-guided grasp to a moving object, spatial and temporal predictions must be made so that the hand is aimed at a location where it will meet the object, rather than the position at which the object is seen when the reach is initiated. Last year at VSS, we presented a translational movement study, where we showed that participants fixated the leading edge of a moving target until they initiated their reach, at which point they shifted their gaze to the eventual index finger contact position on the object, above the centre of mass (COM) (Bulloch, Prime & Marotta, 2014). This year, we investigated rotating targets. Do participants track one position on the target while it rotates, or do they shift their gaze to new potential grasping sites as they become available throughout the tracking phase? A 6.2 cm x 10.2 cm computer-generated Efron block (Efron, 1969) was rotated about its COM at one of two speeds (50 deg/s and 30 deg/s). After a delay of 3.5 seconds, participants received a "go" tone and reached out and "grasped" the block. Upon contact with the screen, the block stopped its rotation. Gaze fixations during the delay, and during the reach itself, favoured the left half of the block, above the COM, suggesting that every time a new "top edge" of the block rotated clockwise into position, it became the salient fixation point. These results suggest that anticipated grasping positions on a rotating object are constantly changing due to kinematic constraints (e.g. wrist extension) as the block rotates.

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56.3025 Eye-hand coordination strategies in older adults
Rachel Coats[1] (r.o.a.coats@leeds.ac.uk), Aaron Fath[2], Sarah Astill[3], John Wann[4]; [1]School of Psychology, University of Leeds, [2]Department of Psychological and Brain Sciences, Indiana University, [3]School of Biomedical Sciences, University of Leeds, [4]Department of Psychology, Royal Holloway University London

Hand movement kinematics and eye-hand coordination are affected by aging. These age differences are exacerbated when task difficulty is increased, but the exact nature of these differences has yet to be established. We examined the performance of 12 older adults (mean age = 74) and 11 younger adults (mean age = 20) on a multi-phase prehension task. Participants had to reach for and pick up a target object with their preferred hand, place it in a tray, then reach for a second target object and place that in the same tray (baseline condition). On half the trials (stabilising condition) participants were required to hold the tray as still as possible just above the surface of the table with their non-preferred hand. Hand and eye movements were recorded. Older adults took longer to complete their overall movement but only in the stabilising condition [$t(21) = 3.38$; $p < 0.01$], largely due to an extended duration for the first submovement. They reached lower peak velocities and spent proportionally less time decelerating than the younger adults. Group differences were most apparent at the start of the movement and in the stabilising condition, suggesting both that older adults look more like their younger counterparts if given enough time, and that the added complexity of the stabilising task had a greater effect on the performance of the older adults than the young. Older adults adopted two different eye-hand coordination strategies, preferring to make an eye movement to the next target as soon as possible in some circumstances, or spending longer fixating the current target when accuracy requirements were high. Older adults appeared to employ an eye movement strategy that enabled them to benefit from visual feedback, presumably to aid hand movement control and improve task performance.

56.3026 Does the grasp type reveal action intention?
Yi Zhang[1] (zhangyi2331@gmail.com), Yezhou Yang[1], Cornelia Fermuller[2], Yiannis Aloimonos[1]; [1]Computer Science Dept, University of Maryland, College Park, [2]UMIACS, University of Maryland, College Park

The hand grasp type provides visual information about a person's intended action. We conducted an experiment to evaluate how accurately humans can judge basic manipulation action categories from static images and how much image information they need to make this judgment. We classified manipulation actions into three basic categories, namely 'power action' (including actions, such as lifting, cutting, hitting with force), 'precision action' (such as playing an instrument, writing, or stirring with a straw) and 'casual movement' (such as showcasing, posing, or gesturing). Images were shown in sequences of three: the first one showing the bare hands segmented from background, the second one showing square patches around the hands, and the third showing the full image. Mechanical Turkers were shown 39 images, and asked to make a judgment on the action category. 57 subjects participated, of which 48 were considered valid responses. The accuracy of action classification was nearly the same, when subjects saw the hand patches as when they saw the whole image (71% vs.77% in average over all actions). Accuracy decreased significantly when subjects only saw the segmented hands (54 % accuracy over all images) (confirmed as a significant difference with 99.9% using t-testing). The findings confirm the importance of the grasp type as a symbolic feature for action interpretation. The statistics will be used also to provide confidence intervals for our computational algorithms that recognize human manipulation actions from images and video.

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56.3027 Training of compliance control across different scales of movement yields general learning in children
Winona Snapp-Childs[1] (wsnappch@indiana.edu), Aaron Fath[1], Geoffrey Bingham[1]; [1]Psychological & Brain Sciences, Indiana University

Introduction: Previously we (Snapp-Childs et al., 2013a; 2013b; 2014) developed a method that supports active movement generation to allow practice with improvement of good compliance control. We showed that the method allowed children with Developmental Coordination Disorder to improve at a 3D tracing task to become as proficient as Typically Developing children who had also trained. We also showed that the training improved figure copying. In this study, we expanded the training protocol to include a wider variety of ages (5-10 year olds) and we varied the scale of training (smaller or larger figures of the same shape) to assess the generality of learning. Methods: Fifty children (eighteen 5-6 year olds, sixteen 7-8 year olds, and sixteen 9-10 year olds) were tested with the Beery VMI, the 3D tracing task, and a 2D letter-like figure-copying task. The children then trained on one version of the 3D tracing task (smaller or larger scale figures) until they all reached comparably good proficiency. The 3D tracing and copying tasks were tested again following training. Results: Performance on the 3D tracing task at baseline varied as a function of the level of difficulty, size of figure, and age. After training, the age differences were eliminated but the level of difficulty and size effects remained although the differences were greatly reduced. Also, training (on small versus larger figures) now influenced performance: training with small figures gave an advantage on smaller figures, while training with large figures gave an advantage on larger figures. Conclusions: Training on the 3D tracing task, whether with larger or smaller scale figures, greatly improved performance and eliminated age differences but yielded some training specific effects. In conclusion, the training method does yield general learning and is not highly specific to one particular age group.

Acknowledgement: NIH

56.3028 Global and local attentional influences on target selection for action J. Daniel McCarthy[1] (dan_mccarthy@brown.edu), Joo-Hyun Song[1,2]; [1]Department of Cognitive, Linguistic & Psychological Sciences, Brown University, Providence, RI, [2]Brown Institute for Brain Science, Brown University, Providence, RI

In daily life, humans interact with multiple objects in complex environments (e.g., fetching a glass from the cupboard, selecting a book on a shelf, etc.). Target selection is biased toward recently attended features, such that reaches are faster and trajectory curvature is reduced when target features (i.e., color) are repeated—a phenomenon referred to as "priming of pop-out". However, it is unclear how selecting a single target for action is impacted when it is grouped as part of a greater whole. We examined this question using a visually guided reaching task requiring participants to search for uniquely colored target among distractors and reach toward its location. Importantly, targets were Pac-men that were oriented to be either consistent or inconsistent with a global Kanizsa triangle. We found that movement initiation was faster when an illusory figure was present independent of color repetition and this effect increased with successive figure presentations. Additionally, movement duration and reach curvature were reduced when colors were repeated irrespective of configuration, consistent with priming of pop-out. An interaction also emerged for curvature: color switches were less costly when the configuration changed as well. We interpret this as evidence of binding between target color and global structure. To summarize, repeated Kanizsa figure presentations induced an early global priming effect indicated by faster movement initiation, whereas local color feature priming reduced movement duration and curvature, reflecting later focal decision processes. These results demonstrate that global and local attentional mechanisms play distinct roles in target selection for action and impact behavior during different stages of the decision process.

56.3029 Modulation of the Material-Weight Illusion in objects made of more than one material Vivian Paulun[1,2] (Vivian.C.Paulun@psychol.uni-giessen.de), Gavin Buckingham[3], Karl Gegenfurtner[1], Roland Fleming[1], Melvyn Goodale[2]; [1]Department of Psychology, Justus-Liebig-University, Giessen, Germany, [2]The Brain and Mind Institute, The University of Western Ontario, London, Canada, [3]Department of Psychology, School of Life Sciences, Heriot-Watt University, Edinburgh, UK

Knowledge about the material properties of objects is essential for successful manual interactions. Vision can provide useful information about features such as weight or friction even before interaction, allowing us to prepare the action appropriately, e.g. adjusting initial forces applied to an object when lifting it. But visual information can also alter multisensory perception of object properties during interaction. When violated, visually-inferred expectations can result in perceptual illusions such as the material-weight illusion (MWI). In this illusion, an object that appears to be made of a low-weight material (e.g., polystyrene) feels heavier than an equally-weighted object of a heavier-looking material (e.g., wood). However, objects are often made of more than one material. Thus, in the present study, we investigated the perceived heaviness of symmetrical objects consisting of two halves, which appeared to be made of different materials: polystyrene, wood, or stone. The true mass of these bipartite objects was identical (400g) and evenly distributed around their geometric centre. Thus, the objects and their halves were visually distinct, but identical in terms of their weight and mass distribution. Participants were asked to lift the objects by a small handle attached centrally, while forces and torques were recorded. Additionally, they were asked to report the perceived weight of both halves of the objects. The visual appearance did indeed alter perceived heaviness. Although estimates of heavier and lighter portions of the objects converged after lifting the objects, the heavier-looking materials in our bipartite objects were still perceived as heavier than the lighter-looking materials. Again, prior expectations appear to affect the perception, but in a direction opposite to that of the MWI. Despite the effects of the visual appearance on perceived heaviness, no corresponding effects were observed on forces or torques.

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56.3030 Does behavioral dissociation of real vs. pantomime movements only apply to visually guided action? Jenni Karl[1] (jkarl3@uwo.ca), Derek Quinlan[1], Ian Whishaw[2], Jody Culham[1]; [1]Department of Psychology, The Brain and Mind Institute, Natural Sciences Centre, Western University, London ON, Canada N6A 5C2 , [2]Department of Neuroscience, Canadian Centre for Behavioural Neuroscience, University of Lethbridge, Lethbridge AB, Canada, T1K 3M4

Pantomime reaching movements to imagined objects differ kinematically from real reaching movements to visual objects. It has been proposed that these differences may be related to the availability of online visual input. Specifically, real reaches are proposed to rely on online visual information localized largely in the left dorsal stream whereas pantomime reaches are proposed to rely on perceptual information processed in more widespread areas including the ventral stream and the right dorsal stream. Withdrawing the hand to place an object in the mouth is a natural and common movement; yet, it differs from other reaching movements in that it relies almost entirely on somatosensory guidance and may be mediated by a 'hard-wired' cortical motor representation that controls the arm, hand, and mouth. Given these differences, it could be hypothesized that hand-to-mouth movements might not be subject to the same real vs. pantomime dissociation as visually guided reaching. The present study used frame-by-frame video analysis and linear kinematics to analyze hand and mouth movements as participants withdrew the arm and hand to place either real or imagined food items into the mouth for eating. Pantomime hand-to-mouth movements were characterized by longer movement durations, lower peak velocities, and smaller openings of the mouth aperture to receive the food item than real hand-to-mouth movements. Nonetheless, mouth opening scaled to object size regardless of whether the food item was real or imagined. The results are discussed in relation to the idea that neurobehavioral dissociation of real vs. pantomime actions is a general feature of movement control that applies to both visually and nonvisually guided actions.

Acknowledgement: NSERC

56.3031 Inhibitory modulation of perception and action by repeated colors without consciousness Hee Yeon Im[1] (heeyeon.im@gmail.com), Joo-Hyun Song[1,2]; [1]Department of Cognitive, Linguistic and Psychological Sciences, Brown University, [2]Brown Institute for Brain Science, Brown University, Providence, RI

Previous studies on priming of pop-out have shown that when the target color is repeated, an odd-colored target among uniformly colored distractors can be selected faster for attention and saccadic and reaching movements. Here we examine whether invisible stimuli can prime the subsequent oddity target selection for visually-guided reaching. Using a continuous flash suppression paradigm, we subliminally presented a prime array consisting of an odd-colored target with three distractors. The colors of the target and distractors were randomly switched in each trial between red and green. A blank screen was then presented, followed by a visible response array consisting of an odd-colored target with three distractors as in the prime array. The odd-colored target in the prime and response arrays was either repeated or switched. Participants were asked to reach for an odd-colored target in the response array using a stylus pen on a touch pad. In contrast to the phenomenon of priming of pop-out, we observed that subliminal color repetition resulted in an inhibitory effect. When the target color was repeated between the prime and response arrays, the initial latency and movement time of reaching became slower, and reaching trajectories were more curved towards the location of distractors rather than the target, compared to when the target color was switched. Furthermore, we also observed the same inhibitory effect by target color repetition when perceptual discrimination was required instead of reaching. These results suggest that attention is attracted to the invisible oddity target, which subsequently modulates both goal-directed movements and perceptual discrimination in the same manner. Specifically, in contrast to the classical pop-out priming by visible stimuli, we demonstrate that attention captured by subliminal stimuli inhibits subsequent target selection. We suggest that the inhibitory effect is due to a suppressed response towards an odd-colored item in the invisible prime array.

Object Recognition: Categories

Tuesday, May 19, 2:45 - 6:45 pm

Poster Session, Banyan Breezeway

56.3032 Animate shape features influence high-level animate categorization Abla Alaoui Soce[1] (abla_alaoui-soce@college.harvard.edu), Bria Long[1], George Alvarez[1]; [1]Harvard University

The distinction between animate and inanimate entities is fundamental at both the cognitive and neural levels (e.g. Mahon and Caramazza, 2009; Konkle & Caramazza, 2013). Previous work suggests that animate versus inanimate entities have consistent perceptual differences that can be

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extracted at early stages of perceptual processing (Long et al., in prep). Do these visual features feed-forward to activate high-level, conceptual representations? In Experiment 1, we developed a flanker interference task in which recognizable images of animals and objects influenced reaction time on a word categorization task. In Experiment 2, we used the same paradigm with textures that were unrecognizable at the basic-category level, but which preserved statistical features of the original images (by coercing white noise to match the low and mid-level statistics of animal and object images, Freeman & Simoncelli, 2011). On each trial, participants categorized a written word (e.g., 'FERRET') as either an 'animal' or an 'object'. Words were presented concurrently with a distractor image that was either congruent (e.g., a picture of a panda) or incongruent (e.g., a picture of a tractor) with the broad category of the word. With recognizable images (Experiment 1), participants were faster at categorizing the words as animal or object when the distractor image belonged to the same (versus the different) category (Congruent=735.33ms, Incongruent=762.14ms, $F(1,15)=41.539$, $p< 0.001$). With texture images (Experiment 2), participants were again significantly faster at categorizing words when the textures were from images that originally belonged to the same broad category (Congruent=728.76ms, Incongruent=744.12ms, $F(1,15)=22.010$, $p< 0.001$). The textures were unrecognizable at the basic level (average identifiability=3.5%), but with unlimited viewing time they could be classified as animate versus inanimate (d prime=1.01). These results suggest that animate versus inanimate entities differ in perceptual features, and that these features feed-forward to automatically activate the conceptual representations of animate and inanimate entities.

56.3033 Modeling the Dynamics of Visual Object Categorization

Jianhong Shen[1] (jianhong.shen@vanderbilt.edu), Thomas Palmeri[1]; [1]Department of Psychology, Vanderbilt University

Novices are faster and more accurate to verify category membership at an intermediate level of abstraction, the so-called the basic or entry level (e.g., "bird"), than a superordinate (e.g., "animal") or subordinate level (e.g., "Blue Jay"). One explanation for the relative speed of basic-level categorization is that categorization at this intermediate level is a prerequisite for more superordinate and subordinate categorizations – you need to know that it is a bird before you can tell whether it is an animal or a Blue Jay. An alternative explanation is that basic-level categorizations are fast because the basic level is more differentiated and informative, not that it happens first. We evaluated these two hypotheses by fitting the well-known drift-diffusion model of perceptual decision making to accuracy and response time data from a large sample of online participants, including both novices and individuals with varying levels of birding expertise. We specifically identified these two hypotheses with differences in process parameters within the diffusion model: variability in non-decisional, perceptual processing time across category levels would indicate the former hypothesis, whereas variability in drift rate across category levels would indicate the latter hypothesis. We specifically applied the diffusion model using a Bayesian hierarchical framework, which provides a powerful account of individual differences in the model parameters across conditions. Behaviorally, we replicated the basic-level advantage for novices in our online experiments. Theoretically, we found that variability in categorization speed across levels of categorization were well captured by variability in the drift rate across levels without any changes in the non-decisional, perceptual processing time across levels. Our results help to unravel the psychological processes that give rise to the behavioral pattern in speeded categorization and inform the understanding of individual differences in visual object categorization.

Acknowledgement: Grant # NSF SBE-1257098 and the Vanderbilt Vision Research Center Grant # P30-EY008126

56.3034 Greebles actually do look like faces (but not in the way you thought).

Juliet Shafto[1] (jshafto@andrew.cmu.edu), John Pyles[1], Carol Jew[2], Michael Tarr[1]; [1]Psychology Department, Carnegie Mellon University, [2]Department of Brain and Cognitive Sciences, Rochester University

What factors contribute to selectivity for object categories within the ventral stream? Recently, Nasr et al. and Yue et al. (2014) reported selectivity for low-level visual properties within category-selective regions. Face-selective regions were found to respond preferentially to images containing curved contours; in contrast, scene-selective regions responded preferentially to images containing rectilinear contours. These findings raise the question as to whether category-selective responses for non-face, non-place stimuli are driven by the presence or absence of such low-level properties. We were curious whether "Greebles" – non-face stimuli that, with expertise, selectively recruit the functional face network – gave rise to "face-like" responses, in part, due to their being comprised primarily of curved contours. To investigate, we developed new Greebles comprised of predominantly rectilinear contours. During fMRI subjects viewed either curved Greebles or rectilinear Greebles. Face-, place-, body part-, and object-selective regions were also localized. Subjects were not trained to identify individual Greebles, however, a 2IFC same-different matching task forced subjects to distinguish between visually dissimilar (easy) or similar (hard) Greebles. An ROI analysis of category-selective regions revealed that – in the absence of any expertise training – curved Greebles evoked higher responses in face-selective regions relative to rectilinear Greebles, while the converse was true in place-selective regions. We suggest that category selectivity arises from multiple factors: beyond experience and task demands, selectivity for low-level visual properties may help bootstrap the acquisition of ecologically-consequential visual categories or, alternatively, may arise from statistical regularities inherent in these categories (learned via other mechanisms). In either case, it appears that the original Greebles do share potentially critical visual properties with faces – it remains to be seen whether these low-level properties do influence the acquisition of visual expertise.

Acknowledgement: B2 Grant (NIH T32GM081760)

56.3035 Coding of object size and object category in scene regions

Jack Ryan[1] (jack.jackryan@gmail.com), Joshua Julian[1], Russell Epstein[1]; [1]Department of Psychology, University of Pennsylvania

Recent work suggests that scene-responsive regions such as the parahippocampal place area (PPA), retrosplenial complex (RSC), and occipital place area (OPA) might play a role in processing of nonscene objects in addition to their role in processing scenes. For example, Konkle & Oliva (2012) reported that these regions respond more strongly to large objects than to small objects. Does this indicate that scene-responsive regions encode objects in terms of their real-world size--or, alternatively, preferentially encode large objects? To investigate this issue, we scanned subjects while they viewed objects drawn from 20 categories, 10 of which were physically large (e.g. stove, copier) and 10 of which were physically small (e.g. binoculars, mug). Objects were shown for 1 s each with a 2 s ISI. Large and small categories were matched in terms of a number of low-level image properties, including retinotopic size, chrominance, luminance, and spatial frequency. Preliminary results replicated the previously reported univariate effect: PPA, RSC, and OPA all responded more strongly to big objects than to small objects. Moreover, this finding was echoed in multivoxel pattern analyses: pattern similarity in these regions was greater for object categories of similar size (e.g. stove-copier) than for object categories of different size (e.g. stove-mug). Notably, we did not observe evidence for coding of object category in these regions when object size was controlled. That is, across scan runs, multi-voxel patterns were no more similar for objects of the same category and size than for objects of different category but the same size. In contrast, object category could be readily decoded in the lateral occipital complex. These results suggest that scene regions code spatial properties of objects useful for navigation but are not centrally involved in object recognition.

56.3036 The development of visual object categorization as revealed by fast periodic visual stimulation

Stefanie Peykarjou[1,2] (stefanie.peykarjou@psychologie.uni-heidelberg.de), Stefanie Hoehl[2], Bruno Rossion[1], Sabina Pauen[2]; [1]Face Categorization Lab, UC Louvain, Belgium, [2]Department of Developmental and Biological Psychology, Heidelberg University, Germany

Categorizing objects in the visual environment is an effective strategy to enhance processing efficiency. The development of this ability has rarely been investigated using similar methods across age. We addressed this issue by means of fast periodic oddball visual stimulation, an approach that provides an implicit, objective, and robust measure of categorization in adults (Liu-Shuang, et al., 2014; Rossion, et al., in press) and, potentially, in infants. Adults (N = 11; 2 males), 4- (N = 30; 14 males) and 7-month-olds (N = 39; 18 males) were presented with short sequences of animal and furniture pictures. 4 items of the same category were presented consecutively (standard category); every fifth stimulus belonged to the other (oddball) category. Base stimulation frequency F was 6.033 Hz. The oddball response (1.21 Hz; F/5) and its harmonics (nF/5) were used to measure discrimination. In adults, oddball responses were observed in the animal and furniture oddball conditions (SNR/Z-scores: furniture oddball = 4.05/5.39, $p < .0001$, animal oddball = 4.72/5.91, $p < .0001$). Low-level visual cues contributed only minimally to the response: Discrimination was substantially decreased for phase-scrambled images with identical power spectra as the original images (SNR/Z-scores: animal oddball = 1.52/1.12, $p = .13$, furniture oddball = 2.53/1.97, $p < .05$). In 7-month-old infants, animal (SNR/Z-score = 1.83/1.83, $p < .05$) and furniture oddballs elicited discrimination (SNR/Z-score = 1.54/1.51, $p = .07$). The discrimination response for animal oddballs was erased by phase-scrambling images (all SNRs/Z-scores < 1.51/1.40). In 4-month-olds, animal oddballs

elicited discrimination (SNR/Z-score = 1.67/1.69, p < .05), but furniture oddballs did not. Further data collection on phase-scrambled conditions is under way. Our findings suggest that both infants and adults are capable of categorizing animal and furniture items even when the category is represented broadly and diverse images are displayed in a rapid fashion.

Acknowledgement: Fonds de la Recherche Scientifique, Belgium

56.3037 Human Visual Search Performance for Camouflaged Targets

Olivia Matthews[1] (Olivia.Matthews@bristol.ac.uk), Eric Liggins[2], Tim Volonakis[1], Nick Scott-Samuel[1], Roland Baddeley[1], Innes Cuthill[3]; [1]School of Experimental Psychology, University of Bristol, [2]QinetiQ, Cody Technology Park, Farnborough, [3]School of Biological Sciences, University of Bristol

There is a paucity of published systematic research investigating object detection within the military context. Here, we establish baseline human detection performance for five standard military issued camouflage patterns. Stimuli were drawn from a database of 1242 calibrated images of a mixed deciduous woodland environment in Bristol, UK. Images within this database were taken during daylight hours, in summer and contained a PASGT helmet, systematically positioned within each scene. Subjects (20) discriminated between the two image types in a temporal 2AFC task (500ms presentation for each interval), with the detection scenario being the percentage of instances participants correctly detected the target. Cueing (cued/not-cued to target location), colour (colour/greyscale) and distance from the observer (3.5/5/7.5m) were manipulated, as was helmet camouflage pattern. A Generalized Linear Mixed Model revealed significant interactions between all variables on participant performance, with greater accuracy when stimuli were in colour, and the target location was cued. There was also a clear ranking of patterns in terms of effectiveness of camouflage. We also compare the results with a computational model based on low-level vision, and eye tracking data, with encouraging results. Our methodology provides a controlled means of assessing any camouflage in any environment, and the potential to implement a machine vision solution to assessment. In this instance, we show differences in the effectiveness of existing solutions to the problem of camouflage, concealment and deception (CCD) on the battlefield. Funded by QinetiQ as part of Materials and Structures Low Observable Materials Research Programme.

Acknowledgement: Qinetiq

56.3038 Visual search speed is influenced by differences in shape arbitrariness

Anna Leshinskaya[1] (anna.leshinskaya@gmail.com), Alfonso Caramazza[1]; [1]Psychology Department, Harvard University

We hypothesized that the visual system is particularly tuned to those features which correlate with behaviorally relevant dimensions, and compared a few possibilities: how man-made an object is (naturalness), how often an object is eaten (edibility), how often an object is manipulated (manipulability), and the degree to which an object's shape is arbitrary (shape arbitrariness; Prasada, 2001). For example, the shape of a hammer is more constrained by the kind of thing that it is (i.e., is less arbitrary) than the shape of a rock. Does variability in perceptual similarity among sets of small, inanimate objects correlate with behavioral ratings on any of these dimensions? We chose four sets (categories) of stimuli: manipulable artifacts (e.g., pens), non-manipulable artifacts (e.g., lamps), natural objects (e.g. pinecones), and fruits/vegetables. These categories did not differ on ratings of typicality, familiarity, internal details, and visual complexity, or in area, aspect ratio, contour variance, extent, spatial frequency, contrast, or luminance. Participants searched for a target image among distractors from the same or different category; they pressed a space bar when they found the target, and reported its location by clicking X's that replaced the original images. For each category pairing, the difference in search speeds between same- and different-category trials was taken as an index of perceptual dissimilarity, and correlated with distances in each dimension for each subject (representational similarity analysis). Neither manipulability nor edibility explained the pattern of perceptual dissimilarity among categories (all r< .1, t< 1, p>.3). Although naturalness explained some variance (r=.16, t=2.13, p=.048), shape arbitrariness explained more (r=.40, t=4.05, p< .0001). Visual features correlated with shape arbitrariness include shape symmetry and regularity, according to ratings(r=.74, p< .001). These results suggest that, among inanimate objects, the visual system may be particularly sensitive to the perceptual features correlated with the arbitrariness of their shapes.

56.3039 The effect of category learning on the temporal dynamics of object similarity

Jonathan Folstein[1] (jonathan.r.folstein@gmail.com), Kelly Fuller[1], Thomas DePatie[1], Dorothy Howard[1]; [1]Psychology, Arts and Sciences, Florida State University

Category learning causes objects to become less similar. This is hypothesized to have a diverse set of consequences: 1) categorized objects become more perceptually discriminable, (psychological distance increases) 2) decisional similarity, thought to be a non-linear function of psychological distance, decreases, and 3) early rule-based categorization strategies are supplanted by increasingly rapid similarity-based strategies. To investigate the effect of category learning on similarity at multiple decision stages, a category learning paradigm was combined with a rare target detection ERP task. Participants learned a logical rule for distinguishing two categories of cartoon animals, each with typical members and ambiguous members. ERPs were recorded while subjects categorized the objects. To manipulate the P300 component, one category was designated the rare target category while the other was the frequent non-target, holding feature-frequency constant. Typical members of the target category had to most target features, followed by ambiguous targets and non-targets, followed by typical non-target category members. The initial ERP session was followed by two days of categorization practice, followed by a second ERP session. The results suggested two stages of similarity representation. ERPs from 300 to 330 ms showed a linear pattern of target similarity on both days: positivity decreased linearly from typical targets to typical non-targets, the pattern becoming steeper and more linear during session 2. The peak of the P300, from about 330 to 750 ms, showed a very different pattern. During the first session, typical targets and non-targets were about equal, and more positive than ambiguous targets and non-targets. After category training, a similarity gradient emerged that was similar to the early stage, but curvilinear. These results suggest that 1) similarity is represented in multiple processing stages, 2) similarity decreases with category learning, and 3) similarity based strategies may replace rule based strategies.

56.3040 Pushing the Boundaries of Fine-Grained Object Classification with fMRI Decoding in Human Occipito-Temporal Cortex

Clara Fannjiang[1] (clarafj@stanford.edu), Marius Cătălin Iordan[1], Diane Beck[2], Li Fei-Fei[1]; [1]Computer Science Department, Stanford University, [2]Psychology Department and Beckman Institute, University of Illinois, Urbana-Champaign

Multi-voxel pattern analysis or 'decoding' has become a widespread tool for investigating how much object and scene category information is linearly readable from fMRI response patterns. Previous studies have compared the performance of various classifiers on this task (Laconte et al., 2005; Misaki et al., 2010; Yourganov et al., 2014), however, with the fundamental limitation that comparisons are made on simple, often binary classification problems. Arguably, as questions probed by fMRI experiments become more complex, they demand methods that can expose subtle distinctions between large sets of categories. To address this issue, we performed the first evaluation of multivariate classifiers on fine-grained object categorization. We tested several commonly used classifiers: correlation classifier (CC), linear support vector machine (SVM), and linear discriminant analysis (LDA). For the latter, we employed two regularization schemes: principal components (LDA-PC) and ridge regression (LDA-RR). We benchmarked these classifiers on three passive-viewing, block-design fMRI datasets comprising 16, 27, and 32 fine-grained object categories, respectively. To assess the classification tasks, we selected several regions of interest (ROI) across visual cortex: early visual areas (V1, V2, V3v, hV4), scene- (PPA, TOS, RSC), face- (FFA), and object-selective regions (LOC). We evaluated the classifiers on the following criteria: mean decoding accuracy, number of categories decoded significantly above chance, and robustness of decoding accuracy to ROI size. Our comparisons on these challenging fine-grained datasets showed that, while all classifiers could decode category above chance across multiple regions, LDA-RR consistently outperformed the others across most ROIs on both mean decoding accuracy and number of categories decoded above chance. We reached a peak classification accuracy of 16% on 32-way categorization in LOC. Thus, despite the current popularity of CC and SVM in fMRI studies, our results suggest that LDA-RR should be the tool of choice for experimental questions involving complex, fine-grained category distinctions.

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56.3041 Right away! Early, lateralised color category effect revealed by first-saccade dynamics.

Merryn Constable[1,2] (merryndconstable@gmail.com), Stefanie Becker[3]; [1]Faculty of Kinesiology and Physical Education, University of Toronto, [2]Department of Psychology, University of Toronto, [3]School of Psychology, University of Queensland

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In visual search colours from a different category (blue vs. green) are located faster than colours from the same category (aquamarine vs. turquoise). A number of studies have found that this category effect manifests only when targets are presented in the right hemifield. As such the effect has been linked with the lateralization of language and taken as strong support for the Sapir-Whorf hypothesis that language shapes perception. Subsequent studies, however, have often failed to find the left-lateralized category effect and instead found a bilateral category advantage. In the present study we examined the time-course of the (lateralized) category effect, by monitoring the participants' eye movements in search for equiluminant across- and within- category colour targets. The results showed a bilateral category effect in the mean response times (RT), which comprised of two lateralized category effects: A Whorfian left-hemispheric category effect at an early stage of visual search (i.e., first eye movements) which was followed by a right-hemispheric category effect during later stages of visual search (search time, response). The right-hemispheric category advantage was especially pronounced when participants had initially missed the target (with the first eye movement). To assess whether the results indeed generalize to covert attention shifts, we measured performance in a control task, in which participants were instructed to localise the target while maintaining fixation thus preventing hemifield shifts. An analysis of the RT distribution revealed the same results as in the eye movement task, again showing that the bilateral category effect in the mean RT was composed of an early, left-lateralized and a later, right-lateralized category effect. These findings reconcile previously seemingly discrepant findings in the literature and shed new light on how language-based and non-language based mechanisms facilitate categorical search.

Acknowledgement: This research was supported by an Australian Research Council (ARC) Future Fellowship (FT130101282) granted to SIB.

56.3042 Contextual influences on object representations in the occipito-temporal cortex Olivia Cheung[1,2,3] (sccheung.olivia@gmail.com), Alfonso Caramazza[2,3]; [1]New York University Abu Dhabi, [2]Harvard University, [3]Center for Mind/Brain Sciences (CIMeC), University of Trento

What are the factors that determine how objects are represented in the visual system? Apart from visual shape, conceptual information such as animacy and object size has been established as major organizational principles for object representations in the occipito-temporal cortex. However, it remains unclear whether object representations may also be influenced by contextual information (i.e., where objects appear in the world). There has been debate regarding whether contextual information is retrieved when objects are seen, and whether the neural locus of contextual effect may be in the object-selective lateral occipital complex (LOC) or the scene-selective parahippocampal cortex (PHC). We examined how object representations in the occipito-temporal cortex may be influenced by animacy, object size, and context. We used 24 items, including 4 animals, 4 big and 4 small inanimate objects for each of 2 contexts (e.g., beach items: dolphin, lifeguard chair, goggles; house items: dog, coffee table, vase). Sixteen exemplars were included for each item. Using fMRI, neural responses for the 24 items were obtained when participants (n=15) performed a one-back task to match identical images. To analyze the nature of object representations, we first calculated representational similarity matrices (RSMs) on the neural response patterns for the 24 items in both the LOC and the PHC (defined in a separate localizer). We then correlated the neural RSMs with several candidate models of RSMs. We found that a RSM that incorporated the effects of animacy, object size, and context was significantly correlated with the RSMs in both LOC and PHC. The correlations were stronger compared to those with other candidate RSMs, which concerned only animacy and size, or animacy alone. These results suggest that contextual information is engaged, even when such information is task-irrelevant. It appears that multiple sources of object knowledge contribute to form object representations in the occipito-temporal cortex.

56.3043 Task modulates category selectivity along a gradient from occipitotemporal cortex to prefrontal cortex in word- and face-selective regions Lior Bugatus[1,2] (liorbu@stanford.edu), Kevin Weiner[1,2], Kalanit Grill-Spector[1,2]; [1]Department of Psychology, Stanford University, Stanford, CA, [2]Stanford Neuroscience Institute, Stanford University, Stanford, CA

The human brain contains separate functional networks constituting of multiple regions across occipital, temporal, and prefrontal cortices that are involved in processing faces and words. It is hypothesized that regions in occipitotemporal cortex process visual attributes of these stimuli and regions in the prefrontal cortex are involved with higher cognitive functions such as selective attention or working memory. However, it is unknown whether task and stimuli differentially affect responses of regions within these networks. Here we addressed this question by scanning 9 subjects using fMRI while they viewed stimuli from five categories: faces, bodies, houses, cars, and pseudo-words. Subjects performed in the same session three tasks in separate runs, and task order was counterbalanced across subjects. Oddball: subjects detected a randomly presented phase-scrambled image. Working memory: subjects indicated whether a stimulus repeated after an intervening image. Selective attention: subjects viewed superimposed images from two categories, attended to one stimulus category and reported when the attended stimulus was flipped upside-down. Word- and face-selective regions of interest in analogous anatomical locations were identified independently in each subject. Our analysis found a differential effect of task on stimulus selectivity across category-selective regions (task by region interaction, $F(8,184) = 2.68$, $p = 0.008$). Specifically, category-selectivity in lateral occipital cortex regions was similar across tasks, but was moderately increased in ventral temporal regions during the working memory task. In prefrontal cortex, however, the working memory task had a significant effect on category-selectivity: there was prominent face- and word-selectivity during the working memory task, but insignificant selectivity during the oddball and selective attention tasks. Together, these results reveal a gradient of selectivity that is modulated differentially by task, suggesting that the multiplicity of face- and word-selective regions may be related to task-relevant functional differences of individual components in these functional networks.

Acknowledgement: NEI grant 1R01EY02391501A1 CNI seed grant

56.3044 Recognizing Urban Tribes with pre-trained Convolutional Neural Networks Yufei Wang[1] (yuw176@ucsd.edu), Garrison Cottrell[2]; [1]ECE Department, UC San Diego, [2]CSE Department, UC San Diego

In the past few years, the power of Convolutional Neural Networks (CNNs) has been especially strong in image categorization. However, the analysis the social features of images of groups of people has not attracted much research. Analysis of social group is difficult in that group categories are semantically ambiguous, and have high intra-class variance. We investigate the generalization ability of pre-trained CNN features on social group recognition. We propose a CNN-feature based architecture for social group recognition and test it on an 11-category "urban tribes" dataset. Our model takes in both individual images and global scene images, and features are extracted by a fine tuned pre-trained CNN. The pre-trained CNN architecture we use is the one developed by Krizhevsky et.al. (2012), which was pre-trained on the 1000-class Imagenet dataset. In our recognition scheme, patches from the images representing individuals are first extracted, then these individual patches and the original complete scene are processed by the CNN, and the two penultimate fully connected-layer activations are extracted as features. SVM classifiers are then used to predict probabilities from both individual and scene features, and are then combined to get the final recognition result. Our result on the urban tribes dataset is 71.23%, which is a boost of performance from the previous state of the art of 46%. We further investigate why features extracted from pre-trained CNN are useful for the urban tribe recognition task. For an input image, there is a correlation between the probability of it being in Imagenet classes and being in urban tribes classes. Moreover, the degree of correlation is related to the recognition rate of different urban tribes classes. This may indicate that the "generic" features extracted by pre-trained CNN networks are not so generic. However, the actual relationship between the two types of categories is still mysterious in most cases.

56.3045 Visual Classification Expertise without Training Brett Roads[1] (brett.roads@colorado.edu), Michael Mozer[1]; [1]Department of Computer Science and Institute of Cognitive Science, University of Colorado Boulder

Decision-support systems have been built to assist individuals in categorizing a visual stimulus by presenting the stimulus next to two or more reference images with known category labels. Such systems transform the task of categorization into the task of similarity judgment. Decision-support systems are playing an increasing role in diverse applications such as commercial software products, human-in-the-loop computer vision, and citizen science projects. To explore the capabilities of decision support, Mechanical Turk experiments were devised in which participants make a sequence of similarity judgments between a test exemplar and four reference exemplars. Experiment 1 used rectangles that vary along the dimensions of width and height. Judgments from this experiment were used to select and parameterize a model of human forced-choice selection. This model was used to optimize the choice of reference exemplars for specific categorization tasks. Experiment 2 evaluated implicit classification accuracy on three different categorization tasks, each corresponding to a

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different decision boundary in the 2D space of rectangles—vertical, horizontal, and diagonal. High classification accuracy (M = 91%, SD = 2%) was achieved even though the three implicit tasks were intermixed and subjects had no awareness that they were performing specific categorization tasks. (From their perspective, the task was similarity judgment.) Through intelligent selection of exemplars, naïve individuals can be guided to make correct classification decisions. Further experiments calibrated the forced-choice selection model—and the reference exemplars chosen based on this model—to individual participants and used more complex and naturalistic stimuli, yielding further encouraging results.

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56.3046 **The emergence of decision boundaries is predicted by second order statistics of stimuli in visual categorization** Feryal M. P. Behbahani[1] (feryal.mehrabanpour10@imperial.ac.uk), A. Aldo Faisal[1,2,3]; [1]Dept. of Computing, Imperial College London, UK, [2]Dept. of Bioengineering, Imperial College London, UK, [3]MRC Clinical Sciences Centre, Hammersmith Hospital, London, UK

Categorization is a fundamental and innate ability of our brain, however, its underlying mechanism is not well understood. Previous experimental work on human categorization shows data that is consistent with both discriminative and generative (typically Bayesian) classification. However, the experimental designs used were not able to deliver a test that unambiguously accepts one method while simultaneously rejecting the other. Therefore, we designed a novel experiment in which subjects are trained to distinguish two classes A and B of visual objects, while exemplars of each class are drawn from Gaussian parameter distributions, with equal variance and different means. During the experiment, we test how the subject's representation of the categories changes as a result of being exposed to outliers for only one of the categories, A, far from category B (i.e. increasing category A's variance). Generative classifiers are by necessity sensitive to novel information becoming available during training, which updates beliefs regarding the generating distribution of each class and assumes class A's variance has increased significantly, thereby reaching across the region occupied by B which predicts an emergence of a new boundary. In contrast, discriminative classifiers are sensitive to novel information only if it affects the immediate discrimination of classes. We observe that, initially, when both categories have equal variance, subjects' decision boundary lies between the two categories consistent with both discriminative and generative algorithms. However, the introduction of the outliers for category A, influences the subject's knowledge of the distribution associated with alternative categories such that objects closer to category B and farthest from category A's outliers will be classified as belonging to category A and thus a new boundary emerges, only predicted by our simulations of generative classifiers. These results give evidence that visual categorization is only consistent with generative and not discriminative classification mechanisms.

Motion Perception: Local and higher order

Tuesday, May 19, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4001 **The effects of different orientations of in-phase and counter-phase backgrounds on horizontal motion discrimination** Andrew Silva[1] (aesilva@ucla.edu), Zili Liu[1]; [1]Department of Psychology, University of California, Los Angeles

Introduction: When a paired-dot stimulus is locally balanced such that the dots within each pair travel in opposite directions and in close spatial proximity over a short distance (counter-phase motion), a flicker-like percept occurs (Qian, Andersen, & Adelson, 1994). However, if the motion of one dot per pair is reversed such that both dots travel in the same direction (in-phase motion), a globally transparent percept occurs (Lu, Qian, & Liu, 2004). Here, we examined how discrimination sensitivity to horizontal motion is affected by different orientations of a superimposed in-phase or counter-phase background. A reasonable hypothesis is that near-horizontal background orientations should result in better overall performance than steeper orientations, as the former case creates stimuli with greater numbers of directional signals near the target direction. However, it is unknown whether this expected pattern is modulated by the local balancing of the counter-phase background. Method: Fourteen participants discriminated the direction of a horizontally moving field of target dots. This field was presented simultaneously with 676 pairs of background dots, all exhibiting in-phase or counter-phase motion along a common orientation between 0 and 90 degrees from horizontal. A 2-down, 1-up staircase measured the number of target dots required to achieve 71% accuracy. Results: Background orientations between 0 and 30 degrees from horizontal resulted in low overall thresholds and a relatively small difference between in-phase and counter-phase thresholds. Steeper background orientations resulted in increased thresholds, though the rate of increase was considerably faster for the counter-phase background. Conclusions: A detrimental effect of local balancing was found. However, this effect was less apparent for near-horizontal background orientations, suggesting that a global target motion can perceptually capture any similarly-oriented background dots in locally balanced as well as locally unbalanced backgrounds.

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56.4002 **Dmax: Motion seen better in the periphery than in the fovea** Neal Dykmans[1] (ndykmans@ucsd.edu), Stuart Anstis[1]; [1]Department of Psychology, University of California, San Diego

We present a rare example of peripheral vision being better than foveal vision, based upon Dmax (Braddick, Vision Res. 1974). A field of dense random dots jumps clockwise around a circular orbit while remaining upright (without rotating). Viewed foveally, the field appears to "twinkle" randomly (like dynamic visual noise). In peripheral vision, the circling motion is clearly seen. Our results show that Dmax is smallest for small dots and progressively larger for large dots and clumps of dots. In the fovea, individual dots jump through distances exceeding their own Dmax, and therefore look random, masking out the circling motion of low-frequency random clumps of dots. In the periphery, low spatial acuity filters out this masking twinkle, revealing the circling clumps. By varying the jump size and dot size, we showed that jumps through a distance of x dot diameters gave visible circling only at eccentricities proportional to x0.68 or greater. Thus Dmax is determined not by dot size per se, but by the ratio of jump size to dot size.

56.4003 **Misperceived motions of stripes moving behind holes.** Stuart Anstis[1] (sanstis@ucsd.edu), Sae Kaneko[1]; [1]Psychology, UC San Diego, La Jolla CA

1. A coarse vertical grating drifts to the right behind a screen that is pierced with numerous small, randomly placed stationary round holes, like a Swiss cheese. The holes are one grating period in diameter. Result: When the screen is mid-grey, the motion is clearly seen; the holes themselves seem to drift to the right; and stopping the motion yields a strong leftward motion aftereffect. But when the screen is black, little or no motion, nor motion aftereffect, is seen; and the holes do not budge. In short, the black screen appears to silence the motion. Conclusion: The mid-grey screen "crispens" the grating, increasing its perceived contrast and hence motion salience. 2. A large hole and a fine grating behind it, move in synchrony to the right, like a disk painted with stripes. On a black surround, the stripes are correctly seen in step with the disk. But on a black/white flickering surround, the stripes appear to overtake the disk and move at twice its speed. Conclusion: Reverse phi apparently slows the disk, but not the stripes it contains.

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56.4004 **Feeling the future** Patrick Cavanagh[1] (patrick.cavanagh@parisdescartes.fr), Marianne Duyck[1], Cécile Eymond[1], Gerrit Maus[2], Frank Schumann[1], Viola Störmer[3], Arielle Veenemans[1], David Whitney[2], Daw-An Wu[4]; [1]LPP, Université Paris Descartes, CNRS UMR 8424, [2]Psychology, University of California Berkeley, [3]Psychology, Harvard University, [4]Humanities and Social Sciences, CalTech

When a moving target is flashed briefly, the position of the flash is mislocalized in the direction of the motion (Cai & Schlag, 2001). A similar forward shift is also reported for the localization of a click added to a moving auditory target (Krüger et al, 2014). However, the reports for touch are mixed: the location of a tactile stimulus presented to a moving finger can be referenced forward in the direction of the finger's motion (Dassonville, 1994; Watanabe et al, 2009) or backward (Maij et al, 2011). Our goal was to measure this tactile mislocalization and compare it to the auditory case under similar test conditions. We designed a simple tabletop procedure for both, one that could be easily duplicated for classroom use with no equipment. In the touch condition, blindfolded subjects moved their index finger 40 cm across a table leftward or rightward in about 500 ms, either voluntarily or passively. At mid-trajectory, there was a notch in the table that subjects could feel. After completing the hand movement, subjects pointed to the felt location of the notch. Surprisingly, subjects systematically mislocalized the notch backwards, closer to the beginning of their trajectory, when they moved their own hand but not when the experimenter moved it. In the auditory condition, blindfolded subjects passively

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listened to the sound of a key dragged across the table over the same trajectory, making a click as it passed over the notch. Here, they pointed to a location that placed the click ahead on its path. When subjects had both auditory and tactile information, dragging the key with their own hand, the mislocalizations cancelled. Our simple tabletop tests replicate forward mislocalizations in the auditory domain and suggest that under active control, the felt location of a moving hand lags its physical location.

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56.4005 Speed of visual attention and localization of motion onset

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In the Fröhlich effect, the onset of a moving object's trajectory is perceived further ahead in the direction of motion (Fröhlich, 1923). One hypothesis suggests that upon stimulus presentation the focus of attention is shifted to the stimulus and that the moving stimulus is not visible until attention arrives (Müsseler, Ascherschleben, 1998). However, according to the earlier observations, even if the future location of the stimulus is cued ahead of time, the effect, although smaller, remains significant, suggesting that even when cued to its location, the attention shift to the object was not completed before the motion onset, or that attention cannot fully account for the Fröhlich effect. The aim of the present study was to systematically measure the Fröhlich effect under various cueing conditions and to compare the results with the estimates of attentional latencies. The measurement of the Fröhlich effect was carried out using rotational motion at one of four possible locations with valid, invalid or uninformative peripheral cues for the to-be-tested location. To measure the speed of attentional deployment we presented simultaneously rotating bars at the same four locations, asking the subjects to indicate the angle of the bar they saw on an unexpectedly highlighted stimulus (paradigm adapted from Carlson, Hogendoorn & Verstraten, 2006). Consistent with previous reports, the Fröhlich effect was larger in the uncued condition and the longer attentional latencies to the target location measured in this condition accurately predict this increase. Also consistent with previous results, we still find a Fröhlich effect when validly cued. However, our data reveal that the speed of attentional deployment to the cued location allows attention to reach the cued position well ahead of target onset, suggesting that the Fröhlich effect, while prone to attentional modulation, is not simply the consequence of delayed attentional arrival at the stimulus.

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56.4006 Both Dedicated and Flexible Motion Detection Benefit From Interocular Integration

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Motion perception is determined by changing patterns of neural activation initiated by spatiotemporal changes in stimulus features. These changing stimulus features may serve as input to systems dedicated to processing a specific type of feature, or to systems that flexibly compute motion from a variety of feature types. Spatiotemporally changing luminance detected by motion energy mechanisms is representative of such a dedicated system, while counterchange (oppositely signed changes in neural activation initiated by spatiotemporal changes in any feature) is representative of a flexible motion detection mechanism. Dedicated motion detection computations likely occur earlier in the visual system than more flexible ones, possibly before information from the eyes has been combined, raising the possibility that dedicated motion detection mechanisms may benefit less from dichoptic integration than more flexible mechanisms. Method. Two experiments compared dichoptic and monocular viewing of multistep apparent motion with varying frame durations. The monocular stimulus comprised one of the interleaved halves of the dichoptic stimulus. Experiment 1 utilized Kanizsa squares to create counterchange-based translating motion of an illusory square surface. Experiment 2 created apparent motion by sequentially incrementing the luminance of stationary, explicitly drawn squares. Results. Luminance-based motion perception was best for shorter frame durations, and counterchange-based motion perception was best for longer frame durations. Perception of motion improved with dichoptic viewing for both stimuli, as compared to monocular viewing. Discussion. Dedicated (motion energy-based), and flexible (counterchange-based) motion computations may occur at different stages in the visual processing stream, but both benefit from dichoptic integration. Flexible counterchange mechanisms are a likely basis for 3rd order motion perception (Lu & Sperling, 1995), and are well suited for the integration of information distributed to the two eyes. However, such integration is not a definitive indicator of 3rd order motion processing.

56.4007 Head tracking in virtual reality displays reduces the misperception of 3D motion

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Observers rely on multiple complementary sensory cues to guide behavior. Previously, we showed that when observers estimate 3D object motion, they exhibit a surprising tendency to confuse approaching and receding motion (Fulvio et al, JOV 2014). However, such confusion seems to rarely occur in real world motion estimation. Extra-retinal cues such as head motion likely help disambiguate motion in depth. We tested this using the Oculus Rift, a head-mounted virtual reality display that can provide appropriate sensory feedback in response to changes in head orientation. We predicted that if observers rely on head motion to disambiguate motion in depth, accuracy in estimation of 3D object motion would improve with more natural viewing conditions. On each trial, a target with one of 3 contrast levels moved in a randomly chosen direction in the horizontal plane for 1s before disappearing. Observers (n=28) then adjusted the position of a 'paddle' around an invisible orbit so that it would intercept the target had it continued along the trajectory. Three head-motion conditions were tested: (i) 'fixed' – no updating with head orientation; (ii) 'tracked' – display updating with changes in head orientation; (iii) 'lagged' – display updating delayed by 50ms. Feedback was not provided. Reduced target contrast increased the proportion of motion in depth confusions across head-motion conditions ($t(207)=-12.905$, $p< 0.001$, $d=0.89$). Importantly, changes in head orientation were small (average max ~ 0.94deg in 3D space), yet had a significant effect on performance ($t(207)=-3.3491$, $p< 0.001$, $d=0.23$) - motion in depth confusions were less likely in the tracked versus fixed condition ($t(166)=-1.94$, $p=0.027$, $d=0.42$). We did not find differences between the tracked and lagged conditions ($p=0.69$), or fixed and lagged conditions ($p=0.13$). These results reveal a critical role for extra-retinal cues in 3D motion perception and contribute to the understanding of cross-modal integration.

56.4008 Two eyes more sensitive than one: Monocular speed discrimination is better across eyes than within an eye

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When an object moves directly towards or away from an observer, it projects opposite horizontal directions of motion upon the two retinae. Binocular 3D motion perception relies on this cue, the inter-ocular velocity difference (IOVD). However, many animals have little or no binocular overlap, but are known to depend upon inter-ocular velocity comparisons for navigation (Srinivasan et al., 1996). Likewise, even humans have substantial portions of monocular visual field. We asked whether human subjects use similar inter-ocular velocity comparisons across the monocular portions of the two eyes' views, and assessed whether these monocular IOVDs are processed similarly to motions in other parts of the monocular and binocular visual fields. Subjects performed a 2AFC speed discrimination on a pair of drifting gratings (~10 deg radius) as a function of baseline speed (10-40 deg/s), across a wide range of binocular and monocular portions of the visual fields. "Intra-monocular velocity discrimination" involved comparing both gratings within one eye's monocular field, while "inter-monocular velocity discrimination" required comparison across the 2 monocular fields. We also performed a reference condition involving more conventional dichoptic viewing within the central binocular visual field. Speed discrimination thresholds were significantly lower for inter-monocular viewing (i.e., one grating in each eye's monocular field) compared to intra-monocular (i.e., both gratings in one eye's monocular field). Control experiments confirmed the intra-monocular advantage was not due to inter-monocular crowding or interference. Performance in the central binocular control conditions was better overall, but did not depend on whether stimuli were presented within or across the 2 eyes. IOVDs may be a privileged visual computation, both within the central (binocular) visual field and across the far temporal (monocular) fields. These results suggest that both binocular and monocular IOVDs may reflect the same basic mechanism.

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56.4009 Phase Integration Bias Predicts Performance in a Motion Binding Task Jessica Cali[1] (calij@mcmaster.ca), Matthew Pachai[1], Patrick Bennett[1], Allison Sekuler[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Studies of motion binding often examine the integration of components such as orientation and speed. We examined motion binding using a task requiring only integration of relative phase (Cali et al., VSS, 2014). Observers discriminated clockwise and counter-clockwise motion in a stimulus comprising four sets of linearly arranged dots, two moving horizontally and two moving vertically along sinusoidal trajectories differing in phase. Across conditions, noise jitter could be added along the trajectory perpendicular to each dot's motion. Interestingly, as originally showed by Lorenceau (Vision Res., 1996), noise improved discrimination accuracy, consistent with the notion that noise acts as a grouping cue encouraging perception of global motion. Furthermore, when noise was absent from the stimulus, accuracy was not at chance, but significantly below chance; observers consistently reported motion in the incorrect direction. Here we test the hypothesis that observers perceive reverse motion because their representation of the relative phase of the motion components is systematically biased. We asked observers to adjust the relative phase of motion components to produce the most compelling clockwise or counter-clockwise motion with stimuli that did or did not contain noise. We also measured discrimination accuracy for clockwise and counter-clockwise motion. We found that i) phase adjustment error was significantly greater with no noise; ii) discrimination accuracy was significantly below chance with no noise; and iii) the correlation between phase adjustment error and discrimination accuracy were significant in both noise conditions. Our results support the hypothesis that observers misperceive the direction of motion without noise because their representation of the relative phases of motion components is biased. This bias may occur because observers sample the motion components sequentially in the zero noise condition and simultaneously in the high noise condition. More generally, this result suggests the presence of an integration bias in other motion tasks.

Acknowledgement: Canadian Research Chairs Program, Canadian Institutes for Health Research, National Sciences and Engineering Research Council

56.4010 EEG and fMRI correlates of non-retinotopic motion processing in the human visual system Evelina Thunell[1] (evelina.thunell@epfl.ch), Gijs Plomp[1, 2], Wietske Van der Zwaag[3], Haluk Ögmen[4], Michael Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland, [2]Functional Brain Mapping Lab, Department of Fundamental Neuroscience, University of Geneva, Geneva, Switzerland, [3]CIBM, École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland, [4]Department of Electrical and Computer Engineering, Center for Neuro-Engineering and Cognitive Science, University of Houston, Houston, TX, USA

While most of the visual brain areas are organized retinotopically, perception is typically non-retinotopic. For example, as a bicycle passes by, we perceive a reflector on its wheel to move in a circular or prolate cycloidal orbit. By contrast, the true retinotopic trajectory traced out by the reflector is a curtate cycloid. We cannot see the retinotopic motion because the horizontal motion of the bicycle is discounted from the motion of the reflector. The bicycle thus serves as a moving, non-retinotopic reference system, within which the motion of the reflector is computed. Despite the important role of non-retinotopic processing in visual perception, almost nothing is known about its neural correlates. Here, we used the Ternus-Pikler display to contrast retinotopic processing in a stationary reference system against non-retinotopic processing in a moving one. In a 7T fMRI experiment, we found hMT+ to be the first area in the visual processing stream where non-retinotopic percepts were reflected in the BOLD signals. The signals in the early visual areas (V1-V3) instead reflected the retinotopic stimulation. We propose that hMT+ computes the motion of the reference system and immediately discounts this motion in order to compute relative motions. This is in line with our EEG study, where we found neural correlates of non-retinotopic perception already from the earliest evoked peak around 120 ms after stimulus onset and throughout the rest of the visual processing.

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56.4011 Predictability, efference copies, and non-retinotopic motion Marc Lauffs[1] (marc.lauffs@epfl.ch), Haluk Öğmen[2], Michael Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, [2]Department of Electrical and Computer Engineering, Center for NeuroEngineering and Cognitive Science, University of Houston, Houston, TX, USA

Perception is usually non-retinotopic. For example, visual perception is stable even though the retinal image is constantly changing due to eye and body movements. Likewise, a reflector on the wheel of a bicycle is perceived to rotate on a circular orbit, while its "true" motion (in retinotopic or exogenous coordinates) is cycloidal. In the first example, the brain uses efference copies to predict and compensate for eye movements. But how does the brain compensate for motion without efference copies? To investigate non-retinotopic motion perception, we used the Ternus-Pikler display. Two disks are flashed on a computer screen. A dot moves linearly up-down in the left disk and left-right in the right disk (retinotopic percept). If a third disk is added alternatingly to the left and right, the three disks form a group moving back and forth horizontally. The dot in the central disk now appears to move on a circular orbit (non-retinotopic percept), because the brain subtracts the horizontal group motion from the combination of the up-down and left-right motion. Here, we asked whether predictability is necessary to compute non-retinotopic motion. In experiment 1, the three disks moved randomly in any direction, rather than horizontally back and forth. Still, a strong non-retinotopic dot rotation was perceived. In experiment 2, we additionally varied the shape and contrast polarity of the stimuli from frame to frame. Still, a strong non-retinotopic dot rotation was perceived. Hence, the visual system can flexibly solve the non-retinotopic motion correspondence problem, even when the retinotopic reference motion is unpredictable. It seems that, in the case of non-retinotopic motion, the brain computes the reference-frame in real-time and does not need efference copy-like signals based on the predictability of the stimulus.

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56.4012 Binocular integration of pattern motion signals in the human oculomotor system Christian Quaia[1] (quaiac@nei.nih.gov), Lance Optican[1], Bruce Cumming[1]; [1]Laboratory of Sensorimotor Research, National Eye Institute, NIH, DHHS

Psychophysical and neurophysiological evidence indicates that the computation of pattern motion is partially, but not completely, disrupted when two drifting gratings forming a plaid are presented dichoptically (i.e., one to each eye, Tailby, Majaj and Movshon, 2010). Here we set out to quantify the extent of this disruption along the visual pathway that underlies short-latency reflexive eye movements in humans. Unikinetic plaids, formed by summing a drifting and a static sinusoidal grating of different orientations, elicit short-latency ocular following responses (OFRs) that can be used to study pattern motion computations (Masson and Castet 2002). In our experiments we combined a vertical drifting (20 Hz) grating and a static oblique grating tilted 45 deg away from vertical (both gratings had a spatial frequency of 0.25 cpd). With this configuration, the magnitude of the vertical component of the OFR is a direct proxy for the strength of the pattern motion signal. We used three stimulus configurations: Binocular - both eyes saw the unikinetic plaid; Monocular - unikinetic plaid in one eye, gray background in the other; Dichoptic - drifting grating in one eye, static grating in the other. We measured, in three subjects, the strength of the vertical component of the OFRs induced by these stimuli. On average, the pattern motion signal for the dichoptic condition was 30% of that generated under binocular presentation, and 52% of that induced by the monocular stimulus. From this latter number we infer that the pattern motion computation is evenly split amongst monocular and binocular pathways, and it is thus likely to rely on computations occurring in primary visual cortex, where both monocular and binocular neurons are present.

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56.4013 Effect of light level on the postdictive perception of visual motion Sanae Yoshimoto[1,2] (n1384003ys@gr.jwu.ac.jp), Tatsuto Takeuchi[1]; [1]Japan Women's University, [2]Japan Society for the Promotion of Science

Visual motion perception is affected by the subsequent visual input. This is a type of postdictive modulation induced by the spatiotemporal integration of motion signals. The aim of this study was to clarify the effect of light level on the postdictive modulation of visual motion, because motion perception can be varied with the light level (Yoshimoto & Takeuchi, J. Vis., 2013). For this purpose, we investigated how the perceived direction of a directionally ambiguous test stimulus is changed by the unidirectional drifting of a subsequent stimulus under various light conditions. The test stimu-

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lus was generated by shifting the phase of a sine-wave grating by 180°. Because the postdictive modulation of visual appearance occurs within a limited time range (Eagleman & Sejnowski, J. Vis., 2007), the stimulus-onset asynchrony (SOA) between the test and the subsequent stimulus was set to 250 ms. The eccentricity of stimulus presentation was varied from 0.0° to 10.0°. Observers judged the perceived direction of the test stimulus (rightward or leftward), which preceded a subsequent stimulus at different light levels ranging from photopic to scotopic levels (42–0.0024 cd/m2). We found that postdictive modulation, in which the test stimulus was perceived to move in the same direction as the subsequent stimulus, was stronger under mesopic conditions than under photopic or scotopic conditions. The strongest postdictive modulation was observed when the stimuli were presented at an eccentricity of 3.3°–6.7°, where the relative contributions of the cones and rods are almost equal under mesopic conditions (Raphael & MacLeod, J. Vis., 2011). These results suggest that motion integration is facilitated as a form of postdictive perception of motion to deal with the incoming spatiotemporally different signals from cones and rods.

56.4014 **The automaticity of perceiving animacy: Seeing goal-directed motion in simple shapes influences visuomotor behavior even when task-irrelevant** Benjamin van Buren[1] (vanburenb@gmail.com), Stefan Uddenberg[1], Brian Scholl[1]; [1]Department of Psychology, Yale University

Visual processing recovers not only simple features such as color and shape, but also seemingly higher-level properties such as animacy and intentionality. Indeed, even abstract geometric shapes are readily perceived as intentional agents when they move in certain ways, and such percepts can dramatically influence behavior. In the wolfpack effect, for example, participants maneuver a disc around a display that contains a number of randomly-moving dart shapes, which they must avoid. When the darts collectively point toward the user-controlled disc, however, participants (falsely) perceive that the darts are chasing them, and they perform substantially worse than when the darts are always oriented perpendicular to the disc (a control condition that perfectly equates the degree of correlated motion). However, the nature of such effects, despite their power, remains unclear. Are they reflexive, automatic features of visual processing? Or might they instead arise only as contingent strategies in tasks where participants must interact with (and thus focus on the features of) such objects? We explored these questions in an especially direct way — by simply embedding such displays into the background of a completely independent 'foraging' task. Participants now moved their disc to collect small dots (which appeared sequentially in random locations) as quickly as possible. The darts were task-irrelevant, and participants were encouraged to simply ignore them. Nevertheless, foraging was significantly slowed when the randomly-moving darts all pointed at the participant-controlled disc — compared to control conditions when the darts either (1) were always oriented perpendicular to the participant-controlled disc, or (2) always pointed at a separate (and also task-irrelevant) moving shape. The perception of animacy may thus influence downstream visuomotor behavior in a reflexive, automatic manner, such that participants cannot override the influences of seemingly animate shapes while attempting to completely ignore them.

Face Perception: Development, adaptation, and learning

Tuesday, May 19, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4015 **Fundamental differences in early face experiences** Swapnaa Jayaraman[1] (swapnaa@indiana.edu), Linda Smith[1]; [1]Psychological and Brain Sciences Department, Indiana University

Properties of the visual system are deeply rooted in the regularities of visual environments. It is likely that properties of the human face processing system arise, at least in part, from regularities in face input available in early environments. Several studies have attempted to characterize early visual input using head mounted cameras in natural infant environments (Aslin, 2009; Jayaraman, Fausey & Smith, 2013; Sudgen, 2013; Jayaraman, Fausey & Smith, in press). Jayaraman, Fausey & Smith (in press), specifically, describe changing statistical regularities in face input over the first year of life. Results from the above studies characterize visual experiences of middle class infants from North America. However, they may not represent visual environments of all human infants. One hypothesis is that the altricial nature of infants necessitates nearly-universal constraints on the nature of face experiences. Alternatively, parenting practices and socio-economic constraints could drive face experiences. To explore these hypotheses, we obtained head camera recordings from infants in an urban fisherman community in India. Preliminary analyses suggest that face availability in early visual environments of these Indian infants are dramatically different from that of American infants on three critical measures: face exposure, range of faces, and face distance. Youngest American infants experienced faces that belonged to few individuals very frequently and up close (< 2ft) – a trend that declined by 12 months. Indian infants, in contrast, experienced a much wider range of faces at greater distances throughout the first year. Results indicate that infant face experiences are not universal. Implications of these differences in early visual experiences can be one of three: (a) adult face processing abilities are not homogenous across all communities, (b) multiple developmental pathways can lead to a mature face processing system, (c) adult face processing system is robust against variations in early input.

56.4016 **Capturing developmental shifts in facial identity and expression processing strategies.** Louise Ewing[1,4] (l.ewing@bbk.ac.uk), Annette Karmiloff-Smith[1,2], Emily Farran[3], Marie Smith[1]; [1]Department Psychological Sciences, Birkbeck, University of London, [2]Birkbeck Centre for Brain and Cognitive Development, Birkbeck, University of London, [3]Department of Psychology and Human Development, Institute of Education, University of London, [4]ARC Centre for Excellence in Cognition and its Disorders, Department of Psychology, University of Western Australia

Children are widely accepted to process faces differently from adults, with aspects of adult-like processing and neural specialization continuing to develop into early adulthood. Critically, however, little is known about the specific information processing strategies employed as children mature. Here, we investigate the development of face processing strategies in children aged 7-12 years using a reverse correlation approach to determine the visual features driving categorizations of face identity and expression. Specifically, 106 participants (90 children, 16 adults) were trained to identify three unfamiliar faces by name and 200 participants (180 children, 20 adults) were asked to categorize expressions of four basic emotions (fear, sadness, happiness, anger). Across experimental trials we created subsampled versions of these faces by randomly sampling visual information from the images (across different locations and spatial frequency bands) using circularly symmetric apertures ('bubbles'). Participants had to make their categorization decisions based upon only the information directly behind these apertures; the rest was hidden from view. Results revealed that children make less use of the eyes than adults during both tasks. When reading face identity, adults rely on information from the eyes and mouth, particularly in high spatial frequency bands. In contrast, young children make less use of information from the eyes and focus their attention more on the mouth region, with this bias attenuating with age. During expression categorizations we found that relative to adults, children showed a much greater reliance on information from the mouth region when judging fear, sadness and anger, the three emotions that they found most challenging to identify. For happiness, however, which they recognized with near adult-like accuracy, children used information in a more equivalent manner to adults. Across both tasks, these results signal a clear developmental shift in participants' strategic information use when making judgments about key facial characteristics.

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56.4017 **Horizontal tuning of face-specific processing from childhood to elderly adulthood** Valerie Goffaux[1,2,3] (valerie.goffaux@uclouvain.be), Aude Poncin[1,2], Christine Schiltz[4]; [1]Institut de recherche en sciences psychologiques (IPSY), Faculté de psychologie et des sciences de l'éducation, Université Catholique de Louvain (UCL), Louvain-la-Neuve, Belgique, [2]Institute of Neuroscience (IONS), Université Catholique de Louvain (UCL), Louvain-la-Neuve, Belgique, [3]Cognitive Neuroscience Department, Maastricht University, Maastricht, The Netherlands, [4]Education, Culture, Cognition and Society (ECCS) unit, Faculty of Language and Literature, Humanities, Arts and Education (FLSHASE), University of Luxembourg, Walferdange, Luxembourg

Face recognition in adults recruits specialised mechanisms that are selectively driven by horizontal information. This range indeed conveys the most optimal and stable cues to identity. Whether the horizontal tuning of adult face recognition reflects horizontal bias already active at infancy and/or whether it also results from the extensive experience acquired with faces over the lifespan is elusive. Answering these questions is crucial to determine the information constraining the developmental specialisation of core visual functions such as face perception. Participants aged between

6 and 74 years matched unfamiliar faces that were filtered to retain information in narrow ranges centred on horizontal (H), vertical (V), or both orientation ranges (HV). H and V ranges respectively maximize and minimize the recruitment of face-specific mechanisms (Goffaux and Dakin, 2010). Stimuli were presented at upright and inverted planar orientations and the face inversion effect (FIE; i.e., better performance for upright than inverted faces) was taken as a marker of face-specific processing. In H and HV conditions, FIE size increased linearly from childhood to adulthood, manifesting the progressive specialization of face perception. FIE emerged earlier when processing HV than H faces (FIE onset: 6 and 12 years, respectively) indicating that until 12 years horizontal information is necessary but not sufficient to trigger face-specialised processing. Partial correlations further showed that FIE development in HV condition was not fully explained by FIE development in H condition. Besides a progressive maturation of horizontal processing, the specialization of the face processing system thus also depends on the improved integration of horizontal range with other orientations. In contrast, FIE size was small and stable when processing V information. These results show that the face processing system matures over the life span based on the refined encoding of horizontally-oriented (upright) face cues.

56.4018 Neural discriminability for face identity improves from childhood to adulthood

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Face recognition requires fine-grained discrimination among highly similar exemplars. Discrimination accuracy increases with increasing perceptual dissimilarities between identities and this accuracy improves from age five. Neurally, recovery from adaptation also increases with dissimilarities among identities. However, it is unknown whether neural mechanisms underlying face discrimination develop from age 5 to adulthood. We addressed this question using an fMRI-adaptation (fMRI-A) paradigm, in which subjects viewed own-age faces and other-age faces that parametrically varied in their degree of similarity. We examined if there are differences in neural adaptation profiles of face-selective regions in the inferior occipital gyrus (IOG-faces), posterior fusiform gyrus (pFus-faces/FFA-1), and mid fusiform gyrus (mFus-faces/FFA-2) across children (ages 5-12, n=15) and adults (ages 19-34, n=12). We generated face identity morphs, whereby each morph was a linear weighting of a source face and one of six target faces. Morph-levels ranged from source face (0%) to target faces (100%), by 20% increments. Each block consisted of 6 identities at the same morph-level from their source face. We measured neural adaptation with respect to age of subject and age of stimuli in face-selective regions. First, we find a linear relationship between the response amplitude across morph-levels, with larger slope in adults than in children, in the left IOG and right pFus and mFus. Second, adults as compared to children showed larger fMRI-A, defined as the difference in the response amplitude to 100% versus 0% faces, in the left IOG, bilateral pFus, and right mFus. Third, we found an own-age bias that is larger fMRI-A to own-age faces than other-age faces in bilateral pFus. Our results suggest that neural sensitivity to detect small changes in face identity improves with age, which may be linked to developments in perceptual discriminability throughout childhood.

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56.4019 The development of gender and age biases in face recognition from childhood into adulthood

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Multiple biases characterize face recognition behavior in adults. For example, middle-aged adults have superior recognition for similarly aged adult faces compared to those of older adults or children (i.e., own-age bias, OAB) and for faces of individuals from within their own gender (i.e., own-gender bias, OGB). However, the developmental trajectories of these biases and the influences shaping them are largely unknown. A recent model (Scherf et al., 2012) predicts that adolescence, and puberty in particular, may be a unique developmental period in which critical transformations in face recognition behavior (e.g., these biases) emerge. The present study examined how the OAB and OGB develop over the course of adolescence by dissociating the relative effects of age and puberty. To do so, we tested age-matched adolescents in early and later stages of puberty, as well as prepubescent children (6-8) and young adults (18-25 years) in an old/new face recognition paradigm. Participants completed 4 separate blocks, including male and female faces from developmental groups matching participant groups (6-8, 11-14 early puberty, 11-14 late puberty, 18-25; see figure 1). Adults were the only group to exhibit an OAB. All three developmental groups were more accurate at recognizing adult faces, not faces from their own peer age group. In terms of gender biases (see figure 2), only adult males evinced an OGB (e.g., more accurate at recognizing own-gender faces). Children were more accurate at recognizing female compared to male faces, regardless of their own gender. Adolescents in early puberty did not exhibit any clear pattern of gender biases, whereas age-matched adolescents in later puberty showed an emerging OGB. These results are consistent with the notion that experiences with caregivers in childhood shape early face recognition biases, and that puberty uniquely influences the salience of gender, but not age, in face recognition behavior during adolescent development.

Acknowledgement: National Science Foundation

56.4020 No quantitative differences in face memory with regard to different viewpoints and viewpoint changes between children and adults

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The ability to recognize faces under varying contexts and conditions is essential for our social perception. One factor varying strongly in different situations is the viewpoint a face is presented in. The question has been raised if there are quantitative differences in face processing with regard to different viewpoints or viewpoint changes between children and adults. Here, we investigated face memory performance in school-aged children and adults in two experiments: Experiment 1 addressed the effects of different viewpoints on face memory performance in five- to ten-year-old children and adults (N = 110). In a within-group design three versions of a 2AFC-task were completed by each participant, comprising pictures of faces in either front, three-quarter or profile views. Experiment 2 investigated the effects of viewpoint changes on face memory performance in six- to ten-year-old children and adults (N = 180). Three main viewpoint changes between study and test phase were investigated (45°_front: front/three-quarter or three-quarter/front; 45°_profile: three-quarter/profile or profile/three-quarter; 90°:, front/profile or profile/front). A between-group design was applied, in which each participant completed one direction of each viewpoint change. Data of experiment 1 revealed a main effect of age group and a main effect of viewpoint – with frontal and three-quarter views being remembered more often than profile views. Experiment 2 revealed a main effect of age group and a main effect of viewpoint change – the difficulty level rising from 45°_front to 45°_profil to 90°. The lack of a viewpoint x age group interaction (Experiment1) and the lack of a viewpoint change x age group interaction (Experiment 2) indicate similar viewpoint and viewpoint change effects across age groups. Our results support the notion that there are no quantitative differences in face processing with regard to different viewpoints and viewpoint changes in children and adults.

56.4021 Development of small-world networks for own- and other-race face recognition in children from preschool to adolescence

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Adults show a neural other-race effect (NORE) paralleling the behavioral other-race effect (we recognize own-race faces better than other-race faces). However, the developmental origin of the NORE is limited (Ding et al., 2014). This study used graph theory to examine the development of small-world neural networks for recognizing own- vs. other-race faces. We used functional near infrared spectroscopy (fNIRS) to measure 3- to 13-year-old Chinese children's cortical neural responses to own- and other-race faces (N=139, age range: 3.25- 13.49 years). We computed functional connectivities between all NIRS channels (Figure 1). We found that for network segregation, the age effect and age by race interaction were significant, $F(1, 137) = 16.35$, $p < .001$, $\eta 2 = .11$, and $F(1, 137) = 4.28$, $p = .04$, $\eta 2 = .03$: with age, children's network segregation increased for other-race, but not own-race, faces. For network integration, children's network integration was greater for own-race faces than other-race faces, $F(1, 137) = 8.86$, $p = .003$, $\eta 2 = .06$. Also, the age and age by race interaction were significant, $F(1, 137) = 14.43$, $p < .001$, $\eta 2 = .10$, and $F(1, 137) = 4.91$, $p = .028$, $\eta 2 = .04$: with age, the network integration increased significantly for own-race, but not other-race, faces. For the network smallness index, the age effect and age by race interaction were significant, $F(1, 137) = 16.35$, $p < .001$, $\eta 2 = .11$, and $F(1, 137) = 4.28$, $p = .044$, $\eta 2 = .03$: with age, the network smallness increased for other-race, but not for own-race, faces (Fig.2). These results taken together show that children's small-world neural networks for face processing undergo developmental changes and these changes are also influenced by their increased differences in experience with own- and other-race faces.

Acknowledgement: NSERC, NSFC

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56.4022 **Development of functional connectivity during own- and other-race face processing: A Granger causality analysis** Guifei Zhou[1] (Guifei_Zhou@hotmail.com), Xin Jiang[2], Pu Zheng[4], Jiangang Liu[1], Xiaopan Ding[3], Genyue Fu[3], Kang Lee[3,4]; [1]Beijing Jiaotong University, [2]University College London, [3]Zhejiang Normal University, [4]University of Toronto

Recent research has shown that children and adults show robust neural other race effect (NORE) whereby their brains responds to own- and other-race faces differentially (Ding et al., 2014; Liu et al., 2014, Anzures et al., 2013). The present study used Granger causality analysis (GCA) to examine the development of children's cortical networks in processing own- and other-race faces. Children were between 3 to 13 years. An old-new paradigm was used to assess their own- and other-race face recognition with ETG-4000 (Hitachi Medical Co., Japan) acquiring functional near infrared spectroscopy (fNIRS) data. After preprocessing, for each participant and under each face condition, we obtained the causal relationship map by calculating the weights of causal relations between the time courses of [oxy-Hb] of each pair of channels using GCA. We used the Pearson correlations of the results of GCA value in own-race task minus GCA value in other-race task and ages of participants to index NORE (the statistical threshold was set at $p < 0.01$). We found that children's neural other-race effect changed with increased age. First, age-related causal connections were mostly positive, suggesting age-related strengthening of functional connectivity. Second, for youngest children, the NORE caused by more Granger causality connection in the recognition of other-race faces than that of own-race faces; for older children this result was reversed. Thus, that with increased age, children become increasingly more experienced with processing own-race faces than other-race faces, and consequently, their neural networks involved in own- and other-race face processing also undergo dramatic developmental changes.

56.4023 **Normal repetition probability effects in the occipito-temporal cortex in Schizophrenia** Mareike Grotheer[1,2] (mareike.grotheer@uni-jena.de), Igor Nenadic[3], Lisa Münke[3], Szabolcs Kéri[4], Gyula Kovács[1,2]; [1]Department of Cognitive Neuroscience, Institute of Psychology, Friedrich Schiller University Jena, 07743 Jena, Germany , [2]DFG Research Unit Person Perception, Friedrich Schiller University Jena, 07743 Jena, Germany, [3]Department of Psychiatry and Psychotherapy, Jena University Hospital, 07743 Jena, Germany , [4]Department of Cognitive Science, Budapest University of Technology and Economics, 1111 Budapest, Hungary

A growing body of evidences suggests that the comparison of expected and incoming sensory stimuli (predictive error (PE) processing) is impaired in schizophrenia (SZ). For example in studies of mismatch negativity, an ERP component that signals PE, SZ patients show deficits in both the auditory (Fulham et al., 2014) and the visual (Neuhaus, Brandt, Goldberg, Bates, & Malhotra, 2013) modality. In order to test the role of impaired PE processing in SZ further, using neuroimaging methods, we applied a repetition suppression (RS) paradigm (Summerfield, Trittschuh, Monti, Mesulam, & Egner, 2008). 17 patients diagnosed with SZ according to DSM-IV-R / DSM V as well as 17 age and gender matched healthy control (HC) subjects were presented with pairs of faces which could either repeat or alternate. Additionally, the likelihood of repetition/alternation trials was modulated in individual blocks of fMRI recordings, testing the effects of repetition probability (P(rep)) on RS. We found a significant RS in the fusiform and occipital face areas, as well as in the lateral occipital cortex that was similar in both groups. More importantly, we observed similar P(rep) effects (significant RS in blocks with high repetition likelihood but not in blocks with low repetition likelihood) in both groups as well. Crucially, this suggests normal predictive processes in patients with Schizophrenia.

56.4024 **A bias-free measure of the face viewpoint aftereffect from radial frequency patterns** Bruce Keefe[1] (bruce.keefe@york.ac.uk), Samuel Lawrence[1], Alex Wade[1], Declan McKeefry[2], Antony Morland[1,3]; [1]York Neuroimaging Centre, Department of Psychology, University of York, UK, [2]Bradford School of Optometry and Vision Science, University of Bradford, Bradford, UK, [3]Centre for Neuroscience, Hull-York Medical School, York

The face viewpoint aftereffect (FVA) is an illusion that biases the perception of a frontward facing test face in the opposite direction to the adapting face (Fang & He, 2005). Changes in the outer contour of the head that highlight these changes in face viewpoint can be modelled using radial frequency (RF) patterns (Wilson et al., 2000). We used RF patterns together with a recently developed procedure to tease apart the FVA from observer response bias. The psychophysical procedure we used was necessary because traditional methods for measuring perceptual illusions confound perceptual changes, with changes in an observer's criterion (Morgan, 2013; 2014). The contours describing the shape stimuli had a luminance profile that followed the fourth derivative of a Gaussian. Participants adapted to two vertically aligned, contrast reversing (1Hz) stimuli facing in opposite directions. Eight separate test conditions were randomly interleaved, each with two static test stimuli, vertically aligned to the same spatial position of the adaptors. Test stimuli could face in either the same or opposite directions and allowed us to make tangible predictions to distinguish adaptation from response bias. A two-alternate forced choice adaptive staircase procedure was used in which the participants indicated which of the two test stimuli appeared most asymmetric. Results showed a large FVA from RF patterns that could not be attributed to shifts in observer response bias. By varying the size of the test stimuli we were able to rule out a purely retinotopic account of adaptation. Halving the size of the test stimuli reduced the FVA by ~50%, suggesting an extra-striate locus of adaptation. These results are consistent with the proposal by Wilson et al., (2000) which suggests an extra-striate locus for the processing of face viewpoint from RF patterns.

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56.4025 **Adaptor gaze direction affects the magnitude of face identity aftereffects** Nadine Kloth[1] (nadine.kloth@icloud.com), Linda Jeffery[1], Gillian Rhodes[1]; [1]ARC Centre of Excellence in Cognition and its Disorders, School of Psychology, The University of Western Australia

The face perception system partly owes its efficiency to adaptive mechanisms that constantly recalibrate face coding to our current diet of faces. Moreover, faces that are better attended produce more adaptation. Here, we investigated whether the social cues conveyed by a face can influence the amount of adaptation it induces. We compared the magnitude of face identity aftereffects induced by adaptors with direct and averted gaze. We reasoned that faces conveying direct gaze may be more engaging and better attended, and thus produce larger aftereffects, than those with averted gaze. Using an adaptation duration of 5s, we found that aftereffects for adaptors with direct and averted gaze did not differ (Experiment 1). However, when processing demands were increased by reducing duration to 1s, we found that gaze direction did affect the magnitude of the aftereffect, but in an unexpected direction: aftereffects were larger for adaptors with averted rather than direct gaze (Experiment 2). Eye tracking revealed that differences in looking time to the faces between the two gaze directions could not account for these findings. Subsequent ratings of the stimuli (Experiment 3) showed that adaptors with averted gaze were actually perceived as more expressive and interesting than adaptors with direct gaze. Therefore it appears that the averted gaze faces were more engaging and better attended, leading to larger aftereffects. Overall, our results suggest that naturally occuring facial signals can modulate the impact a face exerts on our perceptual system. Specifically, the faces that we perceive as most interesting also appear to calibrate the organization of our perceptual system most strongly.

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56.4026 **Faces are repulsive: Gender and identity aftereffects involve local repulsion, not re-normalisation** Katherine Storrs[1] (k.storrs@uq.edu.au), Derek Arnold[1]; [1]School of Psychology, University of Queensland

After looking at a photograph of someone, an average face can appear 'opposite' in gender, identity, and other attributes – but what happens to the appearance of other faces? Face aftereffects have repeatedly been ascribed to perceptual re-normalisation. According to this account, the adapting face, and more exaggerated versions of it, should appear more neutral, a pattern linked to adaptation within norm-based opponent channels. Other spatial aftereffects (e.g. tilt and spatial frequency) have a locally-repulsive pattern, in which differences between adapting and test stimuli are exaggerated, with little change to the adaptor's appearance. This pattern has been linked to multi-channel encoding schemes. Existing face aftereffect reports do not provide clear evidence for either pattern, because most quantify the aftereffect as a shift in a category boundary during a binary classification task. Such tasks are sensitive only to changes in the appearance of near-neutral stimuli, for which re-normalising and locally-repulsive aftereffects make the same prediction. We overcome this problem by using a spatial comparison task to measure the relative aftereffect induced between two differently-adapted retinal locations. By interleaving three standard stimuli, we are able to measure the relative aftereffect at three points: each of the two adapted values, and mid-way between them on the stimulus dimension. In our experiments, re-normalisation should manifest as the same magnitude and direction of relative aftereffect at all three standard values. Local repulsion should manifest as a larger relative aftereffect at the central standard value than either of the adapted standard values. In behaviourally-matched experiments we compared aftereffect patterns after adapting to tilt, facial identity, and facial gender. In all three experiments, data matched the predictions of a locally-repulsive but not a re-normalising aftereffect. Data are consistent with there being similar encoding strategies for tilt, identity, and gender, likely involving multiple channels with no unique norms.

56.4027 An objective measure of face identity adaptation with fast periodic visual stimulation

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The human brain is remarkably adept at extracting identity information from faces, although understanding this process remains a challenge. Here, a novel neural measure of objective discrimination between two individual face identities at the system level of organization is presented. This measure utilizes fast periodic visual stimulation (FPVS) in electroencephalography (EEG) combined with an adaptation paradigm (as in Ales & Norcia, 2009). Adaptation to a facial identity is induced through repetition of one identity displayed over a 10-second baseline, flickering at a base rate of 6 images per second (6 Hz). Subsequently, this identity is alternated with its anti-face, from a multidimensional face space (e.g., Leopold et al., 2001), over 20 seconds at the same rate. During the alternation of the two identities, a response exactly at half the base presentation rate (i.e., at 3 Hz), localized over the right occipito-temporal cortex, indicates that adaptation has produced an asymmetry in the perception of the two facial identities. Importantly, this 3 Hz response is not observed in a control condition without the single-identity baseline, while the response at the 6 Hz base presentation rate does not differ between conditions. These results indicate that neural adaptation to one identity can produce a measurable electrophysiological discrimination response between that identity and another, which could be further investigated with different categories or specific face pairs in future studies to increase understanding of individual face representation.

56.4028 Noise can be good: Visual adaptation to noise with different Fourier power spectrum characteristics affects the electrophysiological correlates of face processing

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Visual adaptation and spatial frequency content are known to have an effect on face processing. The slope in the log-log plots of the Fourier power spectrum of an image is a relative measure for the energy in low and high spatial frequencies. To investigate whether adaptation to noise with different image statistics as compared to a target face affects face processing differentially, we studied the effect of different Fourier power spectrum slopes in an adaptation paradigm. We used a gray image as a control, and noise images with five different slopes in the Fourier power spectrum. These possessed either the same slope as the face images (matching condition), two different steeper slopes (lower spatial frequencies enhanced) or two different shallower slopes (higher spatial frequencies enhanced). In a block design, participants were first adapted to noise images with one of the five slopes (or a gray image) for three minutes, followed by trials, in which an oval cut-out face appeared on a noise (or gray) image that remained on the screen. We measured event-related potentials (ERPs) for the faces while participants performed an age categorization task. ERP results showed that adaptation to noise images compared to the uniform gray control condition enhances face processing. This was evident by an increase of the N170 and a decrease of the P200 component amplitudes in all noise conditions when compared to the gray condition. Moreover, in the P200 time window, adaptation to shallower slopes increased the signal-to-noise ratio more than to steeper slopes, with the matching condition yielding to intermediate results. In conclusion, our data suggest that adaptation to noise images, especially with enhanced high spatial frequencies, facilitates the neural processing of faces.

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56.4029 Learning faces from variability

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There are large behavioural differences in the perception of familiar and unfamiliar faces. However, little is known about face learning – how faces make the transition from unfamiliar to familiar. Most experimental work on this topic examines the effects of study time, and systematic variation of exposure (changes in pose etc). We have argued that a critical component of face learning is within-person variability – i.e. exposure to the range of naturally-occurring variations which are idiosyncratic for a particular face. Here, we present two experiments which manipulate the degree of variability to which viewers are exposed during face learning. Participants learned name and face associations for twenty unfamiliar identities presented with high and low within-person variability. Stimuli were ambient images, showing faces 'in the wild'. We show more accurate performance on a speeded name verification task for identities learned in high compared to low variability. We go on to show that exposure to high variability across just two images improves performance on a face matching task. The results demonstrate the critical role of variability in face learning.

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56.4030 Neural mechanisms of the implicit learning of average and principal component faces

Xiaoqing Gao[1] (dr.x.gao@gmail.com), Hugh Wilson[2], Frances Wilkinson[2], Kang Lee[1]; [1]University of Toronto, [2]York University

A recent study (Gao & Wilson, 2014) suggested that humans automatically extract similarities and the most significant dimensions of differences among faces, through a mechanism that resembles Principal Component Analysis. Here we investigated the neural underpinning of such a mechanism. Ten adults studied 16 faces while their neural responses were recorded with fMRI. The 16 faces were synthesized from 3D scanned male adult faces. They are of equal physical distance to the average face in a multidimensional image space. The first principal component of the 16 faces explained 50% of the variance among them. In 6 sessions, each of the 16 faces was presented for 6 times in a fast event-related design. In the last two sessions, we also presented the average face and two faces representing the first principal component (PC) of the studied faces. We analyzed similarity of the neural response patterns (Kriegeskorte, Mur, & Bandettini, 2008) among studied faces and between the studied faces and the average and PC faces in four cortical areas identified in an independent face localizer scan: the bilateral fusiform face areas (FFA) and occipital face areas (OFA). Pattern similarity among studied faces decreased with learning in the left OFA and bilateral FFA ($ps< 0.05$). Pattern similarity between studied faces and PC faces remained the same throughout learning in all areas (ps=NS). Pattern similarity between studied faces and average face increased with learning in left OFA and right FFA ($ps< 0.05$). The results suggest that, with learning, the neural representations for individual faces become more differentiated. At the same time, the relation between the studied faces and faces that capture the similarities and the most significant differences among the studied faces remains stable. Thus, we provided the first evidence of the neural mechanisms underlying the implicit learning of average and PC faces.

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Face Perception: Disorders

Tuesday, May 19, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4031 Developing Behavioural Tools for Characterizing Normal and Abnormal Face Perception in 6-14 Years Old Children

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Congenital prosopagnosia (CP) is a neurodevelopment disorder characterized by life-long impairments in face processing in the absence of an overt lesion or a neurological disease. Surprisingly, most research in this domain is conducted on adults and little is known about its manifestation in children. The purpose of our study is to investigate the normal and abnormal developmental trajectory of face perception in a large cohort of children using different measures that were adapted from those used in research on CP in adults. Seven different measures were included in the battery: 1. A famous face questionnaire was used to investigate long term memory 2. The Children CFMT test was used to determine short term memory for faces 3. Shoes recognition test was used to examine object recognition. 4. A hierarchical shape test was used to examine deficits in global processing 5. An upright-inverted test was used to examine the face inversion effect. 6+7: ASSQ questionnaire and a face expressions test were used to exclude cases of

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children with ASD. Data collected so far from 44 children in ages 6-14 in the normal population reveal the presence of an inversion face effect and global precedence for shape processing across all ages. Additionally, quantitative performance differences were found along ages in face and shoe short term memory tests. The current results support a quantitative rather than qualitative trajectory of face and shape processing maturation in the normal population. The collected data will contribute to the development of a valid and firm diagnostic tool for abnormal face perception in children and to the understanding of the developmental changes that underlie CP in children.

56.4032 **Recognition of facial emotion in Developmental Prosopagnosia** Federica Biotti[1] (federica.biotti@city.ac.uk), Richard Cook[1]; [1]City University London, United Kingdom

Leading models of face perception posit that, after initial structural encoding, separate streams are responsible for the analysis of identity and expression. Interestingly, many individuals with developmental prosopagnosia (DP), a condition characterized by difficulties recognizing faces, are apparently unimpaired on expression recognition tasks. This pattern of performance is suggestive of a specific deficit in the identity processing stream, rather than a deficit of structural encoding. However, some authors have suggested that this apparent dissociation may reflect the use of expression recognition tasks that lack the necessary sensitivity to detect subtle impairments. The present study sought to investigate emotion recognition in DP using a task that systematically varies judgment difficulty. Sixteen adults with DP and 16 typically developing (TD) controls completed a computer-based emotion recognition task. Stimuli consisted of cropped eye-regions taken from happy, fearful, disgusted, angry, surprised and sad faces. Each source face was morphed with an image of the same actor exhibiting no emotion to obtain three sets of stimuli with varying levels of emotion intensity (100%, 66% and 33%). Results showed that DP and TD observers did not differ in emotion recognition ability at the 100% intensity level. However, as the emotion signal became weaker (in the 66% and 33% conditions), members of the DP group were increasingly likely to exhibit evidence of impairment, relative to members of the control group. Residual perceptual sensitivity, augmented by compensatory strategies, may be sufficient to judge unambiguous expressions to a broadly typical level of performance. However, as tasks become increasingly difficult, perceptual deficits may often be revealed. Where observed, co-occurring deficits of identity and expression recognition are consistent with impaired structural encoding of faces.

56.4033 **Impaired face detection may explain some but not all cases of developmental prosopagnosia** Kirsten Dalrymple[1] (kad@umn.edu), Brad Duchaine[2]; [1]Institute of Child Development, University of Minnesota, [2]Department of Psychological and Brain Sciences, Dartmouth College

Developmental prosopagnosia (DP) is defined by severe face recognition difficulties due to the failure to develop the visual mechanisms necessary for processing faces. The Two-Process Theory of face recognition (Morton & Johnson, 1991) implies that DP could result from a failure of an innate face detection system and that this failure could prevent an individual from then developing or tuning higher-level processes for face recognition (Johnson, 2005). Work with adults indicates some individuals with DP have normal face detection whereas others are impaired. However, face detection has not been addressed in children with DP, even though their results may be especially informative because they have had less opportunity to develop strategies that could mask face detection deficits. We therefore tested the face detection abilities of seven children with DP with two tasks. Children were identified as being DP if they reported real-life difficulties with face recognition and scored greater than two standard deviations below age-matched controls on the Cambridge Face Memory Test – Kids and/or the Dartmouth Face Perception Test. One face detection task required participants to find faces among non-faces (objects, scenes, etc.), and the other required participants to find two-tone faces among scrambled face parts. Four of the seven DP children were impaired at face detection to some degree (i.e. abnormally slow, or failed to find faces) while the remaining three children had normal face detection. Hence, the cases with impaired detection are consistent with the Two-Process Theory account suggesting that DP could result from a failure of face detection. However the cases with normal detection implicate a higher-level origin. The dissociation between normal face detection and impaired identity perception also indicates that these abilities depend on different neurocognitive processes.

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56.4034 **Decreased activation to faces in lateral occipital cortex in acquired prosopagnosia** Jiahui Guo[1] (Jiahui.Guo.GR@dartmouth.edu), Tirta Susilo[1], Bradley Duchaine[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College

When face-selective areas are damaged, do other areas involved with visual recognition compensate for the impairment? It has been suggested prosopagnosics process upright faces like objects and that non-face areas such as the lateral occipital cortex (LO) may compensate when face-selective areas are damaged. To address this question, we ran a dynamic functional localizer with acquired prosopagnosia patients who had right posterior lesions. LO was defined as regions with a stronger response to objects than scrambled objects. Responses to objects and scrambled objects in LO for the patients and controls were comparable, but surprisingly, responses to faces were lower in the patients. We also analyzed whether spared face-selective areas in the patients showed heightened responses to faces. Face-selective areas were defined as regions that showed a stronger response to faces than objects. Across fusiform face area, occipital face area, and the face-selective region of posterior superior temporal sulcus, we found no differences between patients and controls. Our results do not support the notion that acquired prosopagnosics process faces in a more object-like manner. Instead our results raise the question of whether regions that are not face-selective are less engaged by faces in acquired prosopagnosia.

Acknowledgement: Hitchcock Foundation

56.4035 **All new kids on the block? Personally familiar face processing in a case of pure prosopagnosia following brain damage** Meike Ramon[1,2] (meike.ramon@uclouvain.be), Thomas Busigny[1], Frederic Gosselin[3], Bruno Rossion[1]; [1]Université catholique de Louvain, Institute of Research in Psychology & Institute of Neuroscience, [2]University of Glasgow, Institute of Neuroscience and Psychology, [3]Université de Montréal, Département de psychologie

Studies of patients with acquired prosopagnosia (AP) have provided invaluable information about human face processing. However, while patients typically complain of familiar face recognition impairments, these studies generally involved processing of unfamiliar faces. Here we conducted a series of 19 behavioral experiments to investigate personally familiar face processing (identification, forced-choice recognition) in PS, a pure case of AP, and her colleagues using faces of the children they supervised in a kindergarten. Stimulus manipulations included variations in the availability of external, color and spatial frequency information, as well as stimulus similarity and spatial location of diagnostic information using anti-caricatures and the response classification technique 'Bubbles', respectively. Further experiments assessed the extent to which facial information was perceived inter-dependently (e.g. whole-part advantage, composite face effect, global facial geometry). Across experiments, PS relied more heavily on the availability of local details as compared to normal controls, and exhibited deficient processing of the overall facial configuration of familiar faces and of the eye region. Although the use of familiar faces led to particularly robust effects and dissociations between the patient and normal controls, these findings parallel observations in PS and other AP patients made previously using unfamiliar faces. We suggest that PS's deficient representation of the eye region arises because it contains multiple features over a small space, and its diagnosticity is heavily dependent on the ability to integrate this information simultaneously (i.e., holistic perception). These observations support the hypothesis that AP is associated with a loss of holistic face perception, which affects both the processing of unfamiliar and familiar faces. More generally, they do not support the view that familiar an unfamiliar face processing differ qualitatively in AP.

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56.4036 **Phonagnosia, a Voice Homologue to Prosopagnosia** Irving Biederman[1,2] (bieder@usc.edu), Sarah Herald[2], Xiaokun Xu[1], Ori Amir[1], Bryan Shilowich[1]; [1]Department of Psychology, University of Southern California, [2]Neuroscience, University of Southern California

Most cases of prosopagnosia—the inability to recognize faces—are "developmental," most likely congenital, in contrast to those that are "acquired" through injury or stroke. There has never been a comprehensive account of the neural basis for the developmental form of this deficit (dPros) in which, somewhat paradoxically, such individuals appear to show normal localization of posterior face areas (OFA and FFA) as well as STS (in contrast to acquired prosopagnosia). dPros demonstrate normal discrimination of faces as same or different but cannot can imagine familiar faces. An investigation of a rare condition of developmental phonagnosia (dPhon)—the inability to individuate familiar people on the basis of their voice--has suggested the possibility of a common account of both conditions. In a manner parallel to dPros, dPhons can discriminate unfamiliar voices as same or different but cannot imagine familiar voices, although they have no trouble in imagining non-voice sounds. A region in the ventromedial prefrontal cortex (vmPFC) may function as a person identification node (PIN, Bruce & Young, 1986) in that it is activated by viewing personally familiar faces or imagining familiar voices (Fig. 1) in normal controls but not by unfamiliar faces repetitively viewed during the course of an experiment. Neither deficit is a consequence of a degraded perceptual representation which would have led to an inability to discriminate faces or voices, but a failure to activate a familiar identity based on face or voice. The conditions are also not a consequence of a general deficit in the functioning of vmPFC as a PIN as dPros and dPhons are normal in recognizing familiar voices or faces, respectively. The conditions may arise from a deficiency in the white matter connections to vmPFC from face-selective areas in the posterior part of the brain (for dPros) and prosody-selective areas (for dPhons).

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56.4037 **Atypical trait inferences from facial cues in alexithymia**

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It is often difficult to distinguish a stranger's permanent facial shape from their transient facial expressions; for example, whether they are scowling or rapid character judgments we make about others. Someone with narrow eyes might be judged to be untrustworthy, because of strong associations between facial anger and threat. The emotion overgeneralization hypothesis suggests that judgments of character traits are based on subtle resemblance to emotional cues in others' neutral faces. To test this hypothesis, we investigated the trait judgments made by individuals with severe alexithymia, associated with impaired recognition of facial emotion. Participants viewed emotionally neutral faces and rated them according to how trustworthy, aggressive, attractive and intelligent they appeared. Participants then rated the same faces according to subtle expressions of six basic emotions. Consistent with the emotion overgeneralization hypothesis, alexithymic participants demonstrated reduced inter-rater consistency when judging trustworthiness, aggressiveness and intelligence of unfamiliar faces, and the presence of subtle emotions. Judgments of attractiveness were more consistent in the alexithymic than control group. Nevertheless, where alexithymics perceived, or misperceived, emotion cues, the character traits inferred thereafter were broadly typical. The finding that individuals with developmental deficits of emotion recognition exhibit atypical attribution of character traits, confirms the hypothesis that emotion recognition mechanisms play a causal role in character judgments. For attractiveness inferences, which may be more objectively made using non-emotional cues, such as symmetry and averageness, it seems that alexithymic individuals are able to use these cues more reliably, due to being influenced by emotional cues less. The fact that trait inferences were made in line with judgments of emotion in both groups suggests that all individuals base trait inferences on subtle emotional cues, regardless of their emotion recognition accuracy.

56.4038 **Caricaturing improves face identity recognition in simulated prosthetic vision**

Jessica Irons[1,2,3] (irons.39@osu.edu), Tamara Gradden[1], GuanLing Zhang[1], Xuming He[4,5], Nick Barnes[4,5], Elinor McKone[1,2]; [1]The Australian National University, [2]ARC Centre for Cognition and Its Disorders, [3]The Ohio State University, [4]National Information and Communication Technology Australia (NICTA), [5]Bionic Vision Australia

The "bionic eye" is a prosthetic device that can restore limited vision to those with degenerative blindness. By directly stimulating undamaged neurons in the visual pathway, the bionic eye allows the wearer to perceive an array of discrete spots of light ("phosphenes"). The resolution of current devices is limited, and performance on complex visual tasks such as face recognition is poor. Thus, researchers have sought image manipulation techniques to enhance visual processing. We explored a technique called caricaturing, aimed at improving face recognition by enhancing high-level face shape information. Caricaturing involves morphing an individual face away from an average face (matched on age, sex, race), exaggerating identity-specific aspects of the individual's face shape. We tested caricaturing in simulated prosthetic vision, by converting face photographs to arrays of artificial phosphenes ("phosphenising") at four resolutions: 16x16, 32x32 and 40x40 all with 30% dropout (simulating electrode failure), and 40x40 without dropout. Caricaturing improved both the perceptual individuation and recognition of phoshenised faces. In the perceptual individuation task, participants were shown pairs of faces and rated how different the two individuals appeared. Caricaturing increased the perceived differences between individuals at all resolutions except 16x16. To assess face recognition, participants learned faces in normal high resolution and performed an old/new recognition task on phosphenised faces. Caricaturing improved recognition accuracy for faces at 40x40 without dropout. Recognition at lower resolutions was at chance. We then modified the task to more accurately simulate the experiences of bionic eye patients, by enabling the phosphene array to scan across the face stimuli, and presenting both learning and test faces at the same resolution. Recognition at 40x40 with 30% dropout improved to above chance and now showed a caricature benefit in recognition accuracy, confidence, and scanning time. We conclude that caricaturing offers practical benefits for face recognition with the bionic eye.

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56.4039 **Altered functional connectivity in the core and extended face-processing network in adolescents with autism**

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Atypicalities in the development of regions within the core and extended face-processing network have been implicated in the development of social symptoms for individuals with autism (Schultz, 2005; Scherf et al., 2014). As a result, the functional organization among these regions may also be impacted. Uddin, Supekar, & Menon (2013) proposed a developmental model, suggesting that adolescence may be a time of functional under-connectivity in neural networks of individuals with autism. To investigate whether the face-processing network exhibits such functional under-connectivity in autism, the current study examined functional connectivity within the face processing networks of 14 adolescents with high functioning autism (HFA) and 14 typically developing (TD) adolescents (13 to 18 years). The fMRI task consisted of a 1-back memory task while viewing multiple visual categories including: human faces, animal faces, and common objects. Regions in the face-processing network were defined at the group level separately for TDs and HFAs, and then fit to each participant's individual activation. For connectivity, the best-fit model for the 12 regions was assessed for each group separately using unified structural equation modeling. We computed graph theory metrics based on the connection weights for each individual participant. The HFA adolescents had significantly higher clustering coefficients and global efficiency ($p < .05$), denoting more direct connections between regions. Following this, there was also a trend for the HFA group to have a greater number of edges or connections between regions. These results suggest that task-related functional connectivity between individual regions in the face-processing network of HFA adolescents is largely over-connected compared to TD adolescents. These results converge with our additional findings that TD adults with weaker face recognition abilities also have over-connected networks compared to those with stronger abilities. Together, these findings suggest that over-connected, redundant networks may interfere with proficient face-recognition behavior.

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56.4040 **Reduced repetition suppression to faces in the fusiform face area of adults with autism spectrum conditions**

Michael Ewbank[1] (michael.ewbank@mrc-cbu.cam.ac.uk), Philip Pell[1], Thomas Powell[1], Elisabeth von em Hagen[1], Simon Baron-Cohen[2], Andrew Calder[1]; [1]Medical Research Council, Cognition and Brain Sciences Unit, Cambridge, UK., [2]Autism Research Centre, Department of Psychiatry, University of Cambridge, UK.

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In neuroimaging studies, repetitions of the same stimulus typically result in a reduction in neural activity, known as repetition suppression (RS). Repeated presentation of the same face is associated with RS in core regions of the face processing network, including the fusiform face area (FFA). At a behavioural level, repeated viewing of the same stimulus causes a change in perceptual sensitivity, known as a visual aftereffect. Evidence indicates that visual aftereffects for faces are attenuated in children and adolescents with autism spectrum conditions (ASC), leading to the proposal that atypical adaptive coding in face processing networks may underlie difficulties in face learning and memory found in ASC. However, whether individuals with ASC show reduced RS to faces remains to be addressed. Here, we used functional MRI to investigate RS to faces and non-faces (simple geometric shapes) in adults with a clinical diagnosis of ASC. We measured activity in face- and object-selective regions of occipitotemporal cortex while participants viewed blocks of images comprising repetitions of the same face/shape or images of different faces/shapes. Participants also completed standardized behavioural tests of face and car memory. Relative to age and IQ matched controls, individuals with ASC showed diminished RS to faces in right FFA. By contrast, RS to shapes in object-selective regions did not differ between groups. This finding could not be explained by differences in gaze fixations or face-selectivity in FFA. In addition, behavioural data revealed that individuals with ASC showed a significant impairment in face memory (compared to controls) but not car memory. These findings suggest reduced RS in FFA as a possible neural mechanism underlying attenuated facial aftereffects found in ASC, and suggest that differences in the adaptive properties of the face-processing network may underlie difficulties in face learning and memory associated with this condition.

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56.4041 Autism and Developmental Prosopagnosia: A Cross-Disorder Study Richard Cook[1] (Richard.Cook.1@city.ac.uk), Punit Shah[2], Anne Gaule[3], Rebecca Brewer[2], Geoffrey Bird[2,4]; [1]Department of Psychology, City University London, [2]MRC Social, Genetic & Developmental Psychiatry Centre, Institute of Psychiatry, King's College London, [3]Experimental Psychology, University College London, [4]Institute of Cognitive Neuroscience, University College London

It has been suggested that developmental prosopagnosia (DP) and autism spectrum disorder (ASD) are co-occurring conditions; i.e., that the incidence of DP is greater in ASD than in the general population, and vice versa. Consistent with this suggestion, several case studies have described individuals with ASD who also exhibit severe face recognition difficulties. These reports document a number of anecdotes widely regarded as classic hallmarks of DP, including the use of hairstyle, voice and clothing cues for identity recognition. Despite the hypothesized relationship between the two conditions, virtually nothing is known about the effects of co-occurring DP on the perceptual abilities of individuals with ASD, or the effects of co-occurring ASD in DP. The present study sought a better understanding of this co-occurrence, and the respective influence of ASD and DP on face and object recognition. A novel three group design was employed, allowing direct comparison of 18 observers with ASD, 18 with DP and 18 typically developing controls. All participants completed measures of prosopagnosic and autistic traits, and completed objective measures of face and object recognition ability. Consistent with the co-occurrence hypothesis, we found that i) individuals with ASD reported more prosopagnosic traits, and ii) individuals with DP reported more autistic traits, than controls. A subset of the ASD group reached the threshold for prosopagnosia and a subset of the DP group reached cut-off for clinically significant levels of autistic traits. As expected, prosopagnosic traits correlated closely with face recognition ability. Interestingly however, autistic traits were not predictive of face recognition ability once prosopagnosic traits were accounted for, but were associated with wider object recognition ability. These results have important implications for future research addressing visual perception in ASD and DP. A better appreciation of this co-occurrence may help to understand the heterogeneity seen in these conditions.

56.4042 Autistic social traits predict poor face recognition behavior in men but not women Mikayla Borusiewicz[1], Daniel Elbich[1], K, Scherf[1,2]; [1]Penn State Department of Psychology, [2]Penn State Social Sciences Research Institute

Although not a core symptom of the disorder, marked impairments in face processing are well documented in autism. Autism is highly heritable and face recognition deficits present frequently in family members of affected individuals. As a result, researchers have begun to investigate whether poor face recognition behavior is a likely endophenotype of autism. Endophenotypes are heritable traits that are related to, but simpler than, the entire disorder and are likely to result from fewer genes and alleles acting with less complexity. Importantly, they indicate genetic susceptibility to the disorder. Recent findings suggest that face processing can manifest differently as an endophenotype for autism in men and women (Rhodes et al., 2013). To investiagte this issue further, we used the Autism Quotient (AQ) to measure levels of autistic traits in typical adults (N = 130) who had no history of neurological or psychological problems in themselves or their first-degree relatives. Participants were tested in the Cambridge Face Memory Test (CFMT) and the Cambridge Car Memory Test (CCMT). Separate correlations between AQ subscores (social skills, communication skills, attention to detail, attention switching, imagination) and behavioral performance on the two recognition memory tasks were run for male and female participants. We observed a significant negative correlation between the AQ Social subscore and CFMT performance in male (n = 48), but not in female, participants. In other words, males who had more autism-like social behaviors exhibited worse face-recognition behavior. There were no relations between AQ subscores and CCMT performance in either group. These findings provide additional evidence that this potential behavioral endophenotype for autism manifests differently for males and females.

Face Perception: Social

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Poster Session, Pavilion

56.4043 Effects of animation face on skin color perception Hyejin Han[1] (iroiroboto@gmail.com), Keiji Uchikawa[1]; [1]Department of Information Processing, Tokyo Institute of Technology

Face perception has a unique processing pathway in the visual system. Many previous studies showed that human face skin-color was precisely reproduced, compared with other objects without facial features. Although it was shown that cartoon face yielded responses similar to those of photo images in human FFA (the fusiform face area) (Tong et al., 2000), color perception of animation faces has seldom been investigated. In this study, we aim to clarify whether and what effect animation faces have on skin-color judgment. In experiment 1, skin-color judgment was compared with stimuli between animation facial and circular images. Test stimuli consisted of 2D face, 3D face, circle and sphere with three colors of A, B and C, which (redness, blueness, luminance (cd/m2)) in the Macleod-Boynton chromaticity diagram were (0.73, 0.65, 42), (0.72, 0.75, 40) and (0.72, 0.69, 59), respectively. Ten Japanese and Korean subjects performed memory color-matching between a test stimulus and a circular stimulus of which chromaticity and luminance the subject adjusted to achieve a matching point. The standard deviation (SD) of matching color points in animation faces was bigger than in circles. In experiment 2, the effects of face-looking stimuli on skin-color judgment were examined. Test stimuli were deformed animation faces, made in five steps (from face-like to non-face like) with three colors as in experiment 1. No difference was found in SD among five steps of deformed faces. In addition, SD of the ideal skin-color (C) matching point was smaller than that of other colors (A, B) only in face stimuli of experiment 1 and 2. These results indicate that animation faces make skin-color judgment difficult compared with images without facial features. Memory skin-color could hinder precise animation skin-color judgment. Moreover, ideal skin-color could make color judgment easily on animation face images.

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56.4044 Facial contrast is a cue for health perception Richard Russell[1] (rrussell@gettysburg.edu), Aurélie Porcheron[2,3], Jennifer Sweda[1], Emmanuelle Mauger[2], Frederique Morizot[2]; [1]Psychology Department, Gettysburg College, [2]Chanel Research & Technology, [3]LPNC, Université Pierre Mendès-France

Facial contrast—the luminance and color contrast between internal facial features and the surrounding skin—is a cue for several aspects of face perception, including face detection, sex classification, age estimation, and judgments of attractiveness. It is also increased by makeup. Here we report evidence that facial contrast is also a cue for the perception of health from the face. Facial contrast was measured from a large sample of Caucasian female faces, and was found to predict ratings of perceived health. Most aspects of facial contrast were positively related to perceived health, meaning that faces with higher facial contrast appeared healthier. For a subsequent experiment we increased and decreased the facial contrast of a subset of these images and presented them to participants in a two-alternative forced-choice task. Participants selected faces with increased facial contrast as appearing healthier than faces with decreased facial contrast. Together these results show that facial contrast is a cue

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for perceiving how healthy people look. This provides additional weight to the notion that facial contrast is an important cue for face perception.

56.4045 Revealing mental defaults in face space with serial reproduction Stefan Uddenberg[1] (stefan.uddenberg@yale.edu), Brian Scholl[1]; [1]Department of Psychology, Yale University

Great strides have been made in recent years in understanding how we perceive faces in terms of underlying "face spaces". Our work is focused on the relatively unexplored notion of default regions of these spaces, toward which our face representations may be attracted. Picture a person standing before you, asking for directions. Now consider: what did that person look like? And where did that information come from? Here we used a novel instantiation of the method of serial reproduction to explore the effective 'default settings' in face space. As a first case study, we explored the perception of race. A single face was briefly presented to each observer, with its race selected from a smooth continuum between White and Black (with all faces matched for mean luminance). The observer then simply reproduced that face, by using a slider to morph a test face along this continuum. Their response was then used as the face initially presented to the next observer, and so on down the line in each reproduction chain. This method has been shown (albeit in very different contexts) to reveal the contents of people's default assumptions about the world. In our experiments, White observers' reproduction chains consistently and steadily converged onto faces that were significantly Whiter than both the original face and the continuum's midpoint. Indeed, even chains beginning near the Black end of the continuum inevitably ended up well inside the White region. These results highlight a default region of face space for White observers, which biases downstream perception and memory. In further experiments, we report extensions both to other cultures (e.g. exploring White and Indian observers' face-space defaults in race continua from White to South Asian faces) and to other types of features (in particular, continua that vary faces' age, gender, and perceived animacy).

56.4046 Diagnostic information for accurate trustworthiness judgments for Caucasian and African-American faces Karolann Robinson[1] (robk11@uqo.ca), Daniel Fiset[1], Josiane Leclerc[1], Caroline Blais[1]; [1]Département de Psychologie, Université du Québec en Outaouais

In a recent study, we used the Bubbles technique (Gosselin & Schyns, 2001) to probe the facial features that lead to changes in the perceived trustworthiness of a face (Robinson et al., 2014). However, this study did not allow us to identify which facial features are involved in accurate trustworthiness judgments. Surprisingly, few studies have investigated whether the diagnostic facial information for trustworthiness judgment is stable across faces from different ethnicities. The present study aims to pinpoint the diagnostic facial features for accurate trustworthiness judgments of Caucasian (Cau) and African-american (AA) faces using Bubbles. First, 40 participants rated the level of trustworthiness of a large number of faces from both races. These judgments were then used as our accuracy measure in a Bubbles experiment, conducted on another group of 50 participants. On each trial, two bubblized faces were shown to the participants and they were asked to choose the one that appeared most trustworthy. The bubbles' locations were the same on both faces. The average accuracy for each face ethnicity was maintained at 62.5% (approximately halfway between chance and the average performance without Bubbles) by adjusting the number of bubbles on a trial-to-trial basis using QUEST (Watson & Pelli, 1983). A paired t-test indicated that participants needed less bubbles with Cau faces (M=67.4, SD=40.2) than with AA faces (M=90.6, SD=43.7), $t(49)=-2.86$, $p=0.006$. We computed distinct classification images for both ethnicities by calculating a weighted sum of the bubbles mask, using the accuracy transformed into z-scores as weights. A cluster test (Chauvin et al., 2005) was applied on the classification images to determine statistical significance. Our results indicate that the left eye is positively correlated with accurate trustworthiness judgments for Cau faces, while the area of the mouth and the right eye are diagnostic for AA faces.

56.4047 Using scalar ratings to track changes in apparent trustworthiness induced by helpful and misleading gaze cues. James Strachan[1] (js756@york.ac.uk), Steven Tipper[1]; [1]Department of Psychology, University of York

Eye gaze is a powerful directional cue, and previous research has found that when a centrally-presented face looks away from the imminent location of a target, judgements about that target are slower and more error prone, and the face is less likely to be selected as trustworthy than another face that cues location validly. Previous research into this area (Bayliss & Tipper, 2006) has used a 2-alternative forced choice (2afc) selection when gauging trustworthiness, which cannot tease apart exactly how these helpful or misleading gaze behaviours change apparent trustworthiness. In three of four experiments, we use two scalar ratings of trustworthiness – one before and one after trust induction – to measure how apparent trustworthiness changes based on faces' gaze behaviour. In Experiment 1, we show that the trust effect for neutral faces is driven by a unidirectional decrease for misleading faces, while trustworthiness ratings for valid-cueing faces remain constant across the experiment. In Experiment 2, we show that this effect is specific to trustworthiness, and the pattern does not generalise to ratings of likeability, meaning that the social inferences being made likely do not reflect a simple valence judgement. In Experiment 3 we replaced the rating scales with two morphed face images (more/less trustworthy) and asked participants to select which they had seen in the experiment. Cueing validity did not affect which face was chosen, indicating that the effect does not interfere with face memory. Finally, in Experiment 4, we show that changing the expression of the faces in the original gaze-cueing paradigm changes the nature of the trustworthiness ratings: trust effects for smiling faces show the decrease of trust for misleading faces that neutral faces show, but also an increase for valid-cueing faces. Taken together these findings hint at a complex online system for updating social impressions during interactions.

56.4048 Competition makes faces look more aggressive Benjamin Balas[1,2] (benjamin.balas@ndsu.edu), Laura Thomas[1]; [1]Psychology Department, North Dakota State University, [2]Center for Visual and Cognitive Neuroscience, North Dakota State University

Observers use facial appearance to predict social behavior and individuals' personality traits. We examined the possibility that social contexts can also influence face perception. To investigate the relationship between competitive social contexts and perceived appearance, we leveraged a known link between aggression and a simple physiognomic cue: the facial width-to-height ratio (WHR). Faces with higher WHRs are perceived as being more aggressive (Carre, McCormick, & Mondloch, 2009) and individuals with naturally higher WHRs exhibit more aggressive behavior (Carre & McCormick, 2008). Participants played a simple skill game either in competition (N=30) or cooperation (N=30) with a confederate prior to reconstructing the facial appearance of their opponent/partner and a refereeing third party by arranging segmented facial features on a screen until they had produced a best likeness of the target individual. We anticipated that higher perceived aggression during competition would lead to higher reconstructed WHRs than cooperation. The results supported this prediction: participants' reconstructions had significantly higher WHRs ($p< 0.01$) following a competitive interaction for both the observer's opponent and the referee. A follow-up experiment that included competitive (N=30) and cooperative interaction (N=30), as well as a baseline condition with no salient social component (N=30) replicated and extended this result. In this second task, we observed a main effect of social context ($F(1,87)=5.14$, $p=0.008$) and post-hoc tests revealed that competition led to higher WHRs than cooperation ($p=0.013$) or the baseline condition ($p=0.026$), while WHRs in the cooperation group did not differ from those in the baseline group ($p=0.96$). This suggests that competition and subsequent perceived aggression systematically bias perceived appearance, while cooperation has little direct effect. These results demonstrate that the social perception of faces is not merely a feed-forward process, but instead that the social contexts in which people interact can shape face perception.

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56.4049 Chinese perceivers' facial first impressions Clare Sutherland[1] (cs770@york.ac.uk), Xixi Liu[1], Ying Chu[1], Lingshan Zhang[1], Julian Oldmeadow[2], Andrew Young[1]; [1]Department of Psychology, University of York, [2]Department of Psychological Sciences, Swinburne University of Technology

Studies of Western perceivers have found a three-factor structure to first impressions of Caucasian faces: approachability, youthful-attractiveness and dominance (Sutherland et al. 2013). These factors are thought to reflect responses to facial cues with a long evolutionary history related to threat and to sexual selection (Oosterhof & Todorov, 2008; Sutherland et al. 2013). If this is the case, then these dimensions should be universal across culture. However, as yet research has only examined models derived from Western first impressions. To address this, we sought to derive models of first impressions of Asian and Caucasian faces from Chinese perceivers' spontaneous judgments. In Study 1, we asked 20 Chinese participants to freely describe 60 Asian face photographs. Participants frequently spontaneously inferred character traits, especially approachability-related traits. In Study 2, 120 Chinese participants rated a set of 500 Asian and 500 Caucasian face photographs on the twelve characteristics most frequently mentioned in

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Study 1. We found a three-factor structure for Chinese impressions of Caucasian faces, in which the first two factors were very similar to the first two factors of Western perceivers' impressions of Caucasian faces (approachability and youthful-attractiveness: Sutherland et al. 2013). For Asian faces, we found four factors, including an additional attractiveness factor, indicating that there are also culture-specific aspects of facial evaluation.

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56.4050 Serial Dependence in the perception of attractiveness Ye Xia[1] (yexia@berkeley.edu), Alina Liberman[1], Allison Yamanashi Leib[1], David Whitney[1]; [1]Department of Psychology, University of California, Berkeley

We perceive objects in the world as stable despite their constantly changing image properties due to factors like occlusion, visual noise, and eye movements. Recent results demonstrate that perception of low-level stimulus features and even more complex perception of human identity are biased towards recent percepts (Fisher & Whitney, 2014; Liberman, Fisher & Whitney, 2014). This effect is often called serial dependence. However, the existence of serial dependence in high-level evaluations such as attractiveness remains unclear. Here, we tested the existence of serial dependence in perception of attractiveness of objects and humans. In experiment one, we presented a random series of images of oranges drawn from a linear morph varying from ripe (attractive) to moldy (unattractive). Participants were asked to report the attractiveness of the oranges in each trial using a Likert scale. Results showed that attractiveness evaluations were systematically biased toward the attractiveness of the oranges seen up to several seconds prior, which suggests the existence of serial dependence in aesthetic judgments. In a second experiment, we extended the experiment to facial attractiveness, a task humans perform on a daily basis. In particular, we also wanted to test whether sequential dependence of attractiveness only holds for images of varying attractiveness of the same face or also for images of different faces. In an online survey, we presented forty-six subjects with a random series of television screenshots featuring female actresses. Each subject reported the facial attractiveness of the actress for each screenshot using a Likert scale. Results show serial dependence predominantly for two sequential images of the same television anchor. This result suggests that serial dependence of attractiveness may be modulated by identity perception. The perceived attractiveness for one person is sequentially dependent--stable over time, whereas for different people we are sensitive to differing levels of attractiveness.

56.4051 Averaging of Social Cues Using Equivalent Noise Joseph Florey[1] (j.a.florey@qmul.ac.uk), Colin Clifford[2], Steven Dakin[3], Isabelle Mareschal[1]; [1]Experimental Psychology, Queen Mary University of London, [2]Psychology, UNSW, [3]Optometry & Vision Science, University of Aukland

INTRODUCTION: The direction of social attention from groups can provide stronger cueing than from an individual (Gallup et al., 2012). It has previously been shown that basic visual features such as size or orientation can be averaged (Dakin 2001), however recently it has also been shown that observers can average gaze direction in a group of 4 faces (Sweeny & Whitney, 2014) . We investigated averaging of both gaze direction and head rotation using an equivalent noise (EN) paradigm. METHODS: Participants judged either (a) the overall direction of gaze, or (b) overall head rotation for an array of faces presented for 300ms. The direction of gaze (or head rotation) for each element in the array was drawn from a normal distribution. External noise was added to the stimulus by increasing the standard deviation of the gaze (or head) distribution (0.5° to 32°). Direction discrimination thresholds were collected at 7 levels of external noise, and an EN function was fit to the data to extract estimates of internal noise (accuracy of direction estimate for a single face) and sampling efficiency (number of faces averaged). Faces were either distributed in a large (16 faces) random array with no fixation or a small (6) circular array around fixation (ecc= 4°). RESULTS: Observers were able to average the direction of a crowds' gaze and head rotation across all conditions, though not very efficiently when judging gaze in the large arrays (sample estimates between 1.5 and 2.5). Averaging of head rotation had less internal noise and was more efficient than for gaze direction (4-6 samples). Internal noise was greatest when faces were presented away from fixation. CONCLUSIONS: Head rotation and gaze direction can be averaged from groups of faces to reliably judge information about a crowd, although this is more reliable when judging head direction.

56.4052 Visual representation of age as a function of the level of ageism Youna Dion Marcoux[1] (dioy03@uqo.ca), Caroline Blais[1,2], Daniel Fiset[1,2], Arianne Goulet[1], Chloë Pruneau[1], Hélène Forget[1]; [1]Département de Psychologie, Université du Québec en Outaouais, [2]Centre de Recherche en Neuropsychologie et Cognition, Montréal

Recently, it has been shown that visual representations of ethnic outgroup faces are negatively biased in prejudiced individuals (Dotsch et al., 2008). The present study verified if the visual representations of young vs. old-aged prototypical individuals are influenced by the level of ageism of the observer. In phase 1 of the experiment, 28 young participants (M_{age}=20.43) took part in a reverse correlation task (Mangini & Biederman, 2004). On each trial, two stimuli were created by adding visual noise to a base face (i.e. morph of 40 young and 40 old faces), and were simultaneously presented to the participant. The task was to indicate which one was the most prototypical of the young-aged group (500 trials), or of the old-aged group (500 trials). The implicit age bias was measured with the Implicit Association Test (Lane et al., 2007). For each participant, the visual representation of the young-aged group (vs. old-aged group) was revealed by summing the noise fields of the stimuli selected as the most typical of the young-aged (vs. old-aged) group. In phase 2, 24 naive participants were asked to estimate, on a scale from 11 to 101, the age of the individual visual representations measured in phase 1. The average estimate across the judge participants was calculated for each of the individual visual representation. The age estimates of the visual representations of the nine participants with the highest vs. lowest level of ageism were compared. For the visual representation of the young-aged group, we found no effet of the level of ageism [M_{high}=28.86; M_{low}=29.97; t(23)=1.55, p=0.13]. However, we showed that the visual representation of a prototypical old-aged individual is older in the mind of the high ageism individuals [M_{high}=44.30; M_{low}=40.92; t(23)=-4.19, p=0.0004]. Thus, our results suggest that ageism alters the perception of old-aged individuals by making them appear older.

Acknowledgement: FQRSC

56.4053 Facial contrast is a universal cue for perceiving age. Aurélie Porcheron[1,2] (aurelie.porcheron@ceries-lab.com), Emmanuelle Mauger[1], Frédérique Soppelsa[3], Richard Russell[4], Frédérique Morizot[1]; [1]Chanel Research & Technology, France, [2]LPNC, Université Pierre Mendès-France, Grenoble, france, [3]Lincoln, France, [4]Gettysburg College, Gettysburg, USA

Aspects of facial contrast decrease with age in Caucasian women, and Caucasian female faces with higher contrast look younger (Porcheron et al, 2013). Here we investigated faces and raters of other racial groups to see whether the link between facial contrast and age is universal. Using sets of carefully controlled full face color photographs of 182 Latina women from the US, 155 black South African women, and 139 Chinese women aged from 20 to 80, we measured the contrast between the internal features (the eyes, the lips and the brows) and the surrounding skin, in the CIELab L*, a*, and b* axes. The luminance contrast around the eyebrows and the eyes, the a* contrast around the mouth and the eyes and the b* contrast around the eyes significantly decreased with age in all racial groups. Though the overall pattern of changes with age was common to all racial groups, there were also some minor differences between the groups. In a separate study, faces of the four races were manipulated to increase or decrease the aspects of facial contrast that were observed to vary with age universally. Caucasian and Chinese participants were asked to select which face between the low contrast and the high contrast faces looked younger. Globally, in more than 75% of the trials subjects judged the high contrast face younger. Interestingly, the effect of the manipulation was found to differ significantly according to origin, gender and age of participant, as well as age of the faces. Together these findings indicate that older faces have less facial contrast than younger faces, regardless of the race of face and that facial contrast is a universal cue to age perception.

56.4054 Emotion perception or social cognitive complexity: What drives face processing deficits in autism spectrum disorder? M.D. Rutherford[1] (rutherm@mcmaster.ca), Jennifer Walsh[1], Sarah Creighton[1]; [1]Psychology, Neuroscience & Behaviour, McMaster University

Faces convey information about sex, identity, age, ethnic group, and internal emotional state, and typical individuals are expert at encoding and interpreting facial information. Individuals with ASD have difficulties with social perception and cognition, and there has been a great deal of scientific focus on the ability of those individuals with ASD's to processing facial information. Still, there is not a clear consensus as to what the core deficits in face processing are characteristic of ASD. The current study examined whether the anomalies in face processing seen in adults with ASD are better

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explained as a deficit in processing emotions, or a deficit in processing the complexity of social stimuli. Participants completed a battery of four face processing tasks: identity discrimination, basic expression perception, complex emotion expression, and trustworthiness perception. The tasks either did or did not involve processing facial expressions, and also varied in the level of social cognitive complexity. If the deficits in face processing in ASD are driven by a core deficit in processing emotional expression information, participants with ASD would perform worse on the basic and complex expression perception tasks. In contrast, if their deficit is related to processing socially complex facial information, they would show poorer performance on the complex expression and trustworthiness perception tasks. Results revealed that ASD participants showed worse performance on basic expression recognition task ($t(44) = 3.06$, $p = .004$) and the complex expression recognition task $t(44) = 4.26$, $p < .001$ compared to typical participants. In contrast, there were no significant group differences in performance on the identification task ($t(44) = 1.33$, $p = .19$) or the trustworthy perception task $t(44) = .93$, $p = .36$. These results support an emotion processing rather than a social complexity explanation for face processing deficits in ASD.

56.4055 **Social features impact visual exploration of naturalistic scenes** Xavier Morin-Duchesne[1] (xavmorin@indiana.edu), Dan Kennedy[1]; [1]Psychological and Brain Sciences, College of Arts and Sciences, Indiana University

The allocation of attention to social stimuli is critical for human social behaviors such as identity recognition, emotion recognition, and joint attention. The importance of social stimuli themselves is further exemplified by our expertise with human faces (Diamond & Carey, 1986) and precision in interpreting gaze cues (Symons et al., 2004). Here, we aim to characterize the impact of socially-relevant information (faces, gaze direction, and targets of gaze) on the visual exploration of naturalistic scenes. Fifteen undergraduate students free-viewed 700 images of naturalistic scenes for 3 seconds each, while their eye movements were recorded. Multiple regions of interest (ROIs), including faces, objects, and targets of gaze, were defined within each of the 700 images (Xu et al., 2014). Among the 356 images with at least one face, we examined the ability of social features and cues to attract, hold, or drive away attention. Our results show that faces and targets of gaze are significantly likelier to be fixated than would be expected from their proportion (e.g., number of faces relative to total number of ROIs), area, and saliency alone (between 1.5 to 9 times likelier), showing that both attract attention. Furthermore, when viewing both faces and targets of gaze, participants made longer fixations (both ps $< .001$) and spent more time per visit ($p = .018$ and $p < .001$, respectively), suggesting that these social features not only attract, but also hold attention more than other objects. Finally, shorter visit times for gazing faces (p

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56.4056 **How do we make social decisions? Gaze strategies used to predict and optimize social information during conversation.** Nida Latif[1] (n.latif@queensu.ca), Mashal Haque[1], Monica Castelhano[1], Kevin. Munhall[1,2]; [1]Department of Psychology, Queen's University, [2]Department of Otolaryngology, Queen's University

Our ability to make quick social decisions during everyday interactions is vital to effective communication. However, in social situations, we have access to an abundance of information and the cognitive challenge to rapidly select optimal strategies to gather information necessary for the social decision-making process. In this study, we investigated how modifying information availability influences observers' decisions and the gaze strategies selected to make affiliation judgment (friends vs. strangers) for silent videos of two interacting individuals. We demonstrated that eliminating information (full-body vs. head-only cues) resulted in a reduced ability to distinguish friends from strangers and the use of different eye-movement strategies to perform the same social task. Observers made more fixations towards the talkers' eyes than other locations in both conditions. However, when information was restricted to a head-only view, participants switched gaze between eyes and mouth more frequently than with full information. Further, availability of full-body cues resulted in observers switching gaze between talkers more frequently to discriminate friends from strangers. When examining how gaze strategy predicts overall accuracy of a social decision given full-body information, we demonstrated that individuals who fixated more on the mouth were likely to be more accurate in affiliation discrimination. We suggest that gaze contributes to social decisions during conversation because we are able to predict the conversational structure of a conversation. For example, we demonstrated that observers are able to predict the point of a turn exchange between talkers by fixating on the talker who is about to speak up to 250 ms prior to them speaking. These results demonstrate that observers select gaze strategies to optimize all available information and that greater optimization predicts increased accuracy of our decisions. We further conclude that human social abilities rely on versatile decision-making and prediction strategies to handle the complexity of our social world.

56.4057 **Direct gaze N170 modulation is dependent of low spatial frequency information** Inês Mares[1] (imares01@mail.bbk.ac.uk), Marie Smith[1,2], Mark Johnson[1], Atsuhi Senju [1]; [1]Centre for Brain and Cognitive Development, Birkbeck College, University of London, [2]Department of Psychological Sciences, Birkbeck College, University of London

Direct gaze is a powerful social cue used to indicate the attention of another on oneself and is of such importance to typical everyday social interaction that it is preferentially attended from birth (Farroni et al., 2002). Previous research has indicated better face encoding and retrieval of faces displaying direct as opposed to averted gaze with electrophysiological studies indicating an enhanced neuronal response to direct gaze in the face selective N170 component (Conty et al., 2007). However the mechanisms underlying these modulations in brain response and behaviour remain unclear. A leading hypothesis proposes that a fast pathway receiving information from the retina directly to the superior colliculus, following through the pulvinar to the amygdala would be critical for the fast detection and enhanced processing of direct gaze (Senju et al., 2009). In the present study we analysed the putative importance of subcortical structures on the neural response to direct vs. averted eye gaze by manipulating spatial frequency content of the faces, as this pathway has been associated with low spatial frequency processing. Specifically, faces in direct and averted eye gaze were displayed in low, high and broad spatial frequency while we measured the electroencephalographic responses of participants. To maintain attention participants were instructed to detect a red square that appeared in 10% of the trials. Results confirmed an enhanced N170 for faces in direct gaze when compared with averted gaze in the broad spatial frequency band condition and indicated that this was driven by the low spatial frequency content (with no significant differences between direct and averted eye gaze faces when only high spatial frequency information was present). The present study indicates the importance of low spatial frequency information in gaze processing, supporting the existence of a subcortical pathway that contributes for the fast detection and processing of direct gaze.

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Attention: Temporal

Tuesday, May 19, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4058 **Gradual development of temporal attention in letter identification and motion judgment tasks** Shiori Sato[1] (s337.0428@gmail.com), Jun Kawahara[1]; [1]Chukyo University

The ability to perceptive a uniquely colored target, embedded within a rapid sequence of nontarget letters of homogenous color, is impaired when the target appears during a relatively earlier part of the sequence. This phenomenon, referred to as "attentional awakening," is thought to occur due to the gradual modulation of temporal attention, such that signal detection should be improved commensurate with later target onset. We investigated this possibility with two types of task. Experiment 1 replicated a typical attentional awakening effect by using a singleton-detection task in which a uniquely colored target was embedded within a rapid stream of 21 nontarget grey letters, presented at a rate of 10 frames per second (3,000 ms in total). Target identification accuracy during the first temporal bin (300-500 ms) was significantly lower compared with the third and fourth bins (1,500-1,700 ms and 2,100-2,300 ms, respectively), indicative of attentional awakening. Experiment 2 tested whether attentional awakening could be elicited by a direction-judgment task, of dots moving with 30% coherence. Participants indicated the direction of motion (up, down, left, or right) during a randomly selected 100 ms period of motion (total period of motion = 3,000 ms). Coherent motion occurred within the same temporal bin used in Experiment 1. The results indicated an absence of attentional awakening, with coherent motion direction accuracy not differing across temporal bins. This is inconsistent with the notion that attentional awakening reflects gradual modulation of temporal attention. We suggest that attentional awakening is task-dependent and might reflect a state of inattention elicited by mandatory processing of the initial letters of a sequence.

56.4059 The role of the continuity field: Serial dependence promotes object stability during occlusion Kathy Zhang[1] (kathy.zhang@berkeley.edu), Alina Liberman[2], David Whitney[1, 2, 3]; [1]Department of Psychology, University of California, Berkeley, [2]Helen Wills Neuroscience Institute, University of California, Berkeley, [3]Vision Science Group, University of California, Berkeley

Object identities appear stable despite noisy and constantly changing visual input, but it is unclear what mechanisms underlie such continuous perception. We have previously shown (Fischer & Whitney, 2014; Liberman et al., 2014) that observers experience serial dependence in the perception of orientation as well as face identity. This effect persists up to 15 seconds back in time and provides evidence for an object-selective continuity field. In the current study, we asked whether the continuity field promotes the perception of an object's stable identity when it is temporarily occluded. While the subject fixated on a centered point, we presented an oriented Gabor patch that traveled from left to right; midway through its trajectory, it moved behind an occluder also centered on the screen. The Gabor could travel either in a straight and continuous trajectory (expected) or in a discontinuous trajectory (unexpected) behind the occluder. Both the Gabor disappearing behind the occluder (first Gabor) as well as the Gabor coming out (second Gabor) had randomly generated orientations. After the second Gabor was no longer on-screen, subjects adjusted a bar by rotating it to match the second Gabor's orientation. Using this response, we tested whether the perceived orientation of the second Gabor was serially dependent on (i.e., captured by) the orientation of the first Gabor. We found that it was: the reported orientation of the second Gabor was pulled toward the orientation of the first Gabor. Importantly, this effect was significantly heightened when the Gabor followed the expected, continuous trajectory while it was occluded compared to the unexpected, discontinuous trajectory. This result suggests that sequential dependence in orientation perception takes advantage of expectations about a stable world, helping to maintain perceived object continuity despite interrupted visibility.

56.4060 The relation of object substitution masking (OSM) and attention dynamics: A neuro-computational modeling study Frederik Beuth[1] (beuth@hrz.tu-chemnitz.de), Fred Hamker[1]; [1]Artificial Intelligence, Chemnitz University of Technology, Germany

Although object substitution masking (OSM; DiLollo et al., 2000, J Exp Psychol Gen) has been discussed being affected by attention (Põder, 2012, J Exp Psychol Gen), OSM is not considered emerging from attentive dynamics and there is little overlap between both fields of research. By means of a neuro-computational modeling study, we demonstrate that OSM can be fully explained by attentive dynamics. The model is inspired by previous systems level models of attention (Hamker, 2005, Cerebral Cortex; Zirnsak et al., 2011, Eur J Neurosci) and includes the ventral stream, particularly area V4 and the frontal eye field (FEF). It simulates the firing rates of neurons over time, and models accurate signal timings in the visual system (Schmolesky et al., 1998, J Neurophysiol; Thomson et al., 2002, Cerebral cortex). It is first shown to fit data from common visual attention experiments, like biased competition and visual search. Next we show that the same model reproduces typical OSM data (e.g. DiLollo et al., 2000, J Exp Psychol Gen, and Argyropoulos et al., 2013, J of Exp Psychology). OSM is explained based on two model mechanisms. Similar as in attentional biased competition, the target and mask compete for a visual representation by means of suppressive connections. This competition mechanism accounts for the mask duration dependency in OSM. OSM also requires a high number of distractors (set size effect) like in visual search paradigms. Our model explains this observation by spatially reentrant processing between FEF and V4. We conclude that OSM can be accounted for by well-known attentional mechanisms within a unified model. Contrary to existing theories of OSM, our model is grounded on a large set of physiological and neuroanatomical data.

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56.4061 Beyond the blink: Understanding order perception in RSVP Ellis Gootjes-Dreesbach[1] (elg34@kent.ac.uk), Howard Bowman[1]; [1]School of Computing, University of Kent

The presented research shows a previously unreported finding in the attentional blink (AB) paradigm, which has been instrumental in exploring different questions on attention, cognitive control and consciousness. The AB is typically demonstrated in Rapid Serial Visual Presentation (RSVP) when identification of two targets is required: performance on reporting the second target declines when it appears between 100-500 ms after a fully processed first target. Several models of this phenomenon have been proposed and are measured against their ability to replicate the drop in second target report performance, Lag 1 sparing (high performance on recognizing both targets when presented in direct succession), and order errors at Lag 1, amongst others. We present evidence for another kind of order error in the AB paradigm: occurrence of half swaps (second target missed but first target reported in the wrong serial position) that are maximal at the end of the AB. The data come from a forced choice AB task where target identity and order of presentation of two letter targets between digit distractors were recorded. After demonstrating the effect, we conducted several follow up studies to characterise the conditions in which the swaps occur by varying target salience, position in the RSVP stream and stimulus-onset-asynchrony. We discuss how, similar to Lag 1 order errors, these half swaps might give new insight into the attentional mechanisms that give rise to the AB. This is especially important in the context of consciousness research employing this paradigm that has been increasing in popularity.

56.4062 Effect of object substitution masking on the perceived duration of supra-threshold object representations Geoffrey Harrison[1] (8gh3@queensu.ca), Chelsia Lau[1], Jason Rajsic[2], Daryl Wilson[1]; [1]Psychology, Queen's University, [2]University of Toronto

Object substitution masking (OSM) describes a decrease in the ability to accurately report the identity of an object (the target) when a surrounding four-dot mask (4DM) remains on the screen after the offset of the target. Current theories propose that OSM results from the visual system updating the initial target plus mask representation in favor of the later mask only representation. Notably, object updating theories of OSM are underspecified with regard to the temporal dynamics of the updating process. To examine the possibility that OSM results in the reduction of a target's perceived duration, two experiments combined a temporal order judgement task with an OSM paradigm. In Experiment 1, eight objects (two targets and six distractors) were presented along with two 4DMs which either overlapped the two targets or two distractors. On every trial, the presentation duration of the distractors and one of the targets were equivalent (100 ms) whereas the other target's duration was varied (25, 50, 75, 100, 125, 150 or 175 ms). Participants made a forced choice judgement of the relative duration of the two targets. Accuracy was used to generate psychometric curves representing perceived durations of targets. Critically, the offset of one of the masks was always simultaneous with its associated object, whereas the offset of the other mask was delayed by 300 ms. When masks overlapped the targets, there was a shift in the psychometric curve indicating that the delayed mask reduced the perceived duration of its associated target. Experiment 2 extended the standard presentation duration of all the objects to 500 ms and used a blocked design in which the masks either overlapped the targets, or were radially displaced from them. Both experiments provide novel evidence that OSM can reduce the perceived duration of supra-threshold objects without affecting detection accuracy.

Acknowledgement: NSERC

56.4063 Dissociation between Attentional Capture and Attentional Engagement: an Attentional Blink study Alon Zivony[1] (alonzivony@gmail.com), Dominique Lamy[1]; [1]The School of Psychology Sciences, Tel Aviv University

Our ability to attend to successive events is severely limited: observers often fail to report the second of two targets that appear within 200-500ms from each other, a phenomenon known as the attentional blink. Here, we examined what processes are disrupted during the blink. Specifically, we examined whether the blink affects (1) the ability of a distractor that matches the attentional set to capture attention and initiate an attentional episode and (2) attentional engagement in this distractor, that is, the extraction of its response-relevant features. We found that attentional capture occurs irrespective of whether the attention-grabbing distractor occurs during or outside the blink, but that attention is engaged in the object that immediately follows this distractor in time. Taken together, these findings strongly support the Delayed Engagement Account of the attentional blink as well as demonstrate that attentional capture and attentional engagement can be dissociated.

56.4064 Musical Minds: Attentional blink reveals modality-specific restrictions Sander Martens[1,2] (s.martens@umcg.nl), Stefan Wierda[1,2,3], Mathijs Dun[1], Michal de Vries[1,3], Henderikus Smid[1]; [1]Neuroimaging Center, University of Groningen, Groningen, the Netherlands, [2]Department of Neuroscience, University Medical Center Groningen, Groningen, the Netherlands, [3]Institute of Artificial Intelligence, University of Groningen, Groningen, the Netherlands

Background: Formal musical training is known to have positive effects on attentional and executive functioning, processing speed, and working memory. Consequently, one may expect to find differences in the dynamics of temporal attention between musicians and non-musicians. Here we address the question whether that is indeed the case, and whether any beneficial effects of musical training on temporal attention are modality specific or generalize across sensory modalities. Methodology/Principal findings: When two targets are presented in close temporal succession, most people fail to report the second target, a phenomenon known as the attentional blink (AB). We measured and compared AB magnitude for musicians and non-musicians using auditory or visually presented letters and digits. Relative to non-musicians, the auditory AB was both attenuated and delayed in musicians, whereas the visual AB was larger. Non-musicians with a large auditory AB tended to show a large visual AB. However, neither a positive nor negative correlation was found in musicians, suggesting that at least in musicians, attentional restrictions within each modality are completely separate. Conclusion/Significance: AB magnitude within one modality can generalize to another modality, but this turns out not to be the case for every individual. Formal musical training seems to have a domain-general, but modality-specific beneficial effect on selective attention. The results fit with the idea that a major source of attentional restriction as reflected in the AB lies in modality-specific, independent sensory systems rather than a central amodal system. The findings demonstrate that individual differences in AB magnitude can provide important information about the modular structure of human cognition.

56.4065 **Biased competition can explain the effect of relative target contrast on the attentional blink**

Simon Nielsen[1] (simon.privat@gmail.com), Tobias Andersen[2]; [1]University of Copenhagen, Department of Psychology, Denmark , [2]Technical University of Denmark, Department of Applied Mathematics and Computer Science

The attentional blink (AB) is observed as the reduced report accuracy of a second target (T2) when it is presented within half a second of a first target (T1; Raymond et al. 1992). The two-stage model (Chun & Potter, 1995) suggests that the AB occurs in a capacity limited second processing stage critical for conscious access. While the first stage was originally assumed to have unlimited capacity, a more recent revision suggests that resource competition in the first stage influences the AB (Potter et al. 2002). This competition two-stage model states that when T2 is presented shortly after T1 it can wrest away resources that were otherwise allocated to T1 as reflected by the relative T1-T2 accuracies at short lags. In this study we examine whether first stage competition in the attentional blink can be understood within the biased competition model of attention (Desimone & Duncan, 1995). According to this model competition between spatially and temporally adjacent stimuli is an intrinsic property of visual perception that is biased both by bottom up and top down task properties, and while temporal order biases competition in this model, so does the relative contrast between targets. Experiment 1 (N=25) shows that T1-T2 contrast modulate T2 accuracy at shorter lags in favour of the relatively higher contrast T2. This effect is at the expense of T1 accuracies thus indicating T1-T2 competition by means of their relative contrast. In Experiment 2, Gaussian noise manipulations varied target contrast while maintaining target accuracies constant. Experiment 2 (N=17) shows that when T1-T2 accuracies are held constant the T1-T2 contrast bias is prolonged to include later lags. In conclusion, these results corroborate and extend the competition two-stage model and support a more general interpretation of first stage competition as a special case of the biased competition model of attention.

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56.4066 **Degraded precision of consciously perceived targets in the attentional blink.**

Jocelyn Sy[1,2] (Jocelyn.l.Sy@vanderbilt.edu), René Marois[1,2], Frank Tong[1,2]; [1]Department of Psychology, Vanderbilt University, [2]Vanderbilt Vision Research Center

A debate regarding the discrete or continuous nature of visual awareness has revolved around the attentional blink (AB). The AB is a transient limitation in the ability to perceive the second (T2) of two masked targets 200-500ms after the attentional processing of the first target (T1). The AB is considered to represent both a central limitation of attention and limitations within earlier visual stages of information processing (Dux & Marois, 2009). Central to this debate is whether the failure to report T2 is due to the discrete failure of information reaching post-perceptual stages of processing, or whether the graded quality of information produces a weak conscious representation. Asplund et al. (2014) applied a mixture-modeling analysis (Zhang & Luck, 2008) to errors in T2 responses to estimate 1) the width of the error distribution to measure the precision of the T2 percept and 2) the probability of successful T2 encoding, assuming an all-or-none representation of T2. They found evidence in favor of discrete failures within central stages of information processing. Here, we tested whether the AB necessarily leads to discrete failures of perception, or whether weak representations can occur once attention is taxed within the same early visual processing channel (Awh et al. 2004), or feature dimension of orientation. Observers were presented with two oriented gratings, which appeared in a rapid serial visual presentation of random noise. Participants performed two task types: report the orientation of both targets, or of T2 alone. Mixture-modeling analysis revealed an AB, defined by the interaction between task and time, in precision but not in the probability of successful encoding. These results suggest that the quality of T2 representations gradually becomes more precise as attentional resources are made available over time, and that discrete or continuous processing depends on the level in which attentional capacity is taxed.

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56.4067 **Temporal yoking in continuous multitasking**

Yuhong Jiang[1] (jiang166@umn.edu), Khena Swallow[2]; [1]Department of Psychology, University of Minnesota, [2]Department of Psychology, Cornell University

We report a unique form of dual-task interference that occurs during continuous multitasking. Continuous tasks such as baggage screening often involve the selective gating of sensory information at the time when "targets" are detected. Previous research has shown that the selection of behaviorally relevant moments in time can enhance perception, learning, and memory. However, it is unclear whether temporal selection for one task can be independent of selection for another concurrent task. To address this question, we asked participants to view a stream of faces and encoded faces of a particular gender for a later memory test (target faces). At the same time, participants listened to a series of tones and pressed a button only for tones of a certain pitch (target tones). We manipulated the timing of target faces and target tones such that temporal selection for the two tasks was unrelated, perfectly correlated, or anticorrelated. Across 3 experiments, temporal selection for both tasks was successful when the tone and face stimuli were either both targets or both nontargets, but not when only one was a target. For example, participants tended to miss target tones that coincided with a nontarget face, or to false alarm on a nontarget tone that coincided with a target face. Similarly, participants were unsuccessful ignoring nontarget faces when they coincided with a target tone rather than a nontarget tone. Attentional selection for separate tasks appears to be yoked in time: When the attentional gate opens for one task it also opens for the other. Temporal yoking is a unique form of dual-task interaction.

56.4068 **Gains and losses in continuous dual-task performance: The role of task engagement**

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When two tasks are performed at the same time increasing the demands of one of the tasks often increases interference in the other task. Surprisingly, it can also facilitate performance across tasks. For example, in the attentional boost effect memory for a picture is enhanced if it is encoded at the same time as an unrelated target square, rather than on its own or with a distractor square. This study tests whether across task facilitation effects depend on the continuous and simultaneous engagement of participants in both tasks. Participants encoded a continuous series of briefly presented pictures (500 ms per picture) into memory. A single colored square could appear in the center of each picture, and participants pressed a key whenever they detected a square in the target color. Participant's engagement in the detection task was manipulated by presenting a square with each image (in a target or a distractor color; target+distractors), by omitting squares in distractor colors but not in the target color and presenting most pictures on their own (target-only), or by asking participants to ignore the squares (single-task encoding). Replicating the attentional boost effect, memory for pictures presented with a target was enhanced relative to those presented with a distractor. In contrast, in the target-only condition detecting a target interfered with memory for pictures that appeared within the next 1.5 s. Memory for pictures presented with targets was similar across conditions. These data indicate that target detection can offset dual-task interference costs even when stimuli for one task occur intermittently and unpredictably. However, engaging in two tasks at once does produce significant and long-lasting performance costs. These data are interpreted within the context of recent proposal that suggest that temporal selection is not task specific.

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56.4069 "Why do cuts work?" – Implicit memory biases attention and gaze after cuts in edited movies Christian Valuch[1] (christian.valuch@univie.ac.at), Raphael Seywerth[1], Peter König[2], Ulrich Ansorge[1]; [1]Faculty of Psychology, University of Vienna, Austria, [2] Institute of Cognitive Science, University of Osnabrück, Germany

Edited movies are sequences of different shots connected by cuts every couple of seconds. In spite of these abrupt image changes, professional editing often results in seamless perceptual experience. We hypothesized that after cuts, attention is primed for features fixated immediately before the cut, enabling instantaneous recognition of related image content. In a first series of experiments we presented two edited sports movies in parallel on the same screen and instructed observers to attend to only one of them. At each cut we interrupted playback for a central fixation. Playback then resumed either at the same or at a switched position. Observers' performance in identifying the previously attended movie was significantly better when visual similarity of the two sequential shots was high than when it was low, and when the movies' positions were the same. In a second series of experiments we investigated eye movements following cuts in edited full-screen movies. We produced 240 Full HD clips of street scenes and presented them in sequences of two in smaller 4:3 crop frames (taken from the left or right border of the original movie). The first clip ended with a blank and central fixation. This was followed by a second clip showing either (1) the complementary crop frame of the same source movie, or (2) the identical crop frame of the same source movie, or (3) an unrelated movie. Assignment of the videos was balanced across participants, allowing us to gauge the contribution of prior visual experience to gaze guidance after within-scene cuts [as in (1) and (2)] against scene exploration after between-scene cuts [as in (3)]. Our results provide strong empirical evidence for movie editors' intuitions and help to understand how memory and attention enable the visual system to combine sequential shots into coherent perceptual experiences.

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56.4070 Attentional Volleying Across Visual Quadrants Andrew Clement[1,2] (aclemen3@nd.edu), Nestor Matthews[2]; [1]University of Notre Dame, [2]Denison University

Introduction: In 1937, Ernest Wever and Charles Bray proposed the Volley Theory to explain how comparatively sluggish neural firing rates might register high auditory frequencies. The theory posits that distinct neural ensembles synchronize at various temporal phases to increase an organism's temporal precision. This neural-ensemble volleying might more broadly be construed as a general neural principle that helps organisms solve time-based problems via biologically manageable episodes. Here, we investigated whether neural resources that govern attention to each visual quadrant might volley to improve temporal precision beyond the canonical ~7.5 Hz limit (VanRullen, Carlson & Cavanagh, 2007). Method: Denison University undergraduates viewed four-stream RSVP displays containing two targets (T1 and T2) and reported the identities of both targets on each trial. Randomly across trials, the four streams flashed either synchronously at 7.5 Hz, or asynchronously with new information occurring at 7.5 Hz per quadrant, 15 Hz per lateral hemifield, and 30 Hz globally. In a flicker-discrimination control experiment, participants viewed 4-stream displays presented simultaneously or in quadrature phase at 15 or 30 Hz, and reported whether the streams flashed synchronously or asynchronously. Results: The synchronous and asynchronous conditions generated statistically indistinguishable, near-ceiling T1-identification accuracy despite the asynchronous condition's 30 Hz global presentation rate, i.e., four times the canonical ~7.5 Hz attention rate. Similarly, the asynchronous condition reduced T2|T1 accuracy by just 4.5 percentage points, a cost only half that associated with the moving T2 from the left to right visual field. These null and small effects occurred even though participants reliably discriminated synchronous from asynchronous displays at 15 and 30 Hz. Conclusion: Our experiments reveal accurate visual attention for spatially distributed targets presented at four times the canonical ~7.5 Hz limit. This supports the possibility that the neural events governing attention to each visual quadrant volley to improve attention's temporal precision.

56.4071 Selective spatial enhancement: Attentional spotlight sizes impacts spatial but not temporal perception Stephanie Goodhew[1] (s.c.goodhew@gmail.com), Elizabeth Shen[1], Mark Edwards[1]; [1]Research School of Psychology, The Australian National University

Visual spatial attention is a core function that prevents limited sensory resources from being overwhelmed by input. A prevailing assumption in the field has been the notion of 'universal enhancement' – that attention confers an advantage on all aspects of processing, and the greater the density of attentional resources applied to a stimulus (a 'focal' attentional spotlight), the greater the magnitude of the enhancement relative to when these resources are spread more thinly (a 'diffuse' attentional spotlight). Recent results, however, challenge this notion. Here we instead propose a novel theory of visual attention, which draws on the established physiological properties of the two major types of visual cells: magnocellular (M-cell) and parvocellular (P-cell) neurons. P cells have greater spatial but poorer temporal acuity whereas M cells have greater temporal but poorer spatial acuity. We reasoned that focussing attention into a small region should draw preferentially upon P-cells, given their smaller receptive field sizes, whereas spreading attentional resources more diffusely over a larger region should call preferentially upon M-cells with their larger receptive fields. This predicts that there should be a qualitative trade-off in spatial and temporal acuity as a function of attentional spotlight size, such that a focal spotlight enhances spatial resolution but impairs temporal resolution, whereas a diffuse spotlight impairs spatial resolution while enhancing temporal resolution. We call this novel theory the 'spatiotemporal trade-off account' of attention. We tested this by manipulating observers' attentional spotlights to be either focal or diffuse, and then measuring their spatial and temporal acuity with spatial and temporal gap detection tasks. We found that while spatial acuity benefited from focal relative to a diffuse spotlight, attentional spotlight size had no impact on temporal acuity. These results do not confirm the spatiotemporal trade-off account, but they do directly challenge the notion of universal enhancement.

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56.4072 The fidelity of attentional set develops during a temporal visual search Tomoe Inukai[1] (inukai@kobe-shinwa.ac.jp), Tomonari Shimomura[2], Jun-ichiro Kawahara[2]; [1]Kobe Shinwa Women's University, [2]Chukyo University

In the present study, we investigated temporal development of attentional set in a task in which observers identify a target letter among sequentially presented nontarget letters. Specifically, we examined whether attentional set can be fully established at the beginning of a trial or whether the set develops gradually within a trial. We manipulated the time from the onset of a trial to a target and the presence or absence of peripheral distractors as an index of fidelity of attentional set. We focused on the effect of feature search mode because previous study had shown that of singleton detection mode (Inukai & Kawahara, 2011). Participants identified a target letter of a specific color (e.g., red) embedded in a stream of rapidly presented nontargets of heterogeneous color while ignoring peripheral distractors. Baseline accuracy when no peripheral distractor was presented increased as the target appeared later in the stream, suggesting attentional awakening. Identification accuracy was impaired by the presence of peripheral distractors (i.e., attentional capture) early in the stream when observers adopted the feature search mode. The magnitude of attentional capture increased to over 1,000 ms under the singleton detection and feature search modes. The result that the magnitude of attentional capture was affected by the temporal position of the target under the two search modes suggests that attentional set develops gradually during the search for a target regardless of search strategy. Importantly, the result that attentional capture occurred early in the stream only under the feature search mode suggests that the fidelity of attentional set was higher under the feature search mode than that under the singleton detection mode at the start of a trial. Such a difference may be because establishing the feature search mode would be a benefit during successive visual search trials.

56.4073 Training-induced Changes in the Dynamics of Attention as Reflected in Pupil Dilation Charlotte Willems[12] (c.willems@umcg.nl), Atser Damsma[123], Stefan Wierda[3], Niels Taatgen[3], Sander Martens[12]; [1]Department of Neuroscience, University Medical Center Groningen, [2]Neuroimaging Center, University of Groningen, [3]Institute of Artificial Intelligence, University of Groningen

One of the major topics in attention literature is the attentional blink (AB), which demonstrates a limited ability to identify the second of two targets (T1 and T2) when presented in close temporal succession (200-500 msec). Given that the effect has been thought of as robust and resistant to training for over two decades, one of the most remarkable findings in recent years is that the AB can be eliminated after a one-hour training with a color-salient T2. However, the underlying mechanism of the training effect as well as the AB itself is as of yet still poorly understood. To elucidate this training effect, we employed a refined version of our recently developed pupil dilation deconvolution method to track any training-induced changes in the amount and onset of attentional processing in response to target stimuli. Behaviorally, we replicated the original training effect with a color-salient

T2. However, we showed that training without a salient target, but with a consistent short target interval is already sufficient to attenuate the AB. Pupil deconvolution did not reveal any posttraining changes in T2-related dilation, but instead an earlier onset of dilation around T1. Moreover, normalized pupil dilation was enhanced posttraining compared to pretraining. We conclude that the AB can be eliminated by training without a salient cue. Furthermore, our data point to the existence of temporal expectations at the time points of the trained targets posttraining. Therefore, we tentatively conclude that temporal expectations arise as a result of training.

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56.4074 Breakthroug Percepts - (Sub)liminal Salience Search and EEG Deception Detection on the Fringe of Awareness

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We use the term (Sub)liminal Salience Search (SSS) to describe humans' extraordinary capacity to (pre)consciously "locate" stimuli that are salient to them [2]. A particularly compelling demonstration is Rapid Serial Visual Presentation, in which the vast majority of stimuli presented are not perceived sufficiently to encode into working memory (hence the term (sub) liminal), but ones that are salient breakthrough into consciousness and are encoded (hence the term search). In addition, the P3 is an EEG correlate of such breakthrough, giving a means to determine what a participant's brain finds salient. We will discuss how theories, such as the Simultaneous Type/ Serial Token model [1], explain SSS, and how it can be used in deception detection [2]. We will review our experiments showing that this Fringe-P3 identity detector is resilient against countermeasures, e.g. artificially elevating the response to the control stimulus [3]. Then we will present our new experimental findings, which show that famous names presented in RSVP break into awareness and that such breakthrough can be detected with EEG on a per-individual basis. This suggests that our Fringe-P3 method can be generalised beyond the exquisite salience of own-name, allowing it to be applied across a variety of Forensics settings. [1] Bowman, and Wyble (2007) The Simultaneous Type, Serial Token Model of Temporal Attention and Working Memory. Psychological Review, 114(1). 38-70. [2] Bowman, et al (2013) Subliminal Salience Search Illustrated: EEG Identity and Deception Detection on the Fringe of Awareness. PLoS-ONE, 8(1). 1-21. [3] Bowman, et al (2014) Countering Countermeasures: Detecting Identity Lies by Detecting Conscious Breakthrough. PLoS-ONE, 9(3). 1-17.

56.4075 Human brain mapping of theta-band behavioral oscillations in masked priming

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Rhythmic neural activities are ubiquitous and play key roles in various cognitive functions. Recent studies, by employing a time-resolved behavioral measurement, have revealed neurophysiologically relevant oscillations directly in visual attentional behavior ('behavioral oscillation'), implicating that multiple locations get sampled alternatively in a theta-band rhythm (Landau & Fries, 2012; Fiebelkorn et al., 2013; Song et al., 2014). Furthermore, our recent work, by using a masked priming paradigm, demonstrate that similar to multi-location rhythmic sampling, multiple perceptual predictions occurring at the same spatial location are conveyed in various phases of a theta-band rhythm (see Huang, Chen and Luo, VSS2015). However, it is unknown which brain regions underlie the 'behavioral oscillation' in visual attention. To investigate the neural underpinning of 'behavioral oscillations', we conducted an fMRI study to measure human brain responses by employing the masked priming paradigm in combination with a time-resolved psychophysical approach. Behavioral results replicate our masked priming oscillation findings (see Huang, Chen and Luo, VSS2015). Importantly, complementing to the behavioral oscillation findings, preliminary fMRI results demonstrate theta-band oscillations as well as out-of-phase relationship between congruent and incongruent conditions in several brain regions, including occipital visual areas, cerebellum, motor cortex, and frontal regions. These results provide critical constraints for developing a neural model to understand the attentional mechanism underlying behavioral oscillations. Based on these results, we propose a model that suggests frontal cortex may generate and coordinate perceptual predictions through an oscillation-based temporal organization scheme, and these perceptual predictions would then be conveyed to modulate neural activity in sensory cortex and motor related brain regions, leading to the observed 'behavioral oscillations' in masked priming.

Attention: Mechanisms and models

Tuesday, May 19, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4076 Attentional control strategies lead to different task performance across cognitive domains

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Performance for visual search improves when subjects use passive, intuitive attentional strategies versus actively directed ones (Smilek & Enns, 2006). It has also been suggested that visual search tasks benefit from bottom-up mechanisms (Proulx, 2005). Smilek & Enns acknowledge that the passive advantage may not transfer to other cognitive domains and Pinto et al. (2013) suggested that attentional mechanisms might be independent in both top-down and bottom-up processing. In order to test this possibility we ran a battery of executive cognitive tasks that we predicted would be impeded by the passive attentional strategies that were shown to be beneficial for visual search. Two randomly selected groups of participants completed a pre-test comprised of a backward digit span task, followed by a subset of Raven's Progressive Matrices. Before repeating these batteries in a post-test, group 1 was instructed, in a manner similar to Smilek & Enns, to "actively direct" their attention (i.e., maintain active focus on the stimuli), and group 2 was instructed to be "as receptive as possible", using a passive, broad focus approach (i.e., using intuition and "gut-feeling"), allowing targets and answers to "pop" into their minds. Group 1 (active) scored significantly higher on post-test items while group 2 (passive) scored significantly lower. This showed that executive cognitive tasks benefit from actively directed attentional strategies, and while passive attentional strategies may be conducive to tasks reliant on visual tasks requiring bottom-up processing, they were found to be a hindrance for those requiring top-down processing. These findings suggest that visual search tasks require distinct cognitive processes compared to complex intelligence batteries, and also provide support for claims that these distinct processes may function with different attentional mechanisms.

56.4077 Visual selectivity and top-down modulation of neurons in monkey V2 during free viewing

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Neurons in early visual cortex are selective for local visual features but their responses can also be influenced by factors like border ownership and selective attention. Most of what we know about the function of these neurons is based on neurophysiological studies in monkeys that hold their direction of gaze fixed while isolated visual stimuli are presented (controlled viewing). However, during natural behavior, primates visually explore cluttered environments by changing gaze direction several times each second (free viewing). How does the visual cortex work under these conditions? We explored neuronal responses using a foraging task in which the monkey chooses where to look and when. Geometrical figures were displayed and the monkey was rewarded for fixating the center of a figure for at least 200ms. In each trial an array of 10 figures (5 squares and 5 triangles) was presented, one of which was randomly associated with reward, and a cue informed the monkey whether it was a square or a triangle. The monkey sequentially fixated the cued shapes (and sometimes also the other shapes) in search for reward. Single neurons were recorded from area V2. After mapping the receptive field of a cell, the figure array was constructed so that fixating the center of a figure would, in most cases, bring an edge of another figure into the receptive field. We show that neural feature selectivity, border ownership coding and attentional modulation can be measured reliably with this method despite the fast pace of fixations (mean time between saccades about 350ms). Some neurons showed enhancement when the figure at the receptive field was the target of the next saccade, but only when that figure was on the preferred border-ownership side of the neuron, indicating a link between saccade planning and mechanisms of contour grouping.

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56.4078 Behavioral oscillation in priming: competing perceptual predictions conveyed in alternating theta-band rhythms

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Neuronal oscillations are ubiquitous in the brain and contribute to perception and attention. Our recent work (Song et al., 2014), in combination with other studies, by measuring response time (RT) in a high time-resolved manner, demonstrates dynamic oscillatory pattern directly in behavioral measurement ('behavioral oscillation') in a spatial attentional task, suggesting that multiple spatial locations are sampled alternatively in various phase of attentional rhythms. However, it remains completely unknown whether such oscillation-based temporal coordination may also mediate processes at the same spatial location. In the present study, we investigate how multiple perceptual predictions are conveyed and coordinated to guide moment-by-moment visual perception at one fixed spatial location, by employing priming paradigms in combination with a time-resolved behavioral approach. We first replicate classical priming effects in slowly developing trends of priming time courses. Importantly, after removing the typical priming patterns, we reveal a new and separable theta-band (~4 Hz) oscillatory component in the priming behavior, regardless of whether the prime was masked or not. Furthermore and critically, these theta-band priming oscillations triggered by congruent and incongruent primes are in an out-of-phase relationship. These findings suggest that multiple perceptual predictions are dynamically yet competitively coordinated in time by being conveyed in different phases of the theta-band oscillations to achieve dissociated but temporally organized neural representation, similar to previous findings in spatial attention. In summary, the results speak to a critical and general role of oscillation-based temporal organization and coordination in visual attention.

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56.4079 Functional MRI Reveals a Cognitive Control Subnetwork Supporting Long-Term Memory-Guided Visual Attention

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Human visual performance exceeds that of powerful supercomputers. Paradoxically, human attentional capacity is extremely limited. We can reconcile this superior performance with our limited attentional capacity by taking into account the important role of long-term memory, which guides attention to the most relevant information in an environment. Previous work from our laboratory (Rosen et al., in revision) has found that three regions located within the posterior Cognitive Control Network (defined using Yeo et al., 2011), including the lateral intraparietal sulcus (latIPS), posterior callosal sulcus (CaS-p), and the posterior precuneus (PrC-p) were more strongly recruited during long-term memory-guided attention compared to stimulus-guided attention. Recent work has suggested that these three regions form a subnetwork and a meta-analysis suggested that they support long-term memory retrieval (Power et al, 2011; 2014). It is unclear if this network plays a specific role in memory-guided attention or a more general role in memory retrieval. Here, we designed an experiment to directly contrast long-term memory-guided attention, stimulus-guided attention and long-term memory retrieval in the same subjects ($n = 24$). Subjects performed a cued target detection task with matched visual stimuli in all conditions. Cues either explicitly directed spatial attention, required subjects to use LTM to direct spatial attention or forced memory retrieval without spatial attention. All three regions of the subnetwork (PrC-p, CaS-p and latIPS) in both hemispheres showed the greatest activity in long-term memory-guided attention (all $p > 0.01$, corrected) with no regions showing differences between long-term memory retrieval and stimulus-guided conditions. Effects were strongly bilateral in PrC-p and CaS-p, but latIPS was more selective for memory-guided attention in the right hemisphere (Hemisphere:Condition interaction $F(2,46) = 13.43$, $p< 0.001$). We suggest that this subnetwork of posterior Cognitive Control Network nodes (PrC-p, CaS-p and latIPS) supports processing that integrates memory- and stimulus-based representations and is preferentially recruited for LTM-guided attention.

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56.4080 Time-resolved neural effects of attention precuing and spatial location in the left and right fusiform face areas

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Neural mechanism underlying attention manifests itself through intertwined perceptual effects. A recent study using time-resolved behavioral measurements revealed that spatial attention mediates the processing of visual stimuli presented at precued location and uncued location in a rhythmic manner (Song et al., 2014). However, how the dynamics of spatial attention effects may interact with object/face representation is unknown. Here we combined this innovative time-resolved approach with fMRI to address this question. In each trial, an uninformative cue was presented in the left or right hemifield. Participants were asked to make speeded responses detecting whether a face or a house was presented at either the cued or uncued location. Critically, the cue-to-target stimulus onset asynchrony (SOA) varied trial-by-trial in a small step of 20ms, from 200ms to 1080ms. Bilateral fusiform face areas (FFA) and parahippocampal place areas (PPA) were localized with separate fMRI scans. On average across SOAs, in the left FFA, right hemifield targets led to significantly increased activity than left hemifield targets for both faces and houses. By contrast, averaged activity in the right FFA was invariant to which hemifield the target was shown, but significantly modulated by which hemifield the cue was presented, suggesting effects of spatial attention for face representation in the right FFA. No such hemispheric asymmetry was found for the PPA. Moreover, both the FFA and PPA results demonstrate theta-band oscillations in the valid cue condition, complementing to results we will report in other VSS2015 abstracts that suggest similar rhythmic effects of visual attention. Together, these results show 1) hemispheric asymmetry of how spatial attention and invariant face representation may interact; 2) reliable neural correlates of the theta-band behavioral oscillation underlying attention, shedding lights on how attention mechanisms dynamically regulate the neural processing of visual stimuli.

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56.4081 The effect of visual entrainment on target detection in visual search.

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A growing body of research has associated brain oscillations with the cognitive process of selective attention, as well as visual perception. Modulation of alpha frequency band (8-14Hz) has been related to changes in perception and attention with an inverse correlation between alpha amplitude and perceptual ability. To date the association between alpha and target detection has been shown in numerous studies but using only near-threshold stimuli. Here we attempt to study the extent to which visual entrainment at alpha and non-alpha frequencies will affect attention in a more complex, higher level target detection task. In the current experiment subjects took part in a visual search task where they were instructed to find a target among a set of distractors. The visual search display was preceded by a stimulus which either flickered in alpha (10Hz), non-alpha (random flicker sequence with an average of 10 Hz) frequency or was a static control. Given that alpha entrainment has been shown to enhance endogenous alpha levels, we predicted alpha entrainment to increase reaction time (RT) for target detection. On the other hand, as non-alpha stimulation should prevent alpha synchronisation, we predicted shorter RTs in this condition. The results reveal that non-alpha flicker stimulation resulted in significantly faster target detection in the visual search task compared to the control condition. Alpha entrainment gave rise to marginally slower RTs than non-alpha, while at the same time marginally faster than the control. The pattern of results suggests that entrainment allows for quicker responses than in the static control condition. These results are in line with research showing that inhibition of alpha is associated with better attentional and perceptual performance.

56.4082 Understanding the PD and the N2pc: modeling the neural mechanisms underlying spatial attention shifts

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When spatial attention is directed by a target towards one side of the visual field, electrodes on the scalp record an asymmetrical electrophysiological potential over parietal cortex called the N2pc. This EEG component has recently been shown to reflect the engagement of attention at a location, but not sustained attentional deployment (Tan & Wyble, In Press). A computational model has interpreted this component as the attentional system "locking-on" to the location of a target (Tan & Wyble, In Press). The Pd is another lateralized component, thought to reflect suppression of distracting information. In contrast to this interpretation, we have run an EEG experiment using four RSVP streams which reveals a Pd elicited by two simultaneously presented targets, when the targets are separated by one degree of visual angle, but not when separated by four degrees. To provide a neural intuition for the mechanisms underlying the Pd component, we have revised our previous neurocomputational model of attentional dynamics so that it simulates both the N2pc and the Pd as suggested by a variety of experimental findings. The new model simulates the Pd as a laterally asymmetric imbalance in the inhibition of attentional control neurons in posterior parietal cortex. This imbalance can have multiple causes, which explains how the Pd is elicited both with and without distractors. Critical to this account is strategic regulation of the attentional focus, such that it is tighter when stimuli are spatially proximal, whether they are targets or distractors. Furthermore, since the Pd can be elicited by distractors without a leading N2pc, the model includes a reactive form of inhibition that can, in some cases, suppress distracting information before it can elicit an attentional response.

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56.4083 **The attentional strobe: auditory manipulation of visual conscious awareness** Julia Thompson[1] (juliathompson@swin.edu.au), David Crewther[1]; [1]Swinburne University of Technology

The discrete nature of visual attention has become a recent topic of interest. Using techniques of psychophysics and magnetoencephalography (MEG), we searched for indications of the presence of an "attentional strobe" and the degree to which it could be manipulated using auditory stimulation. Participants undertook visual change detection tasks. The "rapid" task was used to detect the abrupt change in contrast of one of approximately 15 coloured dots in a standard gap paradigm. The "gradual" task required the detection, in a similar array of dots, of one dot that was slowly fluctuating in contrast. Two auditory conditions were employed – one with 10Hz tone bursts (3.3kHz, duration 5ms, sound level 52dB) and the other without auditory stimulation. For the rapid task, the threshold for least visible step in contrast was measured, while for the gradual task, the least frequency of sinusoidal fluctuation in one of the dots that could be detected was measured. Threshold contrast decreased with 10Hz stimulation for the rapid task while threshold frequency increased for the gradual task with 10Hz stimulation. A significant Task (rapid, gradual) x Auditory (10Hz, no sound) interaction ($F(1,20)=7.6$, $p=.012$) was found. MEG analysis of theta band power difference over posterior parietal sensors showed opposite effects of auditory stimulation for the rapid and gradual tasks at latencies of approximately 150ms. The psychophysical results (better detection of rapid changes, worse detection of gradual changes) are consistent with auditory stimulation producing an increase in attentional strobe rate. The fluctuations in MEG theta power indicate that manipulation of attentional modulation level may also need to be addressed.

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56.4084 **Decoding Feedback to the Lesion Projection Zone of V1 in Individuals with Glaucoma** J. Brendan Ritchie[1,2] (britchie@umd.edu), Susan Wardle[1], Anina Rich[1,3], Stuart Graham[4], Mark Williams[1]; [1]Perception and Action Research Centre and Department of Cognitive Science, Macquarie University, Australia, [2]Department of Philosophy, University of Maryland, College Park, USA, [3]ARC Centre of Excellence in Cognition and its Disorders, Macquarie University, Australia, [4]Australian School of Advanced Medicine, Macquarie University, Australia

Feedback is a fundamental organising principle of the visual system. Using fMRI decoding methods, Jehee, Brady and Tong (2011) demonstrated that orientation information about an attended stimulus could be decoded in regions of V1 that were not directly activated by that stimulus. Their results have been interpreted as evidence for attention-driven feedback to V1. In normally sighted individuals, however, we cannot completely isolate feedback signals from activity due to feedforward processing. Individuals with monocular glaucoma present an opportunity to investigate feedback signals in the absence of direct visual input to the cortical region. We tested whether information about the orientation of a visible stimulus was present in the portion of visual cortex reflecting the scotoma location (lesion projection zone; LPZ) in individuals with glaucoma. We reasoned that if there is feedback to other regions of V1 when a stimulus is attended, then the same feedback could be observed in the LPZ of V1. We recruited subjects with monocular glaucoma of the right eye, and identified a scotopic quadrant and a relatively unimpaired quadrant of the visual field for each subject. Subject specific localization of the four quadrants of V1 was carried out using functional retinotopy (binocular viewing) and anatomical markers. Oriented gratings (3.5° radius, centered 5° from fixation) were presented (monocular viewing) in the visible quadrant. Subjects performed an orientation discrimination task while maintaining central fixation and covertly attending to the stimuli. Linear classifiers were then trained to predict stimulus orientation using neural data from each of the four quadrant regions. Although the decoding results were variable between subjects, for a subset of participants, stimulus orientation was indeed decodable from the LPZ quadrant. Our results provide proof of concept that feedback signals can be preserved in the absence of activity from direct visual input.

Acknowledgement: NHMRC grant # 1028578

56.4085 **Human vision is preattentively sensitive to the mean and variance of L-M cardinal axis white noise textures** Christian Herrera[1] (cherrer2@uci.edu), Charlie Chubb[1]; [1]Cognitive Sciences, UC Irvine

Introduction: What preattentive mechanisms are sensitive to scrambles (spatially random mixtures) of colors from the L-M cardinal axis of DKL space? Methods: On a trial, the participant strove to localize a circular target patch of color-scramble with one histogram in a large, annular background color-scramble with a different histogram. Scrambles were composed of eight motion equiluminant (ME) lights, varying from saturated red to gray to saturated green along the L-M axis of DKL space. For each of two orthogonal histogram perturbations l_k, k=1,2, the participant was tested in two (separately blocked) complementary attention conditions: in the first attention condition, the target histogram was dominated by l_k and the background was dominated by $-l_k$; in the second, the target histogram was dominated by $-l_k$, the background by l_k. Results are modeled by assuming that (1) the participant has a fixed set of mechanisms, each of which is activated nonnegatively by different colors, and (2) in a given attention condition the participant uses an optimal linear combination (with weights constrained to sum to 1) of only those mechanisms more strongly activated by the target than by the background. Results: The data can be accounted for with two preattentive mechanisms: one that assigns oppositely signed values to reds than to greens, and one that assigns oppositely signed values to highly saturated colors than to desaturated colors. The participant can selectively attend either to the positive or the negative responses of either mechanism. Conclusions: Human vision possesses two preattentive mechanisms sensitive to variations along the L-M cardinal axis of DKL space, one sensitive to mean color and another sensitive to saturation variance.

Acknowledgement: UC-Mexus,

56.4086 **A mechanistic cortical microcircuit of attention for amplification, normalization and suppression** Fred Hamker[1] (fred.hamker@informatik.tu-chemnitz.de), Frederik Beuth[1]; [1]Chemnitz University of Technology

Computational models of visual attention have replicated a large number of data from visual attention experiments. However, typically each computational model has been shown to account for only a few data sets. Thus, a general account to fully understand the attentive dynamics in the visual cortex is still missing. To reveal a set of general principles that determine attentional selection in visual cortex, we developed a novel model of attention, particularly focused on explaining single cell recordings in multiple brain areas. Among those are spatial- and feature-based biased competition, modulation of the contrast response function, modulation of the neuronal tuning curve and modulation of surround suppression. Neurons are modeled by a dynamic rate code. In contrast to previous models, we use a two layer structure inspired by the layered cortical architecture which implements amplification, divisive normalization and suppression as well as spatial pooling. 12 different attentional experiments have been simulated. As a proof of concept the model has been fitted to those 12 different data sets. Concluding, our model proposes that attentional selection emerges from three basic neural mechanisms which are amplification, normalized feature and surround suppression. We hypothesize that these attentive mechanisms are not distinct from other neural phenomena and thus also contribute to multiple perceptual observations such as crowding and feature inheritance.

Acknowledgement: EU FP7-NBIS

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56.4087 **Towards a better understanding of the role of parallel attention in visual search.** Alejandro Lleras[1] (alejandro.lleras@gmail.com), Anna Madison[1], Deborah Cronin[1], Zhiyuan Wang[1], Simona Buetti[1]; [1]Psychology Department, University of Illinois

Several traditional accounts of visual search propose that search is completed in two separate sequential stages: a preattentive stage and a capacity-limited attentive stage. We challenge such accounts by showing that the first stage is an attentive stage of unlimited capacity. This stage gathers evidence in parallel at each location across the visual field regarding the likelihood that the item at that location is likely to be the target. Items unlikely to be the target are rejected from further consideration whereas locations of items likely to be the target are passed onto the second stage of attentive processing. The amount of evidence that needs to be gathered for each item is determined by the similarity of that item to the target template. These two properties (parallel unlimited capacity and similarity processing) produce search functions that increase logarithmically with the number of elements in the display such that the steepness of the log function tracks item-target similarity. Key differences between our proposal and past proposals are as follows. (I) Previous theories propose that the parallel stage is the same for present/absent tasks and target discrimination tasks. Here we show that present/absent search tasks require less evidence accumulation as indexed by the flattening of the log functions. (II) Previous theories propose that when items are rejected from consideration (filtered out), this tends to happen "en masse" (by spreading suppression or grouping, Duncan & Humphreys, 1989). Others have proposed that below a given level of activation, items won't be inspected (Wolfe, 1994). Here we show evidence for multiple concurrent thresholds as each item's similarity to the target template determines the evidence threshold at that location. Finally, (III) traditional theories propose an immutable boundary between parallel and limited capacity search stages, whereas we show that the two stages can tradeoff with one another.

56.4088 **Explaining intertrial priming from the visual code** Wouter Kruijne[1] (w.kruijne@gmail.com), Martijn Meeter[1]; [1]Vrije Universiteit Amsterdam

Visual search is heavily affected by recent selection history, as is evident from the phenomenon of intertrial priming: repeating target- and/or distractor features speeds selection of the target, relative to feature changes. Traditionally, this is interpreted as resulting from a boosting of target features and suppression of the distractor features. However, several findings have cast doubt on the idea that target- and distractor features independently contribute to priming. Instead, their relation in feature space may matter more than the absolute individual feature values. Such relational priming is observed for primitive features like color and luminance, but also for somewhat artificial features such as 'spikedness'. We modeled intertrial priming using an existing model of bottom-up visual processing (Attention through Information Maximization or AIM; Bruce & Tsotsos, 2009, Journal of Vision), which uses features that are derived from regularities in the visual environment. We extended this model with a mechanism that suppresses the feature gain of all stimuli present in a display, while specifically increasing the gain of target features. features. This mechanism allowed us to model a vast array of priming results, for visual searches in color, luminance, size, 'spikedness' and 'shape'. Moreover, it naturally yielded relational priming in both primitive and more complex feature dimensions. We additionally report a series of experiments that investigate what in a display elicits suppression, using reaction time and the saccade global effect as dependent measures. The model has consequences well beyond the priming literature by detailing how attentional deployments leave a prolonged mark on the visual system.

56.4089 **Formation of the priority map by the reciprocal connections between LIP and FEF** Koorosh Mirpour[1] (kmirpour@mednet.ucla.edu), James Bisley[1,2,3]; [1]Dept. Neurobiology, [2]Jules Stein Eye Institute, David Geffen School of Medicine, [3]Dept. of Psychology and the Brain Res. Inst., UCLA, Los Angeles, CA

We are able to find objects in a cluttered scene quickly and effortlessly. To achieve this, the brain creates a priority map of the visual world, which incorporates both pre-attentive and cognitive inputs to represent the importance of stimuli in the scene, and which uses inhibitory tagging to track items that have been viewed. Eye movements are then guided by this map. We have previously shown that activity in the lateral intraparietal area (LIP) acts like a priority map, but the absolute responses do not correlate directly with behavior: they have to be normalized first. In this study we examined the responses of neurons in the frontal eye field (FEF), which has reciprocal connections with LIP, to test whether it contributes to the formation of the priority map. Animals searched through 5 potential targets and 5 distractors to find the target loaded with reward. After the stimuli appeared, the animals were free to move their eyes. Stimuli were spaced such that when the animal was looking at one stimulus, another was in the FEF neuron's receptive field. Most of the neurons fit into 4 main classes: neurons that responded preferentially to Ts; neurons that responded preferentially when a stimulus that had been fixated was in the response field, which could drive top-down inhibitory tagging seen in LIP; and neurons that initially showed an enhanced response to a stimulus that had been fixated, but then reversed their response preference 100-150 ms after the saccade. The late responses in this class matched our post-normalization predictions. The final class of neurons didn't differential between search objects, but preferentially responded to the goal of the next saccade. Together these data suggest that the reciprocal connection between LIP and FEF creates the priority map that guides saccadic eye movements during active, goal directed visual search.

56.4090 **Towards grasping the underlying neuronal processes in ADHD using a visual search task: a computational modelling approach.** Eirini Mavritsaki[1,2] (eirini.mavritsaki@bcu.ac.uk), Amy Cook[1], Glyn Humphreys[2]; [1]Birmingham City University, Dawson Building, City North Campus, Perry Bar, Birmingham, B42 2SU, England, [2]Department of Experimental Psychology, Tinbergen Building, 9 South Parks Road, Oxford, OX1 3UD, England

Attention is essential for our everyday life. The role of attention is to identify the most relevant information in our environment to be processed. Deficits in attention processes have been linked to attention deficit hyperactivity disorder (ADHD). ADHD is a disorder with an onset in childhood and is characterised by inattentiveness, hyperactivity and impulsivity. In the present study we investigate the link between ADHD and visual attention. ADHD is linked with a reduction in arousal levels, which is related to norepinephrine and dopamine function. It is difficult to investigate the role of these two neurotransmitters in ADHD without using interventions. An attractive approach is to use computational modelling, as there is no need for interventions, if the appropriate model is used. In the present study, we extended a neural-level model, the spiking Search over Time and Space (sSoTS) model which was developed to simulate visual search [1]. The important characteristics of sSoTS that qualifies it as an appropriate tool is the incorporated top-down processes and the neuronal details of the system. We will present the outcomes of the first step of our study; using neurotransmitter changes to simulate ADHD behavioural results in a visual search experiment. Importantly the combination of simulated dopamine and norepinephrine function in the model allowed us to be able to stimulate the ADHD behavioural results. The next step in this work is to identify the mechanism(s) responsible for the deficit of attentional function in children with ADHD. REFERENCES [1] Mavritsaki, et al. (2011) Psychological Review, 118(1): p.3-41.

Acknowledgement: ELSS, Birmingham City University

Attention: Eye movements

Tuesday, May 19, 2:45 - 6:45 pm

Poster Session, Pavilion

56.4091 **The influence of attention on contrast perception, contrast discrimination, and saccadic reaction time.** Madhumitha Mahadevan[1] (MMahadevan@OPTOMETRY.UH.EDU), Harold Bedell[1], Scott Stevenson[1]; [1]College of Optometry,University of Houston

Visual spatial attention can increase contrast sensitivity and decrease manual or saccade reaction times (SRTs) in attended compared to unattended locations. Because stimulus contrast also influences SRTs, we asked whether an enhancement of suprathreshold contrast can account for the decrease in SRTs with valid cueing. This study used a dual task paradigm that assessed both perceived contrast and SRTs to targets with various physical contrasts. The subjects (N = 3) were presented with a central fixation target, which also carried an endogenous cue (an arrow) to an upcoming peripheral target's direction but not its eccentricity. The cue was 75% valid, 12.5% invalid and 12.5% neutral. A circular grating (angular size of 1 degree with 8 cpd) of a standard suprathreshold contrast was flashed at fixation, followed by a circular grating flashed peripherally at 1 of 13 suprathreshold contrasts for 8 ms (1 frame). Subjects were to saccade to the location where the peripheral target flashed and to respond if the target's contrast appeared to be higher or lower than the preceding central standard. The results exhibit a robust reduction of SRTs with valid cueing, but the peripheral contrast that the subjects judged equal to the central standard did not differ significantly across cueing conditions. The results are not consistent with an attention-induced contrast enhancement for targets of suprathreshold contrast. The cue-related reduction of SRTs to suprathreshold targets may reflect a direct influence of attention on motor programming.

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56.4092 **Feature-based attention modulates onset capture in a feed-forward manner.** Stefanie Becker[1] (s.becker@psy.uq.edu.au); [1]School of Psychology, The University of Queensland, Brisbane, Australia.

Suddenly appearing items (onsets) can attract attention and the gaze even when they are completely irrelevant to the task (onset capture). It has been proposed that onsets modulate affect attention at a very early stage of visual processing, when feature-based information is not (yet) available. Hence, feature-based attention can modulate onset capture only at a late stage of visual processing, via a feedback loop. The present study examined oculomotor capture by differently colored onsets, when the color of the onset either matched or mismatched the expected target color. In line with the view that feature-based attention cannot modulate onset capture, the first results showed high levels of oculomotor capture for a non-matching blue onset as well as a target-matching red onset. However, a control condition revealed that high levels of oculomotor capture by the non-matching blue onset were due to a color aftereffect: When the target changes color from red to grey, it initially appears in a vivid blue that slowly fades to grey. Once the color aftereffect is eliminated (by defining the target as a change from grey to red), the blue onset ceased to capture and only the target-matching red onset captured the gaze. A follow-up study showed that feature-based expectations also modulate onset capture on a trial-by-trial basis, when observers are informed of the target color on the next trial by a word-cue (red or green). Taken together, these results show that feature-based expectations modulate onset capture in a feed-forward manner. Target colors that appear only phenomenally and transiently (e.g., as a result of a color aftereffects), are moreover implemented into feature-based attentional control settings and increase capture for onsets that match the phenomenal target color.

Acknowledgement: Australian Research Council

56.4093 **Disconjugate eye movement responses to direction stimuli** Olivier Coubard[1] (olivier.coubard@cns-fed.com); [1]The Neuropsychological Laboratory, CNS-Fed, 14 rue du Regard, 75006 Paris, France

Attentional control, the ability to sustain information-processing activity over time in the face of distraction, can be assessed using eye movements in 3D space. When normal participants are asked not to move their eyes in response to stimuli appearing in direction or in depth, they nevertheless exhibit erratic movements towards the distracter (spontaneous prosaccades or provergences) or away from it (spontaneous antisaccades or antivergences), as well as microsaccade or microvergence activity. Here we examined whether healthy volunteers may exhibit disconjugate eye movements in response to direction stimuli or conjugate eye movements in response to distance stimuli (i.e., stimuli in depth). Data were extracted from a previous study in which only spontaneous eye movements to stimuli in the same plane (conjugate movements to direction stimuli and disconjugate movements to distance stimuli) were studied. Eight right-handed young adults were invited to suppress their eye movements in an inhibition task. The distracter could appear at 10° left or right at three distances (20-150 cm) calling for horizontal saccades, or 7.5° up or down at two distances (40-150 cm) calling for vertical saccades, or in a central position at close or at far calling respectively for convergence or divergence. Eye movements were recorded binocularly with an infrared light eye movement device. Results showed that (1) the participants produced eye movements in a different plane of space with respect to that of stimuli; (2) disconjugate eye movement responses were observed to direction stimuli, while conjugate eye movement responses could be observed to distance stimuli; (3) microvergence and microsaccadic activities were found in response to respectively direction and distance stimuli. I suggest that moving eyes in a different plane than that of stimuli may be a strategy to facilitate their avoidance. Additionally, anisotropies in direction and distance are useful indicators of visuo-attentional preferences.

56.4094 **Size of attentional suppressive surround** Sang-Ah Yoo[1, 4] (sangahy@yorku.ca), John Tsotsos[2, 4], Mazyar Fallah[3, 4, 5]; [1]Dept. of Psychology, York University, [2]Dept. of Electrical Engineering and Computer Science, York University, [3]School of Kinesiology and Health Science, York University, [4]Centre for Vision Research, York University, [5]Canadian Action and Perception Network, York University

The Selective Tuning (ST) model (Tsotsos, 1995) proposed that the visual focus of attention is accompanied by a suppressive surround in spatial and feature dimensions. Follow-up studies have provided behavioural and neurophysiological evidence for this proposal (Carrasco, 2011; Tsotsos, 2011). ST also predicts that the size of the suppressive surround is determined by the level of processing within the visual hierarchy. We, thus, hypothesized that the size of the suppressive surround corresponds to the receptive field size of a neuron that best represents the attended stimulus. We conducted a free-viewing visual search task to test this hypothesis and used two different types of features processed at different levels – (early ventral) orientation and (late ventral) Greebles (Gauthier & Tarr, 1997). The sizes of search displays and stimuli were scaled depending on the feature levels to match the receptive field size of targeted neurons (V2 and LO). We tracked participants' eye movements during free-viewing visual search to find rapid return saccades from a distractor to a target. During search, if attention falls on a distractor (D1) such that a target lies within its suppressive surround, that target is invisible until attention is released. An eye movement then reveals the target and triggers a return saccade (Sheinberg & Logothetis, 2001). In other words, shifting gaze from D1 to another distractor (D2) releases the target from the suppression and a short latency (return) saccade to target occurs. The distribution of distances between the target and D1 when return saccades occur provides a measure for the size of the suppressive surround. Searching for Greebles produced much larger suppressive surrounds than orientation. This indicates that the size of the suppressive surround reflects the processing level of the attended stimulus supporting ST's original prediction.

56.4095 **Object-based attention influences saccade latency** Gozde Senturk[1] (senturkgozde@hotmail.com), Adam Greenberg[2], Taosheng Liu[1]; [1]Department of Psychology, Michigan State University, [2]Department of Psychology, University of Wisconsin-Milwaukee

In the influential two-rectangle paradigm, attention is preferentially allocated to cued objects over noncued objects (Egly et al, 1994). Improved performance within the cued object manifests itself as a manual reaction time and accuracy advantage. However, no study to date has systematically investigated how saccadic reaction time is affected by object-based attention. Our goal is to determine whether saccade latencies are affected by space-based attention alone or whether object-based attention also plays a role. We employed a modified version of the classic two-rectangle paradigm coupled with a saccade reaction time task. Two horizontal or vertical rectangles (orientation blocked), were presented with an exogenous spatial cue flashed at one end of one rectangle. A target gray disk then appeared at one end of one object on 80% of trials (20% target absent). Of target present trials, 75% were valid trials in which the target appeared at the cued location, and on invalid trials (25%) the target appeared equally likely at the uncued end of the cued object (invalid-same object), or at an equidistant location on the uncued object (invalid-different object). Participants were instructed to make a single saccade to the target. Results showed that the saccadic latency was fastest on valid trials. Moreover, saccadic latency was significantly faster during invalid-same object trials versus invalid-different object trials. This effect was found for both the vertical and horizontal rectangle configurations. These results indicate that the oculomotor system is not only involved in location-based saccade preparation, but it is also guided by object-based attention. The eye-movement planning system may, therefore, be subject to the same boundary conditions that determine the representational basis of attentional selection in the visual scene.

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56.4096 **Attentional Switching in Bilingual and Monolingual Infants: An Eye Movement Study** Mahta Kakvan[1] (mkakvan@yorku.ca), Audrey Wong Kee You[1], Scott Adler[1]; [1]York University

The process of switching between two languages may equip bilinguals with enhanced cognitive control abilities. Research has suggested that executive function mechanisms in bilinguals are enhanced as a result of switching between two languages (Norman & Shallice, 1986; Miller & Cohen, 2001). Much research has revealed bilingual advantages in these cognitive control abilities, particularly the capacity to switch attention, during childhood and adulthood. In the current study, using a paradigm called Visual Expectation Cueing Paradigm (Adler et al., 2007), we examined infants' attentional switching capacities as function of their language environment in order to further understand the effect of exposure to bilingual environment on early visual cognition. Seven-month-old infants, raised in either a monolingual or bilingual environment, viewed stimulus cues presented randomly in a screen's center, each of which predicted a target appearing on either the left or right side of the screen during a pre-switch phase. During the post-switch phase, infants viewed the same cue and target stimuli but with a

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cue-target spatial predictability opposite to that experienced during the pre-switch phase. Infants' anticipatory eye movements were measured to see if infants could inhibit the cue-target spatial predictability learned during the pre-switch phase and switch attention and learn the new cue-target spatial predictability. Results indicated that both bilinguals and monolinguals exhibited equivalent levels of overall anticipatory eye movements. Bilingually-exposed infants' correct anticipations of the target were significantly higher than monolingually-exposed infants' during the last 50% of the post-switch phase. This finding suggests that infants exposed to a bilingual environment are better able to control and switch their attentional processing, thereby learning the new predictability pattern. Thus, the bilingual advantage previously exhibited in adults and children, is likely also present in infants who are simply exposed to a bilingual environment.

56.4097 **Ocular fixations are consistent with the endogenous selection of multiple discrete spatial foci of attention** Dhanraj Vishwanath[1] (dv10@st-andrews.ac.uk), Megan Fluharty[2], Ines Jentzsch[1], Manuel Spitschan[3]; [1]School of Psychology & Neuroscience, University of St. Andrews, [2]School of Experimental Psychology, University of Bristol, [3]Department of Psychology, University of Pennsylvania

Humans have the capacity to selectively attend to more than one item in the visual field. Whether this is accomplished by a single scalable attentional window, grouping targets into a virtual polygon, serial monitoring of targets, or divided multiple foci of attention has remained a controversy. Recent neurophysiological results have demonstrated divided focus of attention in humans and monkeys (Neibergall et al., 2011; Stoermer et al., 2013), but evidence for endogenously selected multi-focal attention that can differentiate between various mechanisms has been elusive. One strategy is to exploit the close linkage between ocular fixations and spatial selection (Goffart, Hafed & Krauzlis, 2012; Fehd & Seiffert, 2008). We used a novel attentional task paradigm where subjects selectively attended multiple static target locations while ignoring distractor locations within a geometric array. The arrays consisted of letters that rapidly changed identity at a rate of 5 or 10 Hertz. The subject's task was to detect the occurence of probe numeral that was briefly displayed (single frame) at one of the target locations. Importantly, in contrast to standard attentional tasks, subjects were free to select their own preferred fixation position. We found that the mean preferred fixation positions were close to the centroid defined over a group of discrete circular windows encompassing target locations only, consistent with divided multi-focal attention. Fixation positions were not consistent with selection based on a single attentional window or a virtual polygon defined by target locations. Moreover, analysis of differences in the detectability of probes in configurations with 3 or 5 target items were incompatible with serial covert monitoring of targets. Our results are consistent with the view that ocular fixation represents the equilibrium point of the spatial distribution of discrete multiple foci of attention and suggest a more nuanced definition of covert versus overt attention.

56.4098 **Context-sensitive adjustments of cognitive control: Further insights from eye movement behavior** Sebastian Pannasch[1] (sebastian.pannasch@tu-dresden.de), Caroline Gottschalk[1], Jens Helmert[1], Rico Fischer[1]; [1]Department of Psychology, Technische Universität Dresden, Germany

Recent research showed that cognitive control (i.e., the ability to respond to task-relevant while ignoring task-irrelevant features) can be recruited and regulated in a context-sensitive manner. Accordingly, a spatial location can serve as context cue if, for instance, trials with a high probability of response conflicts are presented. This would signal an increased demand of cognitive control engagement as compared to a spatial location with a low probability of response conflicts. As a consequence, interference effects are typically reduced in high conflict compared to low conflict contexts. In the present study we aimed at investigating the underlying cognitive mechanisms that enable such context-sensitive adjustments of cognitive control. We specifically measured eye movements to determine the allocation of attention to high versus low conflict contexts and to get insights into conflict resolution at the respective location. We used a Face-Stroop task, in which simultaneous displays of a face and a name were presented at predefined locations on the screen. The combinations could appear either to the left or right of central fixation. The factor conflict context was manipulated by the frequency of incongruent trials, with high conflict context induced by 80% incongruent trials and low conflict context by 20% incongruent trials. Participants indicated the gender of the names while ignoring the gender of the face. On the behavioral level, we found reduced Stroop effects for locations with a high conflict frequency compared to locations with a low conflict frequency, indicating that more cognitive control was invested. With regard to the eye movement behavior, we will present findings from saccade latency, saccadic landing position and pupil size.

56.4099 **Effects of social stimuli on covert attentional orienting and saccaddic eye-movements during visual search** Marcus Morrisey[1] (marcus.morrisey@gmail.com), M.D. Rutherford[1]; [1]Psychology, Neuroscience & Behaviour, McMaster University

Although visual attention and saccadic eye movements are tightly linked, our attention can move to objects in visual space without a saccade to the object, a phenomenon called covert attentional orienting. Socially significant targets like faces and human bodies attract attention. Using a visual search task we examined reaction to social targets by comparing the relationship between performance measures such as reaction time and error rate and saccadic eye movement measures. Participants briefly viewed a word representing 1 of 6 categories. One image from each category then appeared in a circular array on the screen. Participants identified the image in a target frame (the green frame) as either matching or not matching the presented word. On half of the trials, a distracter frame (the red frame) was also present. Consistent with previous results, participants responded faster when seeking a social target (face or body) compared to non-social targets and this effect was not diminished by inversion. They were slower and more error prone on trials containing a distracter frame. Participants saccadeed first and more often to social targets than to non-social targets but spent less time focused on social targets. When images were inverted, participants did not saccade more often to social stimuli than non-social distracters. Participants varied widely on the proportion of trials in which they saccaded to any object, between 2% and 97%,suggesting that some participants are capable of performing this task peripherally. Indeed, a lower proportion of trials with saccades to targets was associated with faster RT. The evidence supported an attentional effect of social stimuli that is independent of saccadic eye movement in addition to modulation of looking behavior.

Acknowledgement: NSERC

56.4100 **Visual distraction in a patient with abnormal occipital gyration – an eye-tracking study** Buse Urgen[1] (buseurgen@gmail.com), Pinar Demirayak[1], Fatma Ustun[1], Katja Doerschner[1,2,3]; [1]National Magnetic Resonance Research Center (UMRAM), Bilkent University, Ankara, Turkey, [2]Department of Psychology, Bilkent University, Ankara, Turkey, [3]Department of Psychology, Justus-Liebig-University Giessen, Germany

Maintaining focus and resisting distraction is critical for many visual tasks. We investigated these abilities in a patient with congenital abnormal bilateral occipital and parietal gyration, caused by a single gene (LAMC3) mutation. Because of the location and nature of these structural idiosyncrasies as well as compromised performance in several attention-related screening tasks we set out to measure the patient's visual attention in detail. Here, we assessed the patient's ability to maintain focus in the presence of several types of visual distractors. The patient's performance was compared to that of five sex- and education-matched healthy controls. Participants performed four eye-tracking conditions in randomized order in one experimental session: Fixation-only, Fixation with rapid sequential visual perception (RSVP), Fixation with relevant peripheral distractor (RPD), and Fixation with irrelevant peripheral distractors (IPD). Participants were required to fixate at the center and to respond when a target was detected (in RSVP, RPD, IPD). In the RPD condition relevant cues were presented for 100 ms at 8.71 degrees visual angle eccentricity in one of four possible directions, followed by a 200 ms target in the same location. In the IPD condition no cues preceded targets, everything else was as in the RPD condition. Experiments were done in MATLAB using Psychtoolbox and with an ASL Eye-Trac6 D6 Desk Mounted Optics. We measured percent correct in RSVP, RDP and IDP tasks and mean deviation from fixation in horizontal and vertical directions in all experimental conditions. Patient and control group performed comparably in behavioral tasks. Fixation results, however, indicated a decreased fixation quality of the patient in the presence of visual distractors, with deviations from fixation more than doubling (compared to controls) in RDP and IDP conditions. We discuss these results in light of the patient's structural connectivity and morphometry.

Acknowledgement: This work was funded by TUBA GEBIP Award and a grant of the Turkish National Scientific and Technological Council (TUBITAK 112K069) awarded to KD.

Tuesday PM

Eye Movements: Statistics

Tuesday, May 19, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4101 Human classifier: Can individuals deduce which task someone was performing based solely on their eye movements?

Michael Dodd[1] (mdodd2@unl.edu), Brett Bahle[1], Mark Mills[1], Monica Rosen[1], Gerald McDonnell[1], Joseph MacInnes[2]; [1]Department of Psychology, University of Nebraska - Lincoln, [2]Faculty of Psychology - Higher School of Economics, Moscow

Numerous investigations have revealed that eye movements and fixation locations differ as a function of how an individual is processing a scene (e.g., Castelhano et al., 2009; Dodd et al., 2009; Land & Hayhoe, 2001; Mills et al., 2011, Yarbus, 1967). As a consequence, a common question of interest is whether a participant's task can be predicted from their observed pattern of eye movements. To that end, a number of researchers have taken a cue from the machine learning literature and attempted to train a task set classifier with varying degrees of success (e.g., Borji & Itti, 2014; Greene et al., 2012; Henderson et al., 2013). In the present experiments, we examine whether human participants can effectively classify task set based on the eye movements of others and how their performance compares to that of a recent classifier (MacInnes et al., VSS, 2014). Participants view either a) the fixation locations and fixation durations of an individual scanning a scene (independent of scanpath), b) the scanpaths of an individual scanning a scene (independent of fixation durations), or c) video playback of eye movement locations (preserving scanpath and duration information), as they attempt to determine whether the original task was visual search, memorization, or pleasantness rating. Moreover, eye movement information is provided to participants under conditions in which the original scene is present, or with the original scene absent. Participants perform this task at above-chance levels though there is considerable variability in performance as a function of task type (e.g. better at identifying search), whether the scene is present or absent, and whether the original task was performed under blocked or mixed (task-switching) conditions. These results provide important insight into our understanding of scene perception and the manner in which individuals interpret the eye movements of others.

Acknowledgement: This research has been supported by the NIH grant R01EY022974

56.4102 Quantifying the variance in eye movements while watching intact versus scrambled movies.

Lucia Farisello[1] (lfarisello@hotmail.com), Karine Elalouf[1], Jacob Applebaum[1], Jim Pfaus[1], Aaron Johnson[1]; [1]Concordia University, Montreal, Quebec, Canada

Eye movement (EM) analyses for static images are well defined, but less so for dynamic stimuli. There are limits in applying static measures, such as fixation duration, to dynamic stimuli, that prevent the appropriate characterization of eye movements over space and time. Consequently, moving stimuli are often analyzed using 'swarm analysis' or dynamic heat maps to describe EM. Although these allow for qualitative representations of EM, it is difficult to quantify similarities between observers. Previous researchers have used the separate variance in X and Y gaze position to describe EM variability, however, in clinical research, two measures of EM stability combine X and Y gaze position: the bivariate contour ellipse area (BCEA), and the within-isoline area. The BCEA calculates the highest density of eye movements using a Gaussian ellipse that encompasses 68% of the fixation data, thus assuming normality in EM. The within-isoline area does not assume normality. It is based on the probability density estimate of EM, with a level of density chosen (e.g., 68%), so that 68% of the data points have a higher density estimate than this level. Here we apply these metrics to EM generated while watching either an intact version of an emotionally salient movie, or a version where the movie's scenes were scrambled in sequence. EM were recorded using a 60Hz binocular tracker (Mirametrix S2), with sample gaze positions analyzed in MATLAB using two algorithms. We found that both algorithms show EM are more variable during the scrambled movie in comparison to the intact movie. However, the BCEA shows greater variance in EM within and across both conditions in comparison to the within-isoline area. We attribute this difference due to the assumption of normality in the BCEA calculation, and recommend the within-isoline area when describing group variance of EM in dynamic stimuli.

Acknowledgement: NSERC Discovery grants to AJ and JP.

56.4103 Effect of Exogenous Factors on Eye Movement-Based User Identification

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Eye movements (EM) can be used to automatically differentiate between users (biometric). EM however are not only caused by user characteristics (endogenous) but also by stimulus properties (exogenous). Understanding the influences of exogenous factors allows for a better evaluation of EM-based identification systems (EMBIS) in order to improve their performance. We investigate how introduction of grouping in random Gabor field stimuli affects accuracy of EMBIS. Groups were introduced based on the principle of similarity by aligning the orientation (orientation-condition) or reducing the luminance (luminance-condition) of a random one-third of the Gabor elements. Three grouping levels were used: none, weak and strong. Luminance and orientation were matched such that group detection accuracy was 65% (weak) and 82% (strong). EM were recorded for eight participants, 120 trials each, during the initial 10s after stimulus onset. In order to ensure that the participants explored the stimulus, they were asked to make a key-press when a red marker appeared anywhere on the screen, randomly 10-13s after stimulus onset. A support vector machine (13 EM features) achieved an overall user identification accuracy of 78.23%. No grouping resulted in lowest accuracy (70.50%), weak grouping in highest (78.30%) and strong grouping achieved 72.88%. Notably, grouping by luminance lead to lower accuracy (74.63%) than by orientation (77.93%). In conclusion, some exogenous properties must be present to invoke user characteristic EM (reflected in higher accuracy for weak, but lower accuracy for no grouping). Although, above a threshold, exogenous properties become a detrimental factor on EM based user identification (lower accuracy for strong than for weak grouping). The differences in accuracy for different cues, e.g., luminance and orientation, can be used to modulate activity of automated EMBIS. We therefore recommend further systematic investigation of exogenous factors with respect to their influence on accuracy of EMBIS.

Acknowledgement: Marie Curie grant (CIG#293901) from the European Union awarded to Tandra Ghose

56.4104 Task Decoding using Recurrence Quantification Analysis of Eye Movements

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In recent years, there has been a surge of interest in the possibility of using machine-learning techniques to decode generating properties of eye-movement data (e.g., observer/stimulus-identity). Previous approaches have considered only aggregate or purely spatial measures of eye movements. Here we explore a relatively new approach to eye movement quantification, Recurrence Quantification Analysis (RQA)— which allows analysis of spatio-temporal fixation patterns —and assess its diagnostic power with respect to task decoding. Fifty participants completed both aesthetic-judgment and visual-search tasks over natural images of indoor scenes. Six different sets of features were extracted from the eye movement data: Aggregate (nFix, meanFixDur, meanSacAmp, area); fixMap (smoothed fixation map); RQA (recurrence, determinism, laminarity, center of recurrence mass); RQA2 (RQA features with the addition of size, regression, latency of recurrence mass); RQAprob (probabilistic version of RQA); RQAprob2 (probabilistic version of RQA2). These feature vectors were then used to train six separate support vector machines using an n-fold cross validation procedure in order to classify a scanpath as being generated under either an aesthetic-judgment or visual-search task. Analyses indicated that all classifiers decoded task significantly better than chance. Pairwise comparisons with Bonferonni-corrected alpha values revealed that all RQA feature sets afforded significantly greater decoding accuracy than the aggregate features. The superior performance of RQA features compared to the others may be that they are relatively invariant to changes in observer or stimulus; although RQA features significantly decoded observer- and stimulus-identity, analyses indicated that spatial distribution of fixations were most informative about stimulus-identity whereas aggregate measures were most informative about observer-identity. Therefore, changes in RQA values could be more confidently attributed to changes in task, rather than observer or stimulus, relative to the other feature sets. These findings have significant implications for the application of RQA in studying eye-movement dynamics in top-down attention.

56.4105 **Fixational eye movements improve visual performance at the sampling limit** Kavitha Ratnam[1,2] (kavitha@berkeley.edu), Wolf Harmening[3], Austin Roorda[2,1]; [1]Vision Science Graduate Group, University of California, Berkeley, [2]School of Optometry, University of California, Berkeley, [3]Department of Ophthalmology, University of Bonn

Purpose: We explored whether fixational movements of the eye in the human visual system might enhance visual acuity, by effectively scanning the retinal image with its sparse receptive fields, rather than taking a static snapshot of the retinal image with a fixed sampling array. Methods: We used an adaptive optics scanning laser ophthalmoscope to test orientation discrimination performance in three normal subjects while simultaneously imaging the underlying cone photoreceptor mosaic. Imaging and psychophysics were done with 840-nm light over a 1.2 deg field at about 1 degree from the foveal center. Stimuli were AO-corrected, negative-contrast tumbling-E optotypes presented randomly at one of four orientations. Stimulus size was held constant, with a gap opening that yielded ~40% correct discrimination performance determined in a preceding acuity experiment (0.57, 0.61, 0.74 arcmin of visual angle for the subjects). At that size and retinal eccentricity, the gap opening was below the retina's Nyquist sampling limit (0.94, 0.90, 0.85 arcmin). Stimulus presentation duration was 750 msec, trial progression was self-paced. Stimuli were presented either retinally stabilized by locking the stimulus to the underlying photoreceptor mosaic, or unstabilized, i.e. habitual retinal image motion was allowed to occur. Discrimination performance is reported based on 500 trials for each viewing condition, all pseudorandomly interleaved. Results: For all subjects, discrimination performance was significantly worse under stabilized than unstabilized conditions. Performance reductions were 33.6, 13.4, and 21.1% (p = 0.015, 0.046, 0.017, binomial z-test) for each subject. Conclusions: Performance in the finest visual acuity tasks for retinal images that are at or below the Nyquist sampling limit seem to be enhanced by the retinal image motion caused by natural fixational eye movements. These findings suggest that fixational eye movements are used to facilitate a form of 'super-resolution' that surpasses the photoreceptor sampling resolution.

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56.4106 **Quiet eyes: Stress, worry, and anxiety fail to influence fixational stability, accuracy, or movement frequency** Arryn Robbins[1] (arobbins@nmsu.edu), Michael Hout[1], Hayward Godwin[2], Gemma Fitzsimmons[2]; [1]New Mexico State University, [2]University of Southampton

Stress, worry and anxiety have long been known to influence a broad array of behavioral functions. Here, we examined how stress influences fixational stability. Fixational stability is known to be heightened in experts (e.g., snipers; Di Russo et al., 2003), but impoverished both in individuals with pathological attention deficits (e.g., ADHD; Munoz et al., 2003) and in participants who are anxious or placed under threat of mild electric shock (Laretzaki et al., 2011). We therefore predicted that anticipatory stress would destabilize eye-movements. Participants fixated a cross that was presented in one of nine possible locations while their eye-movement behavior was recorded. The cross appeared for one second: on 'volitional' trials, the cross then disappeared and participants were instructed to keep their eyes fixed at that location for 15 seconds. On 'stimulus-driven' trials, the cross remained visible for the 15 second period. Between blocks, half of our participants were informed that they would later have to deliver a speech, which they had little time to prepare. This greatly increased their blood pressure and pulse rate. A control group read essays during this period. Fixational stability (measured using the bivariate ellipse contour area) was lower in volitional trials than stimulus-driven trials, replicating previous research. However, despite a large sample (N=44), we found no effect of stress on fixational stability. We further examined individual differences variables, such as rate of worrying, systolic reactivity, and both state and trait anxiety levels, and found that none of these variables modulated fixational stability. Moreover, stress had no effect on fixation accuracy (measured via distance from the target location) or the number of fixations. These data represent a failure to replicate previous work along these lines, and suggest that fixational stability may not, in fact, be influenced by stress or individual differences in stress-related variables.

56.4107 **Microsaccade rate is not suppressed in adults with amblyopia.** Bonnie Lawrence[1] (bml5@nyu.edu), Marisa Carrasco[1]; [1]Department of Psychology and Center for Neural Science

Goal. Amblyopia is a neural developmental disorder characterized by a decrease in visual acuity and contrast sensitivity. Microsaccades are thought to play an important role in visual perception (e.g., enhancing visual acuity). Only one quantitative study (Shi et al., 2012), and one qualitative study (Ciuffreda et al., 1979) have examined microsaccades in amblyopia. Both reported that, under conditions of passive visual fixation –i.e., no visual stimulation other than fixation and no perceptual discrimination– microsaccade rate is suppressed. Purpose. To examine whether, under conditions of active visual fixation –i.e., visual stimulation and perceptual discrimination– the rate of microsaccades is suppressed in amblyopia. Methods. Thirteen amblyopic observers (8-strabismic, 5-anisometropic) and 13 age-matched controls were tested monocularly (amblyopic or fellow eye, left or right eye, respectively). Four Gabor patches appeared along the vertical and horizontal meridians and observers discriminated the orientation of a post-cued Gabor. Task difficulty was equated between eyes and across observers by adjusting stimulus contrast. Eye position was monitored at 1000 Hz. A standard velocity-based detection algorithm was used to detect microsaccades. Results. The peak velocity and amplitude of microsaccades in the amblyopic eye were significantly greater than those of fellow and control eyes, consistent with previous research (Shi et al., 2012). Both groups demonstrated the hallmark biphasic response (i.e, suppression followed by enhancement of microsaccade rate) following visual stimulation. In contrast to previous research (Shi et al. 2012; Ciuffreda et al., 1979), the microsaccade rate of observers with amblyopia was, overall, greater than that of control observers. Conclusion. The present results indicate that the microsaccade rate in amblyopia is not suppressed overall, but rather is enhanced relative to the control eyes. We are currently evaluating whether the increased rate of microsaccades is a compensatory mechanism of visual perception.

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56.4108 **A Bayesian model for microsaccade detection** Andra Mihali[1] (alm652@nyu.edu), Bas van Opheusden[1], Wei Ji Ma[1]; [1]Center for Neural Science and Department of Psychology, New York University, New York, New York 10003

Microsaccades (or small saccades) are fixational eye movements with high velocity. They have been proposed as an index for covert spatial attention, but this proposal has been contested. One reason why it has been difficult to reach consensus is that different studies use different, arbitrary detection criteria such as velocity thresholds. Here, we developed a principled method for identifying microsaccades, based on Bayesian changepoint detection. Our generative model contains a latent state variable that changes between "drift/tremor" and "microsaccade" states at random times. We model the eye position as a biased random walk with a different velocity distribution for each state; on average, microsaccades have higher speed. Using this generative model, we computed the posterior probability over the time series of the state variable given the entire eye position time series. To sample from this high-dimensional posterior while avoiding local maxima, we used parallel-tempered MCMC. To test the validity of our algorithm, we applied it to simulated eye position data from the generative model. At low noise levels, we recovered the true microsaccades near perfectly, while at higher noise levels, we found state vectors with higher posterior probabilities than the true time series. When we apply the algorithm to real data, the inferred microsaccades are comparable with those found by previous methods. Our approach has advantages over previous methods: (1) the detection criterion is derived, not assumed, (2) we obtain a probabilistic judgment (i.e. a confidence rating), instead of a binary one, (3) the method can be straightforwardly adapted as the generative model is refined.

56.4109 **Inter-dependency of microsaccades and its modulation by visual context** Roy Amit[1,2] (roy.amit@mail.huji.ac.il), Shlomit Greenberg[1,2]; [1]Sagol School of neuroscience, Tel Aviv University, [2]School, of Psychological sciences,Tel Aviv University

Purpose: Our eyes are in constant motion. Even when fixating, our eyes produce small saccades called microsaccades. Following a visual stimulus onset, microsaccade rate follows a consistent modulation of a decrease and then increase. However, much less is known on the effect of ocular events on the occurrence of consecutive microsaccades. It was previously suggested that the process triggering microsaccades is a Poisson process, and therefore the inter-microsaccade intervals (IMSIs) follow an exponential distribution. The purpose of the current research was to test this hypothesis in different visual contexts and to compare the effects of visual and ocular events on microsaccade occurrences. Methods: In two experiments we recorded the gaze position of subjects while they were either maintaining fixation or free-viewing a scene. We manipulated the visual scene to be: A) Complete darkness, gray screen or natural scene (experiment 1); B) Checkerboard with low or high spatial frequency (experiment 2). In addition we tested microsaccade rate relative to the abrupt appearance of a visual stimulus. Results: In both experiments microsaccade occurrences were inter-dependent. The distribution of IMSIs demonstrated a good fit to an Ex-Gaussian rather than exponential distribution. Furthermore, with increasing

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complexity of stimulation (natural scene vs. gray screen vs. darkness and also with high vs. low spatial frequency) the rise of the Ex-Gaussian was later, i.e. there was a larger "refractory period" between microsaccades. Moreover, the distribution of the IMSIs was similar to the distribution of the intervals between stimulus onsets and microsaccades. Conclusion: Microsaccades are interdependent and are not driven by a Poisson process as previously thought. The IMSIs distribution is modulated by the amount of retinal image displacement caused by each microsaccade. Our findings suggest that the same process can explain both the modulation of microsaccade-rate by visual events and its modulation by precedent microsaccades.

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Eye Movements: Learning and adaptation

Tuesday, May 19, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4110 Complex changes in eye head coordination in progressive lens wearers during driving

Katharina Rifai[1] (katharina.rifai@medizin.uni-tuebingen.de), Siegfried Wahl[1]; [1]Institute for Ophthalmic Research, University of Tuebingen

In natural uncorrected vision in young observers, a given eccentric fixation target at any distance can be fixated by various combinations of eye and head position with an identical resulting visual input. The properties of the visual input do not depend on the rotational status of the eye. In contrast, the quality of visual input strongly depends on eye position in progressive lens wearers. A specific eye position provides clear, focused vision at a specific distance only. Thus for fixating a target with clear vision, one specific optimal combination of eye and head position exists in a progressive lens wearer. Especially in challenging visual situations a change in eye head coordination is therefore a prerequisite for successful task performance. In modern everyday life, car driving is one of the strongest visual challenges, where a large field of view is scanned permanently with coordinated eye-head-movements. Although free to move their gaze and head, car driver's fixational behavior is constantly determined by the tasks requirements. In progressive lens wearers, specific head movements might therefore be enforced during driving. In the present study, changes in head-movement behavior are shown in progressive lens wearers during driving compared to controls. Progressive lens wearers and controls performed a real-world driving task, each of them driving along the same predefined urban round course track in Stuttgart downtown. Eye head coordination of progressive lens wearers was analyzed with respect to three main parameters: head gain, temporal properties in head movements and variance in head movements. Changes in head movement behavior, specific to progressive lens wearers, were determined in all three parameters, pointing towards complex changes in eye-head-coordination induced by the modification of optical properties in a progressive lens. Therefore, the varying optical properties of a progressive lens can be interpreted as visual learning signal for eye-head-coordinated movements.

56.4111 Peripheral Oculomotor Control Training in Healthy Individuals: Effects of Training and Training Transfer

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Individuals with healthy vision can spontaneously form a stable preferred retinal locus (PRL) over a period of several hours during eccentric viewing tasks. This process is poorly understood and does not appear to be driven by selection of retinal regions that optimize performance. It is also unknown whether PRL formation can be guided by training or attention, or whether the initial process of PRL formation speeds or retards subsequent PRL reformation. Addressing these questions may help individuals with central visual field loss by informing a training program that promotes PRL development in high utility regions and supports PRL retraining in response to disease progression or remediation. In this experiment, four individuals with normal or corrected-to-normal vision were given two, one-hour blocks of eccentric viewing training separated by a week. Their task was to guide a gaze contingent ring over a stable fixation target. The ring's position was oriented 4 degrees either to the right or below their foveal point of regard (POR). Between blocks, the ring's orientation was switched. To prevent foveation, the target was removed if it fell within 2.5 degrees of the fovea. The ring contracted as the subject maintained the ring on-target and expanded as it fell off-target; their task was to "make the ring as small as possible." Task performance was measured in degrees of error between the ring's center and the target's center. All subjects' performance curves fit roughly exponential decay functions between both trials and blocks. Training in the first block also significantly enhanced performance in the second. Finally, significant idiosyncratic effects of orientation on performance were observed. These results suggest that PRL training may be possible (at least among individuals with healthy vision) and that training effects transfer to new PRLs and enhance performance on this task even after significant PRL orientation shifts.

56.4112 Spatially Specific Dependence of Saccade Inhibition on Distractor Repetition

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The sudden appearance of a visual distractor can briefly, but powerfully, inhibits saccades (Reingold and Stampe, 2002). However, this inhibitory influence of distractors may by habituation with repeated distractor presentation at a single retinotopic location, or by a more spatially general dampening of inhibition, occurring when distractors appear at a high frequency at any location in the visual field. Indeed, such a spatially generalized mechanism could be useful during behavior in highly dynamic visual environments. We examined these possibilities by recording the eye movements of 2 subjects in tasks that required the execution of saccades in the face of visual distractors. Eye movements were recorded at 500 Hz (Eyelink II, SR Research). Trials began with central fixation. A 1° square was flashed (250 ms) 10° to the left or right. 700-1000 ms later, fixation point disappearance ("go" signal) cued saccade initiation. Subjects were instructed to make a saccade to the target's remembered location. There were 4 experimental tasks: 1) no distractor; 2) single distractor appearing soon after go signal, opposite the remembered target; 3) 3 distractors at 200 ms intervals at a single location opposite the remembered target; 4) three distractors at 200 ms intervals at three separate locations distant from the remembered target, with the final distractor appearing opposite the remembered target. As in previous experiments (Edelman and Xu, 2009) we found strong inhibition in Task 2. Saccade inhibition was virtually eliminated in Task 3. In Task 4, saccade inhibition was intermediate to that of Tasks 2 and 3. These results suggest that stimulus repetition at a single location strongly ameliorates saccade inhibition, but that a more spatially generalized amelioration mechanism for repeated distractor presentation also exists. Supported by NCRR 2G12RR03060-26A1, NIMHHD 8G12MD007603-27

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56.4113 Differential saccadic adaptation controlled by the target color

Laurent Madelain[1,2] (laurent.madelain@univ-lille3.fr), Jeremie Jozefowiez[1], Sohir Rahmouni[1]; [1]Psychology department, Université de Lille - 3, [2]Institut de Neurosciences de la Timone, CNRS-AMU

Saccade adaptation is a form of motor learning that maintains saccade accuracy in response to new sensorimotor contingencies. Several studies have shown that saccade gain can be adapted separately in double-step paradigms depending on cues affecting the motor command (velocity or direction of target motion, orbital eccentricity, or vergence). However, purely visual cues such as target color and shape consistently failed to drive different gain states during saccadic adaptation. These results are consistent with the dominant view that saccade adaptation is a simple motor recalibration process. Differential adaptation controlled by purely visual properties might imply that saccade adaptation relies on general learning mechanisms in which any informative cue could be used. Here we ask whether this absence of contextual control by color may be due to the irrelevance of target color for the saccadic system. We had 12 subjects making 500 saccades in a double-step paradigm to a red or a green disc target (50% of trials) stepping away from a fixation position (45 deg wrt the horizontal). During the saccade the target was displaced orthogonally to its primary step, upward and backward for the red target and downward and forward for the green target (6 subjects). Target colors were reversed in the other 6 subjects. A distractor appeared simultaneously at the mirror position wrt the original step. The distractor was red when the target was green and green otherwise. We observed a systematic control on saccade angle by target color (average saccade angle difference for the two target colors 6.7 deg, $p < 0.01$). No effect was found in 6 control participants in a similar paradigm but without a distractor (saccade angle difference 0.78 deg, NS). We conclude that target color can control saccade adaptation provided that color is made relevant for the saccadic system by adding a color-defined distractor.

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56.4114 Inter-individual variability in saccadic adaptation

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Saccadic adaptation reflects the oculomotor system ability to adapt in response to changes in sensorimotor contingencies. This may be observed in the laboratory using a double step paradigm (McLaughlin, 1967). Adaptation of saccadic amplitude or direction is triggered by the intra-saccadic target displacement that introduces a postsaccadic position error. Numerous studies explored this form of oculomotor learning revealing the reproductibility of this phenomenon. However, large interindividual variability in the amount of saccade gain change is often observed to the extent that a fraction of subjects do not adapt at all. Previous studies did not systematically describe saccade adaptation variability. Moreover, current theories of motor adaptation do not account for these idiosyncratic effects. To provide a detailed description of variations in adaptation, we conducted experiments in a large number (currently 42) of naïve participants. We used a double step paradigm in which a small disc target jumped away from fixation position (amplitude ranging from 7.5 to 14 deg) with a 45 deg angle with respect to the horizontal. The target was displaced during the saccade, and this second step was either purely horizontal (Backward or Forward) or vertical (Upward or Downward) in four different experiments such that only the horizontal or vertical saccade component would adapt. We found a large dispersion in percent gain changes (ratio of change in gain during adaptation by baseline gain - in the horizontal or vertical component depending on the intrasaccadic step) : Backward adaptation [-21%; -4%], $p< 0.01$ in 9/10 subjects; Forward [+11%; +26%], 13/13 subjects; Upward [-3%; +18%], 4/9 subjects; Downward [-33%; -11%], 10/10. To evaluate the effects of individual oculomotor control on saccade adaptation we also ask, for each subject, whether the amount of adaptation correlates with various saccade parameters such as amplitude in baseline trials, saccade latency or saccade peak velocity.

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56.4115 Meaningful images produce stronger saccadic adaptation

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Saccades are made to scan interesting objects in the environment with foveal vision. In the lab, however, they are usually studied with meaningless point targets. Recent experiments showed that vision of a meaningful target affects saccade kinematics, accuracy, and latency. We investigated whether saccadic adaptation, a gradual change of amplitude when the target is shifted during the saccade, is affected by the content of the target. We expected that the motivation to land accurately on a target may be stronger if the target was not a point but a meaningful picture. Thirty-four subjects (27 female) participated in a scanning outward adaptation experiment in which 4 targets (1.8°x2.8°) in rectangular arrangement had to be viewed successively. One of the targets was a small image of a human figure. A control target contained random noise matched for luminance and spatial frequency. The stimulus set shifted in saccade direction during each horizontal saccade by 33% of the initial target distance (12°). In different conditions, stimuli either remained visible throughout the experiment, or were masked after saccade onset, or 200 ms later. Adaptation was quantified by computing the Gain Change (GC) (($amplitude_{late}$-$amplitude_{pre}$)/initial target distance) for each subject, which was then averaged according to experimental condition. The results showed that saccadic adaptation was greater for saccades directed towards meaningful pictures than towards noise (GC_{human} 14.14 %, GC_{noise} 10.83 %). This was also true when the images were masked 200ms after saccade onset such that only a brief glimpse could be obtained (GC_{human} 13.13%, GC_{noise} 09.68 %). When images were masked at saccade onset, no significant difference in adaptation was observed (GC_{human} 10.48%, GC_{noise} 10.76 %). We conclude that the post-saccadic view of a meaningful image at the saccade landing position facilitates saccadic adaptation.

Wednesday Morning Talks

Spatial Vision: Neural mechanisms

Wednesday, May 20, 8:15 - 10:00 am
Talk Session, Talk Room 1
Moderator: Emily Cooper

61.11, *8:15 am* Overlapping topographic representations of numerosity and object size in human parietal cortex

Ben Harvey[1] (b.m.harvey@uu.nl), Alessio Fracasso[1], Natalia Petridou[2], Serge Dumoulin[1]; [1]Experimental Psychology, Helmholtz Institute, Utrecht University, [2]Radiology, Rudolf Magnus Institute of Neuroscience, University Medical Center Utrecht

Sensory cortical areas contain topographic maps reflecting the structure of sensory organs such as the retina, cochlea or skin. We recently demonstrated tuning for numerosity (the set size of visually-presented objects) in a human parietal topographic map, where numerosity preferences change gradually across the cortical surface (Harvey et al, Science 2013). This demonstrated that topographic maps can emerge within the brain to optimize processing of quantities. This map has organizational properties common across sensory cortices: more of the cortex processes small numerosities than larger numerosities, and does so with finer tuning widths. We make decisions based on numerosity, but other quantities such as object size may affect these decisions. The size of the presented objects can also affect numerosity perception. Here we measure object size-selective responses using 7T fMRI and population receptive field (pRF) modeling (Dumoulin & Wandell, Neuroimage 2008). We use stimuli that minimize correlations between object size and visual field position. We report object size preferences that are also organized as topographic maps. However, small sizes are not over-represented like small numerosities: the representation of small and large sizes covers similar amounts of cortex, and with similar tuning widths. Furthermore, non-preferred sizes produce surround inhibition. This object size map largely overlaps with the numerosity map. Size preferences and numerosity preferences are well correlated. Although both numerosity and size maps partially overlap with the IPS visual field maps, neither numerosity nor size preferences are correlated with visual field position preferences (specifically pRF eccentricity). As such, size tuning here is separated from the position preferences seen in visuo-spatial receptive fields. Instead, this size tuning is linked to preferences for other quantities. Overlapping representations of object size and numerosity may explain why their perceptions interact. These overlapping maps suggest a cognitive representation of quantity that generalizes between numerosity and size.

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61.12, *8:30 am* Feedback Signal Contributes to The Flash Grab Effect: Evidence from fMRI and ERP Study

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When a line is flashed on a patterned disk rotating back and forth at its turnaround point, the perceived location of the line is often dramatically displaced, known as the flash grab effect (Cavanagh & Anstis, 2013). Like other illusions in the motion induced position shift family, the neural mechanism of the flash grab effect remains unclear. We conducted a combined fMRI and ERP study to investigate the spatial and temporal neural correlates of this perceptual effect. In different sessions, participants viewed the visual display showing the flash grab illusion repeatedly in the fMRI scanner and with ERP recording sessions. The physical flashes were presented at the vertical meridian, while the perceived locations of the flashes were either to the left or the right of the vertical meridian. Following the localization of the retinotopic visual areas in each participant, results clearly show that the distribution of fMRI BOLD signals in V1, V2, and V3 could be well predicted by the perceived, but not the physical, positions of the flashes. In the ERP signals, while a robust and clearly lateralized C1 was seen from physically displaced flashed lines, no such lateralized signal was observed in the typical time window of C1 from the perceptually displaced flashes, suggesting that the perceptual illusion was unlikely a result of feedforward processing. For the perceptually displaced flashes, there was a hint of a lateralized signal in the occipital area about 20ms later than C1, and significantly lateralized ERP signals emerge only at the later N1 component. Taken together, the combined spatio-temporal imaging results suggest that the perceived displacement of the flashed target in the flash grab effect is instigated by feedback signals from high-level areas to early retinotopic visual cortex.

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61.13, *8:45 am* Broadband spectral responses in visual cortex revealed by a new MEG denoising algorithm

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Introduction. Recently, intracranial EEG recordings in human and microelectrode recordings from animals have shown that sensory stimuli evoke a broadband elevation in the spectral power of field potentials. This broadband signal is of interest as it correlates with multiunit activity and the fMRI signal. Here we asked whether stimulus-related broadband responses can be reliably measured using MEG. Because extracranial measurements like MEG have multiple global noise sources and relatively low signal-to-noise ratio, we developed a denoising technique that helps reveal the broadband signal of interest. Methods. Subjects viewed 12-Hz contrast-reversing patterns presented either in the left, right, or full visual field, up to 11° eccentricity. Responses in MEG sensors were summarized as an evoked response (12-Hz amplitude) and broadband responses (mean of the log power between 60–150 Hz, excluding stimulus harmonics). A denoising algorithm developed for fMRI ('GLMdenoise'; Kay et al. 2013) was adapted for MEG. The algorithm separated MEG sensors into those that were visually responsive and those were not (the 'noise pool') based on the evoked responses. Using PCA, the noise pool time-series were then summarized as several global noise regressors, which were projected out from the time series of all sensors. Finally, the broadband responses were re-computed from the denoised data. Results. In all subjects, broadband responses were reliably measured in sensors over occipital cortex. The spatial pattern of activation depended on the stimulus, with lateralized stimuli producing bigger responses in contralateral sensors. The signal-to-noise of the broadband responses in visual channels more than doubled as a result of denoising. Conclusions. Spatially localized broadband responses can be measured with MEG from human visual cortex. A new algorithm for denoising MEG data facilitates detection of this signal. Future applications of the denoising algorithm include other measures such as narrow-band oscillations and extension to EEG.

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61.14, *9:00 am* Broadband field potentials, but not gamma oscillations, correlate with BOLD fMRI in human visual cortex

Mai Nguyen[1] (mlnguyen@princeton.edu), Dora Hermes[2], Jonathan Winawer[3]; [1]Department of Psychology, Princeton University, [2]Department of Psychology, Stanford University, [3]Department of Psychology and Center for Neuroscience, New York University

Background: Elucidating the neural circuits underlying the BOLD signal measured with fMRI is an important goal in human neuroscience. One approach is to correlate the amplitude of the BOLD signal with the field potential power in different temporal frequency bands. However, distinct frequency bands do not always correspond to different neural circuits. In visual cortex, field potential power in the gamma band consists of at least two large, distinct signals arising from distinct neural circuits: an oscillatory (narrowband) component and an asynchronous (broadband) component. We propose that the oscillatory component measures neural synchrony, which is unrelated to BOLD amplitude, whereas the broadband component more closely measures the level of neural activity, which influences BOLD. Methods: Electrocorticography (ECoG) responses to gratings and noise patterns were previously measured in two human subjects in V1-V3. Here we measured fMRI responses to the same stimuli. ECoG responses were separated into broadband and narrowband components; the two components were separately correlated with the fMRI response in corresponding cortical regions. Results: In V1,

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the ECoG broadband amplitude was positively and strongly correlated with BOLD across stimuli. In contrast, narrowband gamma amplitude was unrelated to BOLD. In V2/V3, BOLD was again positively correlated with broadband ECoG and unrelated to narrowband gamma; in V2/V3, the degree of alpha band suppression was also predictive of BOLD. Conclusion: In visual cortex, the asynchronous broadband component of the field potential is most predictive of the BOLD signal. Narrowband gamma oscillations appear as large signals in the voltage measurement but are uncorrelated with fMRI. The BOLD signal is not caused by, and does not correlate with, a particular frequency band in the LFP. Rather, it is a function of the level of neural activity, which influences the LFP power in many frequency bands, and is best indexed by broadband field potentials.

61.15, *9:15 am* **What are the natural scene statistics of cortical input?** Emily Cooper[1] (emilyacooper@gmail.com), Anthony Norcia[1]; [1]Department of Psychology, Stanford University, USA

Capitalizing on predictability in the environment is a fundamental principle of biological sensory systems. To understand sensory encoding, it is therefore essential to have a comprehensive description of the regularities in one's experience of the natural world. Statistical descriptions of natural images have delineated key non-uniformities in the relative probabilities of basic visual features, such as contrast, spatial scale, contour orientation, and depth. The information encoded in visual cortex, however, is not a direct copy of the light falling on photoreceptors. We wanted to determine how these well-known regularities in natural images are altered by the processing of early visual pathways. Using a large image dataset, we simulated the transformations these pathways impose on the input to cortex. The simulations included the receptive fields and non-linear response properties of magnocellular (M) and parvocellular (P) pathways, as well as ON and OFF pathway divisions. Statistical patterns of natural images were thus transformed into statistical patterns of afferent neural signals. This analysis indicates that there are regularities in these signals beyond those that have previously been appreciated from the direct analysis of natural images. Not surprisingly, activity patterns diverged with regards to spatial scale between the M and P pathways. However, within the M and P pathways, the ON and OFF divisions also differed substantially in the amount of activity devoted to different levels of contrast and to different spatial scales. We propose that these asymmetries between ON and OFF signals reflect an additional layer of predictability in the visual input that has been exploited when encoding basic visual features in cortex. These ON/OFF pathway differences also suggest that some previously measured response asymmetries to bright and dark stimuli in cortex may have a pre-cortical origin.

Acknowledgement: R01-EY018875

61.16, *9:30 am* **Temporal differentiation by photoreceptors reduces spatiotemporal correlation of natural visual input on the retina** Dawei Dong[1] (ddong@mail.med.upenn.edu), Sergei Nikonov[2]; [1]Department of Animal Biology, School of Veterinary Medicine, University of Pennsylvania, [2]Department of Neuroscience, School of Medicine, University of Pennsylvania

On the retina, the illuminating intensities of natural visual input at different times and spatial positions are highly correlated. Such spatiotemporal correlation is utilized by photoreceptors to reduce noise through temporal integration and spatial coupling. However, the correlation on a longer temporal and spatial scale is a source of inefficiency for visual representation. To understand how photoreceptors deal with such inefficiency, we investigated the shape of the photocurrent impulse response functions and found that they were biphasic during natural stimulation and capable to reduce the spatiotemporal correlation of natural stimuli. This is in sharp contrast to the monophasic impulse response to short light flashes. In particular, we measured the membrane current of the outer segment of rods in retinal slices stimulated with light stimuli derived from awake cats watching natural movies with eye movements. We found that beyond the classic integration time window the photocurrent responded to the temporal difference of the illumination. Due to the fact that the natural time-varying images are dominated by optical flow, the temporal differentiation not only greatly reduced the temporal correlation beyond the integration time window, but also eliminated the spatial correlation beyond a certain scale. We conclude that the photocurrent of photoreceptors efficiently represent the natural visual input.

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61.17, *9:45 am* **Human visual cortex gradually transitions from 2D to 3D spatial representations** Nonie Finlayson[1,2] (nonie.j@gmail.com), Julie Golomb[1,2]; [1]Department of Psychology, The Ohio State University, [2]Center for Cognitive and Brain Sciences, The Ohio State University

We live in a 3D world, and yet the majority of vision research is restricted to 2D phenomena. Previous research has shown that neural representations of 2D visual space are present throughout visual cortex. Many of these visual areas are also known to be sensitive to depth information (including V3, V3A, V3B/KO, V7, LO, and MT) – how does this depth information interact with 2D spatial information? Using fMRI and multi-voxel pattern analysis, we investigated the relationship between horizontal (x), vertical (y), and depth (z) representations in the brain. Participants viewed random dot stereograms with red/green anaglyph glasses. Eight different locations were stimulated in a blocked design: each location was defined by x, y, and z location (left or right, above or below, and in front or behind the fixation cross). The patterns of activation for each of the x, y, and z location conditions were compared across the brain with a searchlight analysis and within functionally localized ROIs. As expected, both x and y location information was present all along the visual pathways, with x information outperforming y information in higher visual areas. Importantly, while only 2D location information could be decoded in early visual cortex, all three types of location information could be decoded in several higher visual cortex regions. Moreover, this pattern seemed to emerge gradually: we found opposite trends for y and z location information, with y information decreasing and z information increasing along the visual hierarchy (both dorsal and ventral streams). In addition, we found that representations of depth are dependent on x location, but tolerant of changes in y location. We conclude that what begins as purely 2D spatial information in early visual areas gradually transitions to 3D spatial representations higher along the visual hierarchy.

Visual Memory: Capacity and models

Wednesday, May 20, 8:15 - 10:00 am
Talk Session, Talk Room 2
Moderator: Melchi Michel

61.21, *8:15 am* **Using a betting game to directly reveal the rich nature of visual working memories** Daryl Fougnie[1] (darylfougnie@gmail.com), Anish Kanabar[2], Timothy Brady[2], George Alvarez[2]; [1]NYU Abu Dhabi, Division of Psychology, [2]Harvard University, Department of Psychology

When asked to remember the features of an object, do we retain single point-estimates in memory, or do we retain richer representations, such as probability distributions over feature space? Continuous color report tasks, which require participants to report the exact color of a remembered object, yield a wide distribution of errors. However, it is unclear whether this distribution of errors reflects random errors in point estimates (which would form a distribution when aggregated across trials), or if it reflects the fact that individual memories are probabilistic in nature. To distinguish between these possibilities, we developed a novel paradigm: Participants were shown a set of colorful circles and, after a brief memory delay, asked about the color of a randomly tested item. Rather than reporting a single color, participants placed 10 bets in the color space (each bet comprised 1/18 of the space). Bets could be stacked or moved to a new portion of color space. Points were awarded equal to the number of bets containing the correct color. We discouraged stacking bets by diminishing the value of higher stack levels. We found that participants have considerably richer representations than simple point estimates. The dispersion of bets was correlated with first response accuracy (the less accurate their first response, the more widely they distributed their bets), indicating that participants' internal confidence was guiding bet placement. Furthermore the distribution of bets on a trial was similar in shape to the probability distributions observed across trials, suggesting that an uncertainty distribution may be coded within individual memory representations. Finally, we found that memory performance improved, relative to the first response, when averaging across multiple bets. This performance benefit increased monotonically with each additional bet. Overall, the betting task revealed that memories are more than noisy point estimates, but are surprisingly rich and probabilistic.

61.22, *8:30 am* **Memory routines for the transformation of visuospatial representations** Benjamin Bernstein[1] (benjaminbernstein2015@u.northwestern.edu), Brandon Liverence[1], Steven Franconeri[1]; [1]Northwestern University

Tasks like map-reading, perspective-taking, and mental simulation all involve transforming (e.g., rotating or reflecting) internal visuospatial representations to match current/imagined viewpoints. Here, we explored the memory routines that implement such transformations, by quantifying their associated mental costs. Participants searched for targets within a 4x4 configuration of real-world objects (viewed one-at-a-time through a central window), using keypresses to move between positions (thereby changing which object was visible inside the window). The configuration remained stable for 30 trials (enabling participants to acquire a robust memory representation) but then changed; participants then completed 10 additional trials. In E1, we contrasted the costs of transforming intrinsic (object-centered) versus global (world-centered) reference frames of visuospatial representations. There were 3 transformation types: 1) Intrinsic: objects' orientations rotated 180° but positions remained unchanged; 2) Global: positions and orientations rotated 180° in sync; and 3) Both: locations rotated 180° but orientations stayed upright. We observed slower RTs after transformation versus before for Global (2.06sec/trial) and Intrinsic (0.63sec/trial), which differed significantly. Notably, though Global (where objects' positions changed and orientations were "upside-down") was more visually distinct from the initial configuration than Both, Global was significantly less costly than Both (2.85sec/trial), underscoring the contribution of intrinsic reference. These results suggest that visual scenes are redundantly encoded in terms of multiple spatial reference frames, and each must be transformed independently. E2 compared 90° and 180° rotations to horizontal and vertical mirror reflections. We observed graded rotation costs (180° worse than 90°), implicating a memory routine for long-term memory akin to mental rotation in short-term memory, and a trend towards larger costs for vertical versus horizontal reflections, possibly implicating two distinct reflection routines. These results help establish a taxonomy of memory routines, and validate our novel paradigm as a powerful tool for studying the flexibility and durability of visuospatial memory representations.

61.23, *8:45 am* **Human cache memory enables ultrafast serial access to spatial representations** Brandon Liverence[1] (liverence@gmail.com), Steven Franconeri[1]; [1]Northwestern University

Can remembering ever be as fast as seeing? Prior work suggests not, as both serial (Sternberg, 1966) and logarithmic (Wolfe, 2013) temporal access costs have been observed in memory search for identity information. Here, we ask whether there are analogous costs for accessing spatial representations of objects' locations. Participants used keypresses to move a "selection window" around a 4x4 grid of images of real-world objects. Their task was to sequentially select four target objects on each trial, though only the upcoming target was displayed on-screen. While targets changed between trials, the grid itself remained stable for 60 trials, enabling participants to learn the objects' locations over time. In the Vision condition, all 16 grid objects were simultaneously visible. In the Memory condition, only the object currently inside the selection window was visible at each moment. Initially, participants were slower in Memory than Vision, but after ~40 trials performance became equally fast (and statistically indistinguishable) across the two conditions (reaching a stable plateau at ~8.5secs/trial), implying that in well-learned environments, searching through memory can become just as fast as visual search. A second experiment used the same design and stimuli, but now all four targets were visible throughout each trial (though participants had to select them in a pre-determined order). While Memory performance matched Study 1, Vision was now significantly faster (~7.5secs/trial), and the Condition-by-Study interaction was highly significant. While visual search may use parallel selection mechanisms to plan efficient "routes" between multiple upcoming targets, memory search appears to be inherently serial, as seemingly only a single memory target can be selected at once. These results constitute evidence for a form of ultrafast human "cache" memory, by analogy to the sort of memory typically integrated into computer CPUs, and subsequent experiments will explore whether this form of memory is similarly capacity-limited.

61.24, *9:00 am* **Placing a Lower Bound on Transsaccadic Memory Capacity Using Visual Search** Nicholas Kleene[1] (nkleene88@gmail.com), Melchi Michel[1]; [1]Rutgers University, Psychology Department

Making eye-movements provides us with visual samples of the world that must be integrated to produce a coherent percept of the visual world. Transsaccadic Memory (TSM) is necessary for storing samples from previous fixations so they can be integrated with the current one. Visual search tasks place greater demands on TSM than change-detection since visual search often requires integration of multiple samples. Our goal was to estimate TSM capacity and investigate its relationship to visual short-term memory (VSTM) using two visual search tasks. Prior to the main experiment, participants completed a forced-choice detection task designed to estimate their psychometric function at each potential target location. Participants then completed a simulated or real saccade search task, requiring the localization of a target signal (Gabor) embedded in a field of 1/f filtered noise. Participants were presented with one, two or four fixation intervals and the target was present in each interval (redundancy condition) or only one (uncertainty condition). Trials were blocked by the number of intervals and target presence condition. In the real saccade task participants made a 5° saccade following each stimulus sample; in the simulated saccade task they maintained fixation while we simulated the dynamic transient produced by saccades. Performance was measured as target localization accuracy. We developed an ideal observer model of transsaccadic integration that takes into account the critical role of TSM. Our ideal observer model allowed us to place a lower bound on TSM capacity for each subject, quantified in terms of bits, a task independent unit of information. We found median capacity estimates of 7 bits for the simulated saccade task and 9.5 bits for the real saccade task. These estimates are somewhat higher than those previously found for VSTM, but they indicate that TSM capacity may play a limiting role in multiple fixation visual search.

61.25, *9:15 am* **"What" and "Where" in Visual Context Learning** Tal Makovski[1] (tal.makovski@gmail.com); [1]Department of Psychology, The Open University of Israel

Contextual Cueing (CC) is the powerful ability of humans to extract regularities from seemingly chaotic environment and utilize this knowledge to assist in visual search. Extensive research has shown that CC is a robust and ubiquitous phenomenon, but it is still unclear what exactly is being leaned, and what constitutes a "context". Prominent models of CC have typically focused on how people learn spatial configuration regularities and accordingly most of the research has used simplified, meaningless search stimuli. Nevertheless, the world we live in is filled with meaningful heterogeneous objects and there is ample behavioral and neuropsychological evidence that object identities ("what") frequently interact with spatial information ("where"). What is the role of what processing in CC? In this study I tested CC with everyday objects and found that the mere repetition of arbitrary spatial configurations was not sufficient to facilitate search when identity information varied across trials. This finding was replicated in three experiments and thus refutes the view that the repetition of spatial configuration is sufficient for context learning. At the same time, the results revealed that the repetition of spatial configuration might be necessary for context learning, as no learning was observed when only identity information was repeated. Instead, context learning was found only when both what and where information remained constant across the trials. Moreover, similar results were obtained when CC was tested in hybrid search tasks, in which people looked for multiple possible targets ("where are the keys, wallet and phone?"). Together these findings challenge current models of CC as well as the ecological validity of standard lab-based CC procedures, and indicate that although visual context learning might be highly specific; this learning is robust and not modulated by memory load.

61.26, *9:30 am* **Breaking Visual Working Memory: Cases of In/dependence between Storage and Manipulation Costs** Hrag Pailian[1] (hrag.pailian@gmail.com), Justin Halberda[1]; [1]The Johns Hopkins University

To what extent are storage and manipulation abilities in visual working memory (VWM) in/dependent? We answer this question by investigating whether factors known to influence VWM storage (memory load, object complexity, precision of representations) produce similar vs. different costs in VWM manipulation. To this end, we developed a novel task that is similar to the shell game. Objects were presented briefly and subsequently hidden behind occluders. These occluders either remained stationary (resembling change detection tasks used to measure VWM storage) or swapped positions a number of times. Since swap conditions required observers to update the featural-spatial bindings of object representations, they allowed us to measure manipulation ability and its interaction with factors, such as memory load, information complexity, and precision of representations. In varying memory load (Exp 1a), we found that participants were able to manipulate only 2 objects without incurring costs, despite being able to store up to 3-4 objects. These manipulation costs were not attributable to temporal decay, interference effects, or limited encoding (Exp's 1b-d). Furthermore, increasing the complexity of these objects (Exp 2) produced additional costs in storage, but not in manipulation. Similarly, the level of precision with which items were stored in VWM was the same for all manipulated representations (Exp 3). Interestingly, the probability with which these manipulated items remained in memory remained unchanged for only 2 items, but decreased as a function of swaps for higher memory loads. These results inform our conceptualization of the VWM system by providing insight into

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the in/dependence of storage and manipulation abilities. Factors constraining storage abilities limit manipulation, to the extent that they influence the input on which manipulation computations are performed (dependence: Exp's 2,3). Nonetheless, these factors are separate from those that constrain the manipulation computations themselves (independence: Exp 1).

61.27, *9:45 am* **Accounting For Variable Precision In Visual Working Memory Reveals A Discrete Capacity Limit** Michael Pratte[1] (pratems@gmail.com), Young Eun Park[1], Rosanne Rademaker[1,2], Frank Tong[1]; [1]Psychology Department, Vanderbilt University, [2]Cognitive Neuroscience Department, Maastricht University

The study of visual working memory (VWM) has recently centered around a fundamental question: Does VWM have a discrete capacity limit, such that only a few items may be actively maintained at any time, or is VWM a continuous resource that can be flexibly allocated to any number of items with varying degrees of precision? The key signature of discrete theories is that pure guessing will occur on some trials when the number of items to be remembered exceeds the capacity of VWM, whereas continuous models predict that all information in a visual scene can be stored with some precision. However, evidence for guessing has proven difficult to assess, as continuous resource models can predict data patterns that mimic guessing by allowing precision to vary randomly across trials. Here, we evaluated the hypothesis that a major source of trial-to-trial variability in VWM performance is due to variation in perceptual sensitivity across stimuli, an effect that both discrete and continuous models can account for. Participants viewed oriented gratings, and after a brief delay reported the orientation held in memory for a probed grating. When simply modeling the distribution of report errors, a continuous resource model with variable precision provided a better fit to the data than a discrete capacity model. However, precision was markedly higher for vertical and horizontal orientations than for oblique orientations, and this well-known perceptual effect accounted for a substantial proportion of the trial-to-trial variability in VWM performance. After explicitly including this source of variability within both models, the resulting discrete capacity model provided a better fit to the data than the continuous resource model. Our results suggest that the variability in VWM precision arises largely from differences in perceptual sensitivity across stimuli, and taking this variability into account reveals evidence in favor of the discrete capacity model.

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Perceptual Learning

Wednesday, May 20, 11:00 - 12:45 pm
Talk Session, Talk Room 1
Moderator: Cong Yu

62.11, *11:00 am* **Stimulus-specificity of training with explicit or ambiguous diagnostic structure** Ali Hashemi[1] (hashea@mcmaster.ca), Matthew Pachai[1], Allison Sekuler[1], Patrick Bennett[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Perceptual learning (PL) is often due to observers becoming more sensitive to the diagnostic information in the specific stimuli used during training. Here, we asked how diagnostic information affects PL in a texture identification task. Specifically, we examined whether learning and stimulus generalization differed when diagnostic information was presented alone or embedded in an uninformative context. Texture stimuli were generated from low-frequency band-pass filtered white noise; to create stimuli with restricted diagnostic information, we applied a ±45 degree orientation filter centered on 0 (HORZ) or 90 (VERT) degrees. Explicit stimuli comprised HORZ and VERT orientation-filtered textures as well as an unfiltered FULL texture. Embedded stimuli comprised HORZ and VERT filtered textures summed with non-informative complementary orientation information from the average of all our texture stimuli. We measured accuracy in a 1-of-6 identification task: Observers were trained with either HORZ-explicit or HORZ-embedded stimuli, and tested with all stimulus types. When trained with HORZ-embedded stimuli, performance improvements could result from: i) increased reliance on the informative horizontal band, manifesting as improved accuracy for all conditions in which HORZ structure is informative, or ii) decreased reliance on the uninformative vertical band, manifesting as reduced accuracy for both VERT-embedded and VERT-explicit stimuli. When trained with HORZ-explicit stimuli, performance improvements can only result from increased sensitivity to horizontal structure. Our results reveal higher pre-training accuracy with explicit than embedded stimuli, demonstrating that uninformative structure impaired identification. Training with HORZ-embedded stimuli eliminated this effect, producing post-training accuracy similar to pre-training explicit stimuli. Further, accuracy for VERT stimuli was not decreased, suggesting that learning was not at a cost to the uninformative band. Finally, embedded and explicit learning were largely stimulus-specific, with minimal transfer to other conditions. Together, these results support an increased reliance on the trained orientation band, without suppression of non-informative orientations, but high context-specificity.

Acknowledgement: NSERC, Canada Research Chairs

62.12, *11:15 am* **Under-stimulation at untrained retinal locations may explain location specificity in perceptual learning** Cong Yu[1] (yucong@pku.edu.cn), Ying-Zi Xiong[1], Jun-Yun Zhang[1]; [1]Department of Psychology and Peking-Tsinghua Center for Life Sciences, Peking University

Perceptual learning (PL) can transfer to a new location/hemisphere completely when the new location is additionally trained with an irrelevant task (Xiao et al, 2008). This double-training result, along with additional findings of learning transfer to untrained orientations/directions (Zhang et al., 2010; Zhang & Yang, 2014) suggests that PL is a high-level learning process occurring beyond the retinotopic visual cortex. However, it is unclear why PL is location specific in the first place, and whether bottom-up stimulation of the untrained location during irrelevant training is sufficient to enable learning transfer. In a failed attempt to solve these puzzles, we found that practicing Vernier at one retinal location, with simultaneous passive exposure to additional Vernier stimuli at a diagonal quadrant location, leads to no learning transfer (Wang et al., 2013). However, the impact of passive exposure stimulation might have been suppressed by demanding Vernier practice. Here we used a continuous flashing suppression paradigm to re-investigate the role of location training in double-training enabled learning transfer. Vernier was trained at one quadrant location, and a randomly oriented Gabor was simultaneously shown at a diagonal location. The perception of the Gabor was suppressed by flashing white noise shown in the other eye, and the observers were unaware of the Gabor's presence. This bottom-up stimulation of untrained location resulted in complete transfer of Vernier learning from the trained location. In a control experiment in which the randomly oriented Gabor was absent while other conditions were unchanged, no learning transfer was evident. These results suggest that bottom-up stimulation of an untrained retinal location can enable transfer of Vernier learning from a trained location. Moreover, location specificity, at least with Vernier learning, may result from under-stimulation of untrained locations. Whether this under-stimulation results from no stimulation or even suppression during training requires further investigation.

Acknowledgement: Natural Science Foundation of China Grants 31230030 and 31000459

62.13, *11:30 am* **Training reveals a coupling between overestimation and improved discrimination** Sarit Szpiro[1] (sarit.sz@gmail.com), Laura Wang[1], Marisa Carrasco[1,2]; [1]Psychology Department, New York University, [2]Center for Neural Science, New York University

Goal. Training improves visual discrimination and detection (perceptual learning). Recently, we found that training on an estimation task leads to increased overestimation of motion directions from a boundary (Szpiro, Spering&Carrasco, Perceptual learning modifies untrained pursuit eye movements. Journal of Vision, 2014). Thus, two different training protocols (discrimination vs. estimation training) with similar motion direction stimuli can lead to seemingly different findings – improved discrimination versus increased overestimation. Can these results be linked? To examine whether and how these two perceptual phenomena are related – we assess the two training protocols with both tasks, for trained and untrained directions. Methods. For each observer, we determined discrimination coherence thresholds for ±4° motion directions from the horizontal via staircases and used it for training and testing. Two separate groups of observers trained on the ±4° with either an estimation (n=7), or a discrimination task (n=7); a third control group did not train (n=7). Training lasted three days. During pre and post-test, all observers were tested on the two tasks: a binary motion direction discrimination (up vs. down) and an analog direction estimation task by rotating a mouse. During testing we presented directions of ±2°(difficult), ±4° (trained) and ±8° (easy). No feedback was given during the experiment. Results and Conclusion. Neither estimation nor discrimination accuracy changed in the control group. In contrast, training on estimation significantly increased overestimation and improved discrimination for trained and untrained directions. Similarly, training on discrimination significantly improved discrimination accuracy and increased overestimation for trained direction and untrained-easy directions. Thus, we found coupling between two different tasks, with different goals (categorization vs. estimation): improved discrimination was paired with increased overestimation and vice versa. These results suggest that improvements in perceptual tasks due to training may stem from a shift in the perceived stimuli, possibly in order to improve categorization.

Acknowledgement: Grant R01 EY016200 (MC)

62.14, *11:45 am* Reducing the size of the human blind spot through training.

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

Some research suggests that visual training in and around regions of insensitivity due to cortical scotomas can result in recovery of function. Such reports are controversial, and have been criticized for inadequate control of eye movements. We reasoned that some improvement through training was plausible, if the brain can adjust gains for still-functioning neurons in relation to input in and around regions of insensitivity. This emphasizes a functional definition of insensitivity, rather than insensitivity being set by the number and distribution of functional neurons. Accordingly, we reasoned that one might be able to improve performance around a region of insensitivity that all sighted people share – the human blind spot. All tasks involved size threshold estimation. Stimuli were presented in annuli with a diameter adjusted according to a 1-up 2-down staircase procedure while we recorded eye movements. For four weeks people trained daily on a motion-direction discrimination task at the periphery of the blind spot in one eye. Comparisons of performance pre and post-training revealed a disproportionate improvement for the trained blind spot, relative to the untrained blind spot, ruling out an explanation based on a generic practice effect. Improved sensitivity generalized to other tasks, including a color discrimination and a naturalistic speeded detection task, wherein participants had to spot a car moving out of their blind spot. These improvements could not be attributed to eye movements. Our results show that functionally defined regions of insensitivity, including the human blind spot, can be reduced through training. This offers an opportunity to develop effective protocols in normally sighted people, which could have clinical application.

62.15, *12:00 pm* Neural mechanism of reactivation of consolidated perceptual learning revealed by the concentration of excitatory and inhibitory neurotransmitters

Ji Won Bang[1] (Ji_Won_Bang@brown.edu), Kazuhisa Shibata[1], Takeo Watanabe[1], Yuka Sasaki[1]; [1]Cognitive, Linguistic & Psychological Sciences, Brown University

Visual perceptual learning (VPL) by training on a task is interfered with by another training if it occurs within one hour after the initial training. This indicates that VPL is fragile immediately after training but is stabilized within one hour so that it becomes resilient against interference. However, already stabilized VPL of a task becomes susceptible to interference by practicing a small number of the task again (Bang et al, 2013, VSS). Although this so-called reactivation has made us reconsider a role of stabilization/consolidation in VPL, the neural mechanism has yet to be clarified. Here, we examined excitatory and inhibitory processing associated with reactivation. There were psychophysical and brain-imaging experiments. The psychophysical experiment lasted 3 days. On Day 1, subjects were trained on a detection task (2IFC) on orientation A with 16 blocks in staircase. On Day 2, subjects were asked to perform 3 blocks on orientation A for reactivation and then were trained on orientation B. On Day 3, performance on orientations A and B was measured. In the bran imaging experiment, using functional magnetic spectroscopy, we measured the concentration of glutamate and GABA in the early visual cortex before, immediately after and 3.5 hours after the reactivation. An E(excitation)/I(inhibition) ratio in the early visual cortex was taken by dividing the concentration of glutamate by that of GABA. Performance on orientation A significantly decreased between Days 2 and 3, indicating that reactivation makes already stabilized/consolidated VPL of orientation A labile to interference again. The E/I ratio increased immediately after reactivation of VPL of orientation A, and then returned to the baseline level 3.5 hours later. This time course changes are similar to those for stabilization after the first training (Shibata et al, 2015, VSS), suggesting that the neural mechanism of reactivation is similar to that of stabilization.

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62.16, *12:15 pm* External reward facilitates visual perceptual learning over a night's sleep

Aaron Berard[1] (aaron_berard@brown.edu), Tyler Barnes-Diana[1], Jose Nanez[2], Yuka Sasaki[1], Takeo Watanabe[1]; [1]Department of Cognitive, Linguistic, and Psychological Sciences, Brown University, [2]School of Social and Behavioral Sciences, Arizona State University

Visual perpetual learning (VPL) is defined as a long-term performance improvement on a perceptual task as a result of perceptual experience. It has been found that sleep strengthens and consolidates VPL. In addition to the effect of sleep, reinforcement given through external primary reward (such as water) has been found to facilitate VPL. However, it is not clear whether sleep and reward independently influences VPL or whether there is a mechanism in which the effect of reward on VPL is particularly enhanced during sleep. To test which model is more plausible, we investigated whether reward and sleep interacts on VPL using a widely utilized VPL paradigm known as the texture discrimination task (TDT). In the standard TDT, participants report the orientation of an array of oblique lines embedded in a field of all vertical or all horizontal lines. Robust over-night improvement has been demonstrated. In the present study, we trained 32 water-deprived participants on TDT at either 9-10am (no sleep included) or 9-10pm (sleep included) and then retested their performance 12 hours later. Half of the subjects received auditory feedback and water as reward through a tube for a correct response while the other half only received auditory feedback for a correct response. Thus, there were 4 groups in total; no-sleep-with-reward, no-sleep-without-reward, sleep-with-reward, and sleep-without-reward groups. Our results show a strong tendency for sleep-dependent performance improvement especially within the group that was rewarded for correct performance with water. This interaction between sleep and reward on VPL suggests that sleep has a specialized mechanism for consolidating reward-based VPL, compared to regular forms of VPL.

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62.17, *12:30 pm* Random walks of internal visual states

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We have previously (Wexler & Mamassian, VSS 2014) reported that there exist two independent biases related to the perception of 3D shape and motion from optic flow. These biases are both robust within observers, and highly variable across observers. Here we present a quantitative analysis of time series of these two variables, sampled once a day over three months in 97 observers. The temporal power spectra and autocorrelation structure of these time series show that they do not consist of independent samples from fixed distributions ("white noise"), but rather depend on internal variables that undergo cumulative changes over time. This observation is amplified by an analysis in the Box-Jenkins ARIMA framework, which shows that in most observers the time series are well modeled as random walks (or "Brownian motion") with superimposed measurement noise. Thus, we have evidence that the perception of at least two families of visual stimuli is governed by internal variables. Further, we show that (1) these variables can change both in response to external stimuli and perturbations, as well as during periods of complete darkness, showing that at least some of their dynamics is internal in origin; (2) the biases are strong enough to withstand a fair amount of counter-evidence from other depth cues; (3) the variables may not be single-valued but are actually vector fields over the visual field, with non-trivial spatial and temporal structure; (4) there are at least two more independent internal variables for 2D motion, corresponding to steps of 1D gratings and the motion quartet. The dynamic behavior of these variables opens a window on the internal dynamics of the visual system.

Eye Movements: Saccades and space

Wednesday, May 20, 11:00 - 12:45 pm
Talk Session, Talk Room 2
Moderator: Laurent Madelain

62.21, *11:00 am* Prediction of visual content across eye movements and their modulation by inferred information in the blind spot

Benedikt Ehinger[1] (behinger@uos.de), Peter König[1,2], José Ossandón[1]; [1]Neurobiopsychology, Institute of Cognitive Science, Osnabrück University, [2]Department of Neurophysiology and Pathophysiology, University Medical Center Hamburg-Eppendorf, Hamburg, Germany

The probabilistic view of brain function postulates that the brain operates by testing and refining predictions about the world. Here, we tested the existence of sensory predictive signals that could occur during eye movements. The local changes in acuity and global visual-field shifts of saccades could in principle be, at least partially, predicted. We analyzed whether these predictions are implemented differently for direct sensory information and for information that is exclusively inferred, as in the monocular blind spot area. This is performed by comparing the electroencephalogram (EEG) of responses after an eye movement to a peripheral visual stimulus, presented monocularly either inside or outside the blind spot. In some trials the stimulus remained the same pre and post eye-movement but in others it was exchanged. The EEG was analyzed using univariate general linear models, corrected for multiple comparison using threshold-free cluster based methods. We observe two main results: (1) early (~100 ms) and intermediate (~200 ms) lateralized EEG responses to saccade-contingent stimulus changes that suggest the occurrence of error signals to low and middle-level predictions within the visual modality. And (2), a late effect which was compatible in timing and topography with a P3 response, suggestive of violations of global constancy predictions. Remarkably, this late, change-related response was diminished when the change occurred in relation to a filled-in percept inside the subjects' blind spots. The results indicate that both sensory and associative predictive signals exist for transformations of visual input secondary to subjects' eye-movements. We show that these predictions occur across multiple levels of visual processing and are based on internal models that can differentiate between bottom-up input originating from the outside world or inferred from surrounding information.

Acknowledgement: SPP1665,ERC-2010-AdG #269716 - MULTISENSE,FP7-ICT-270212 Extending Sensorimotor Contingencies to Cognition

62.22, *11:15 am* **The timecourse of spatial information integration across saccades** Melchi Michel[1] (melchi.michel@rutgers.edu), Umang Parikh[1]; [1]Rutgers University

While most real-world tasks involve multiple fixations, visual performance thresholds are typically measured for single-fixation tasks. How might visual information integration during otherwise equivalent individual fixations differ between single-fixation and multiple-fixation tasks? In particular, how does an intervening saccade affect the characteristics of spatial and temporal integration used in a visual judgment? We investigated this question using reverse correlation in a transsaccadic perceptual discrimination task. Observers were asked to report the average luminance polarity of a small, flickering Gaussian blob displayed peripherally for 500ms, whose luminance in each 10ms frame was selected randomly. The Gaussian blob target was presented across a 10° saccadic eye movement cued to the right or left of the fixation location. Successful performance of this task required integrating information temporally across the intervening saccade. In the main experimental condition, two additional flickering blobs were added to the display, displaced laterally 10° to the left and right of the target. These flanking blobs were added to determine how observers use information from two locations—one corresponding to the prospective retinal location of the target and the other corresponding to the prospective location of 'remapped' receptive field(s) associated with the presaccadic target location—both of which have been reported to influence perceptual judgments. Observers were explicitly directed to ignore these flankers. We averaged the time-varying blob luminances aligned to the onset of the saccade across trials to determine the spatiotemporal pattern of visual information integration. The result of this analysis is a psychophysical kernel that indicates the relative weight given to each of the three spatial locations as a function of time. The computed kernel indicates that observers begin integrating information from the postsaccadic target location about 100ms before the onset of a saccade. We discuss this as evidence of perisaccadic remapping in the direction opposite the saccade.

62.23, *11:30 am* **Near-optimal integration of orientation information across saccadic eye movements** Elad Ganmor[1] (elad.ganmor@nyu.edu), Michael Landy[1,2], Eero Simoncelli[1,2,3,4]; [1]Center for Neural Science, New York University, [2]Department of Psychology, New York University, [3]Courant Inst. of Mathematical Sciences, New York University, [4]Howard Hughes Medical Institute

Visual acuity rapidly declines with eccentricity. Consequently humans move their eyes several times per second, repeatedly placing a new target region of the scene under the high-resolution scrutiny of the fovea. But what happens to the low resolution information acquired in the periphery just before the fovea lands on its new target? Integrating the pre-saccadic information into the post-saccadic estimate would make sense, as it can only reduce the error of the internal representation. But given the discrepancy in acuity between fovea and periphery, under normal viewing conditions the pre-saccadic view will contribute only marginally to the overall accuracy of the estimate. We used the well-established theoretical and experimental framework of cue integration to examine whether, and to what extent, human observers integrate pre- and post-saccadic orientation information. Untrained observers were asked to saccade on cue to one of two pre-determined peripheral targets (5 deg. eccentricity left or right). An oriented Gabor patch was visible either before the saccade, after the saccade, or both before and after saccade. Subjects were asked to determine whether the Gabor was oriented clockwise or counter-clockwise relative to vertical. In order to maximize the potential gain from saccadic integration, the contrast of the Gabor differed between the foveal and peripheral views (unbeknownst to the observers) and was experimentally set so that, for each subject, discriminability at the foveal and peripheral locations was approximately equal. Analysis of the results indicates that subjects integrate pre- and post-saccadic orientation information near optimally, achieving better orientation discriminability when the target is visible both before and after saccade. We conclude that humans are equipped with the apparatus to integrate low-level visual information across saccadic eye movements.

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62.24, *11:45 am* **Perisaccadic perception: temporal unmasking or spatial uncrowding?** David Melcher[1] (david.melcher@unitn.it), Antimo Buonocore[1], Alessio Fracasso [2]; [1]Center for Mind/Brain Sciences, University of Trento, Rovereto, Italy, [2]Experimental Psychology, Helmholtz Institute, Utrecht University, Utrecht, the Netherlands.

Stimuli briefly presented around the time of saccades are often misperceived in terms of their spatial or temporal attributes. Recently, evidence for a peri-saccadic reduction in crowding was reported, interpreted in terms of remapping of receptive fields (Harrison et al., 2013). However, that study used forward and backward masks and weak (always vertical) flankers, creating a "super-crowding" paradigm rather than "pure" spatial crowding (Vickery et al., 2009) We investigated whether these effects are better explained by spatial (pure crowding) or temporal factors (masking), as well as investigating the role of the pre-saccadic shift of attention (van Koningsbruggen & Buonocore, 2013).. In two experiments, we independently varied the distance from target to flankers, the presence of forward and backward masks and whether or not participants made a saccade. Moreover, we controlled for the orientation of the flankers (all vertical or randomized orientation). First, we replicated the pattern of crowding during fixation using masked stimuli but we also found that much of the decrement of performance with the super-crowding display was explained by temporal masking rather than only spatial crowding. Moreover, the level of crowding obtained with random rather than vertical flanker orientations was stronger than the super-crowded display alone, reinforcing the hypothesis of a greater temporal than spatial effect. Second, we replicated the finding of a small peri-saccadic improvement in performance with super-crowding displays as in the original study but found a different pattern in the pure crowding version without masking. Overall, our pattern of results was in accordance with a general benefit from the well-known pre-saccadic shift in attention towards the saccade target. These results are consistent with evidence for peri-saccadic shifts in receptive fields towards the saccade target.

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62.25, *12:00 pm* **Target displacements during blinks trigger corrective gaze adaptation** Gerrit Maus[1] (maus@berkeley.edu), Patrick Cavanagh[2], Thérèse Collins[2], Marianne Duyck[2], Matteo Lisi[2], Mark Wexler[2], David Whitney[1]; [1]Department of Psychology, University of California Berkeley, [2]Laboratoire Psychologie de la Perception, Université Paris Descartes

Observers often do not notice when a visual target is displaced during a saccade (Bridgeman et al., 1975). Instead, if the displacement is repeated on several saccades, the oculomotor system adapts so that saccades land near the displaced target (McLaughlin, 1967). Other disruptions of the visual input may also require a recalibration of gaze. Specifically, here we test whether target displacements during blinks lead to similar adaptation of the oculomotor system. Observers were instructed to fixate a white target dot on a screen in a dark room. Gaze direction and pupil size were recorded and blinks detected in real-time. With every blink—while the lids covered the pupil—the target was displaced laterally by 0.5º (or 1.0º). To counter accumulated shifts, the target jumped to a new random location every 3-4 s. Most observers reported being unaware of displacements during blinks. After adapting for ~50 blinks, gaze positions after the blink showed significant shifts in the direction of the displacement. This automatic gaze shift persisted for several blinks after adaptation, when the target was no longer displaced. In control experiments, we simulated blinks using shutter glasses. Although the displacement occurred while the shutters were closed, observers perceived obvious apparent motion of the target. No adaptive gaze shift occurred for simulated blinks, even when they were cued with a warning tone or triggered when the observer pressed a key. Significant adaptation of gaze shifts occurred exclusively for real blinks. Target displacements during blinks can trigger automatic gaze corrections, just as they can for saccades. This mechanism might be specific to the maintenance of gaze direction across blinks, or this novel effect—along with 'saccadic adaptation'—might be the result of a more general oculomotor adaptation mechanism evoked by intrinsically generated disruptions of the visual input.

Acknowledgement: ERC 324070 (PC)

62.26, *12:15 pm* **A common trans-saccadic map of multi-sensory locations revealed with saccade curvature** Martin Szinte[1] (martin.szinte@gmail.com), David Aagten-Murphy[1], Donatas Jonikaitis[2], Heiner Deubel[1]; [1]Allgemeine und Experimentelle Psychologie, Ludwig-Maximilians-Universität München, Munich, Germany., [2]Department of Neurobiology and Howard Hughes Medical Institute, Stanford University School of Medicine, Stanford, USA.

Our perception of the auditory and visual stimuli in the world remains stable despite frequent head and eye movements. For visual stimuli, this stability is achieved through the correction (remapping) of the object's visual representation in retinotopically organized visual and oculomotor maps. In the present study, we use saccade curvature to investigate the competition between visual saccade targets and different multi-sensory distractors. We report clear physiological evidence for the existence of a supra-modal map of locations across saccades. In a double-step saccade task (consisting of a horizontal and then a vertical saccade made in sequence), we measured the curvature of the second vertical saccade in response to the brief presentation of a visual, auditory, or audio-visual distractor either before or after the initiation of the first horizontal saccade. We found that the second vertical saccade systematically deviated away from the distractor irrespective of its modality, showing that both visual and auditory signals compete with the saccade target representation within an oculomotor map (e.g. SC). More specifically, we found that vertical saccades deviated away from the memorized location of the distractors in space (not on the retina), which passed from one visual hemifield to the other across the horizontal saccade. Taken together these results point toward the existence of a common map of target positions independent of sensory modalities, involved in the trans-saccadic tracking of locations in space.

Acknowledgement: This research was supported by an Alexander von Humboldt Foundation fellowship to MS and DFG grant (DE336/3-1) to DAM and HD.

62.27, *12:30 pm* **Pupil size reveals preparatory processes in the generation of pro- and anti-saccades** Chin-An Wang[1] (josh.wang@queensu.ca), Donald Brien[1], Douglas Munoz[1]; [1]Centre for Neuroscience Studies, Queen's University, Kingston, Ontario, Canada

The ability to generate flexible behaviors to accommodate changing goals in response to identical sensory stimuli is a signature inherited in humans and higher-level animals. In the oculomotor system, this function has often been examined using the anti-saccade task in which subjects are instructed, prior to stimulus appearance, to either look at the peripheral stimulus automatically (pro-saccade) or to suppress the automatic response and voluntarily look in the opposite direction of the stimulus (anti-saccade). Distinct neural preparatory activity has been well-documented between the pro-saccade and anti-saccade conditions, particularly in the superior colliculus (SC) and the frontal eye field (FEF), showing higher inhibition-related fixation activity in preparation for anti- compared to pro-saccades. Moreover, the level of preparatory activity related to motor preparation negatively correlated with reaction times. Pupil size is widely used to index cognitive and neural processing, a link between the SC and the pupil control circuitry has been suggested recently, showing pupil dilation evoked transiently by weak microstimulation of the SC. We hypothesize that preparatory signals in the SC should be reflected on pupil size through this pathway. Here, we examined pupil dynamics in humans during saccade preparation prior to the execution of pro- and anti-saccades. Pupil size was larger in preparation for correct anti-saccades, compared to either correct pro-saccades or erroneous pro-saccades made in the anti-saccade condition. Furthermore, larger pupil size prior to stimulus appearance accompanied saccades with faster reaction times. Overall, our results demonstrated that pupil size was modulated by saccade preparation, providing unique insight into the neural substrate coordinating cognitive processing, saccade preparation, and pupil diameter.

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Wednesday Morning Posters

Color Perception: Models, methods, and meaning

Wednesday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

63.4001 Predicting visual search for abnormal color vision with perceptual models of color deficient vision

Vasco de Almeida[1] (vasco@ubi.pt), Jorge Santos[1], João Linhares[2], Catarina João[2], Sérgio Nascimento[2]; [1]Centre of Physics, University of Beira Interior, 6201-001 Covilhã, Portugal, [2]Centre of Physics, Campus de Gualtar, University of Minho, 4710-057 Braga, Portugal

Performance on a visual search task depends on the conspicuity of the target in relation to the distracters. If these have different colors, performance can reveal the perceptual structure of the color space. The aim of this work was to test how perceptual models of color deficiencies predict the performance of dichromats and anomalous trichromats on a search paradigm. Brettel's transformation and a transformation of the stimuli based on the anomalous photopigments proposed by DeMarco et al. were the models used. Stimuli were presented on a calibrated CRT monitor driven by a VSG2/3 graphics card. The stimuli consisted of one target (diamond shaped) among 150 distracters (squares, circles and triangles). The target was always displayed at 1-deg from the center of the screen and the distracters were randomly spread across 8x7 deg. In the normal condition, the colors of the target and distracters were selected in 48 directions around standard illuminant C in CIE L*a*b* color space and the hue angle between target and distracter was always 60-deg. All distracters had the same color but randomized luminance in the range 9.5-17 cd/m2. Observers were instructed to find a diamond-shaped target among the distracters and signal its presence as quickly as possible using a response box. The experiment was carried out by three deuteranopes, five protanopes, four deuteranomalous and three protanomalous. In the simulation condition, corresponding to Brettel's and DeMarco's transformation of the stimuli of the normal condition, seven normal color observers participated in the experiment. Results show high correlation for deuteranopes (r=0.82) and protanopes (r=0.83) and low correlation for deuteranomalous (r=0.45) and protanomalous (r=0.15). Additionally, both dichromats and anomalous trichromats took longer than normal observers tested with the simulated stimuli. These results suggest that Brettel's model predicts well dichromats perception and DeMarco transformation failed to predict anomalous trichromats perception.

Acknowledgement: This work was supported by FEDER through the COMPETE Program and by the Portuguese Foundation for Science and Technology (FCT) in the framework of the project PTDC/MHC-PCN/4731/2012.

63.4002 Symbolic Effects on Color Preferences in China and the US

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We investigated a prediction of the Ecological Valence Theory (EVT; Palmer & Schloss, 2010) that differences in people's color preferences can be explained in part by their preferences for ecological objects. We measured preferences for 32 chromatic colors in China and the US and found both similarities – e.g., a maximum around saturated-blue and a minimum around brown (dark-orange) and olive (dark-yellow) – and various differences. To test the EVT's cross-cultural prediction, we measured object-based Weighted Affective Valence Estimates (O-WAVEs) from people's liking/disliking ratings of color-associated objects separately in China and the US. Consistent with EVT predictions, O-WAVEs measured in the US correlated more highly with US preferences (.89) than with Chinese preferences (.63), but contrary to EVT predictions, O-WAVEs measured in China correlated less highly with Chinese preferences (.59) than with US preferences (.78). We hypothesized that the discrepancy might arise from symbolic effects on color preference in China (e.g., red is the color of good-fortune). To test this hypothesis, we performed analogous symbolic S-WAVE measurements from people's liking/disliking ratings of color-associated symbols and abstract concepts separately in China and the US. In China, symbolic S-WAVEs correlated better with color preferences (.76) than did object-based O-WAVEs (.59), with combined C-WAVEs correlating highest of all (.80). In the US, both symbolic S-WAVEs and combined C-WAVEs correlated worse with color preferences (.58 and .75, respectively) than did object-based O-WAVEs (.89). We discuss these differences as reflecting greater cultural "melting pot" effects that dilute color symbolism in the US more than in China.

Acknowledgement: NSF Grants BCS-0745820 and BCS-1059088 Gift from Google

63.4003 Testing perceptual models of dichromacy and anomalous trichromacy with a computer-based color-vision test

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The purpose of this work was to evaluate existing perceptual models of inherited red-green color deficiencies by assessing the extent to which they predict color discrimination. For dichromacy, the model was the one proposed by Brettel at al. (1997 J. Opt. Soc. Am. A, 2647). For anomalous trichromacy, the assumption tested was that equal stimulations of photoreceptors produce the same color perception for normal and anomalous observers. The color test was developed in-house and was inspired by the Universal Colour Discrimination Test (Ripamonti et al., 2013 J Vis 13(9): 1023). The stimuli were displayed on a calibrated CRT monitor (GDM-F520, Sony Corp.) controlled by a video board (ViSaGe Visual Stimulus Generator; Cambridge Research Systems). The stimulus was a square target of variable color on a white background. Both target and background were made of small circles of random diameter and subtended 17 deg and 5 deg, respectively. The luminance of the circles was assigned randomly from the interval 6-16 cd/m2. In the standard condition, the color of the target varied along 20 equally-spaced directions in color space around the color of the background. Ten protanopes, five deuteranopes, five deuteranomalous and two protanomalous observers were tested in this condition. In the simulation condition, background and target had the corresponding colors of the standard condition predicted by the models. Twelve normal observers were tested in this condition. In both conditions discriminations thresholds in each direction were estimated using a staircase procedure. The quality of model was evaluated by comparing the results obtained in the two conditions. For dichromacy, the thresholds for the two conditions were similar, indicating that the model describes well dichromats' perception. For anomalous trichromacy, however, the thresholds in the two conditions were clearly different, suggesting that some additional normalization of the visual system may need to be considered.

Acknowledgement: FEDER through the COMPETE Program and by the Portuguese Foundation for Science and Technology (FCT) in the framework of the project PTDC/MHC-PCN/4731/2012

63.4004 Color preferences change with changes in environmental colors

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A previous study on seasonal variations in color preferences found that people like colors associated with a particular season more during that season than during other seasons (Nelson, Schloss, Parker, and Palmer, VSS2012). Color preferences were only assessed once during each season, so the time course of the shifts in color preference was unknown. In this study we investigated whether color preferences change with changes in environmental colors during a single season. In autumn in New England the environment continually changes color as the leaves turn from deep green to yellows, oranges and reds. We were interested in whether people's preferences for autumn leaf colors would increase as the leaves turned. We tested participants' preferences for the Berkeley Color Project (BCP) 37 colors during nine sessions that took place over the course of 11 weeks in autumn (within-subject longitudinal design). The first session (baseline) took place before the leaves began to change and the last session was conducted once the trees were bare. We documented the changes by taking photographs on the Brown University campus every week for the duration of the study. We also collected colorful autumn leaves, matched them to Munsell chips, and determined which of the BCP-37 colors best corresponded to the leaf colors. We tested whether there was a differential change in preference for autumn leaf colors compared to non-autumn leaf colors. As the leaves changed, there was a significant linear increase in pref-

erence for autumn leaf colors, but no significant change for the non-autumn leaf colors. At the end of the study, we assessed individuals' preferences for autumn and for fall specific objects/events, which we obtained from a different set of participants. These results provide the first evidence that changes in environmental colors are linked to changes in color preferences.

63.4005 Visual memory for colour: the long and the short of it

Marina Bloj[1] (m.bloj@brad.ac.uk), David Weiß[2], Karl Gegenfurtner[2]; [1]Bradford School of Optometry and Vision Sciences, University of Bradford, [2]Department of Psychology, Justus-Liebig-University Giessen

An established finding in colour memory research is that memory shifts to more saturated matches. These results are based on 'memory colours' – the typical colours of particular objects, for example the green of grass. The problematic aspect of these findings is that many different exemplars exist, some of which might exhibit a higher saturation than the one measured by the experimenter. Here we avoid this problem by using unique items. Participants (N=12) brought personal coloured objects (toys, etc.). In absence of the object, we secured from the owner a long-term memory match to it. The match was performed in a room under neutral daylight illumination by selecting the chip that best resembled the memory colour of the object from the Munsell Book of Color (Glossy Edition). Participants that were naïve to the objects (N=8) performed the same selection task immediately after looking at each object for 30 seconds (short-term memory match). Subsequently, the same participants provided an object-match under daylight with chips and objects present. We measured the colour coordinates of selected chips, objects and illumination. The Munsell collection did not provide exact matches for every object, so the object-match was used as a proxy for analysis. The comparison between the matches of the owner of the object and the naïve subjects matches showed that owners recalled the colour of their object as being more saturated ($t(11)= -2.61$, $p=.02$) while participants who had just seen the object did not show that effect ($t(11)=-1.15$, n.s.). In CIELab, the saturation effect averaged over all participants and objects was 6.4 units for long-term and 2 units for short-term memory. Our results show that the shifts to higher levels of saturation only occur for objects stored in long-term memory and that this bias is not present for short-term memory.

Acknowledgement: DFG-SFB/TRR 135

63.4006 Assessing the effects of dynamic luminance contrast noise masking on a colour discrimination task on normal and deuteranomalous observers

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Traditional color vision tests use luminance contrast noise to mask cues that could improve color discrimination. Recent computerised color vision tests use dynamic luminance contrast noise to mask the colored target. The impact of such masking wasn't yet assessed. The purpose of this work was to assess the masking effect of dynamic luminance contrast noise on the color vision detection thresholds of normal and deuteranomalous observers. The color test was developed in-house and was inspired in the Universal Color Discrimination Test (Ripamonti et al., 2013 J Vis 13(9): 1023). A video card (ViSaGe) was used to display the stimuli on a calibrated CRT monitor (GDM-F520, Sony Corp.). The stimulus was a square target of variable color on a white background both made of small circles of random diameter and packed to subtend 5 deg and 17 deg, respectively. The luminance of the circles ranged randomly from 6 to 16 cd/m2. The color of the target varied along 20 directions concurrent at the color of the background. Six normal color vision and 3 deuteranomalous observers performed the test, first with static and secondly with dynamic luminance noise at 100 ms, each with three repetitions in a stair case procedure. Color discrimination thresholds were estimated and averaged across the 20 directions for static and dynamic noise on all observers. The average thresholds for static/dynamic noise were 2.77E-3(±4.58E-4)/2.64E-3(±5.71E-4) and 7.06E-3(±2.26E-3)/6.52E-3(±2.54E-3) for normal and deuteranomalous observers, respectively. Errors represent standard deviations. Wilcoxon signed-ranks test with $p>0.05$ in all cases showed no significant differences in-between static/dynamic conditions. The estimated differences in color thresholds with static and dynamic noise seems to indicate that there is no masking effect of dynamic luminance contrast noise on a color discrimination task on normal and deuteranomalous observers.

Acknowledgement: This work was supported by FEDER through the COMPETE Program and by the Portuguese Foundation for Science and Technology (FCT) in the framework of the project PTDC/MHC-PCN/4731/2012.

63.4007 Which color means more? An investigation of color-quantity mapping in data visualization

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Colormaps representing quantities are a standard tool of data visualization (e.g., in correlation matrices, brain activation diagrams, and topographic maps). We investigated people's implicit intuitions about how the extremes of color scales (e.g., dark/light) map onto represented quantities (e.g., large/small, high/low), and whether they are modulated by contrast with the background. Participants were shown fictitious data matrices in which columns represented time, rows represented alien species, and cell color represented how often each species was spotted during each time window. Each participant was shown one colormap and indicated whether there were more animals early or late. Early/late differences were clearly present, but no legend indicated how to interpret the colors. We expected higher-contrast would correspond to larger quantities. In Experiment 1 we tested dark-red/light-orange and dark-blue/light-cyan colormaps on black and white backgrounds. Almost everyone (89%-95%) inferred that darker colors represented larger quantities. Surprisingly, the effect was not modulated by contrast with the background, perhaps because all the colors were relatively high-contrast. In Experiment 2, we used the same colormaps but the background colors were extensions of the scale endpoints (e.g., darker blue or lighter cyan for the dark-blue/light-cyan colormap) so that one endpoint was always low-contrast. We also tested a gray-scale colormap on white and black backgrounds. Against light backgrounds, 90%-98% showed the dark-is-more bias. Against dark backgrounds, significantly fewer participants showed the same bias (53%-74%), but the pattern did not reverse. Therefore, participants have a strong dark-is-more bias, which is diluted, but not reversed, when dark colors are low-contrast. In a systematic survey of colormaps in published visualizations (e.g., in Nature Neuroscience) we found that many violate the dark-is-more bias. Using empirically validated natural intuitions for color-concept associations will help make complex datasets easier to understand.

Acknowledgement: Center for Vision Research, Brown University

63.4008 Measuring saturation

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For most color spaces, there is a measure for the saturation of a color. Most of these measures are not ordinally equivalent and they are mainly based on color discrimination experiments. It is unclear how well they correspond to human supra-threshold perception of saturation. We chose ten color comparison directions and three standard colors at a fixed luminance of 30 cd/m2. In each trial, two color patches were shown for 750 ms on a color calibrated monitor. One patch always had the color of one of the three standard colors while the color of the other patch was sampled by means of an adaptive algorithm from one of the ten comparison directions. Participants were asked to decide which of the two colors was more saturated by pressing one of two buttons. Background luminance was 10 cd/m2. We computed the point of subjective equality (PSE) for each of the standards in all of the ten color directions. We compared these PSEs to those predicted by different saturation measures defined in the CIECAM02, HSV, DKL, LAB, LUV, and CIE 1931 xyY color spaces. The measures differ in their ability to predict human perception of saturation, with LUV and LAB being closest to the observers' judgments and just above the best level allowed for by the inter-observer consistency. The measures defined in CIE xyY and HSV performed worst. The various measures of saturation differ in how well they capture human perception of saturation. For a constant level of luminance, human perception of saturation can best be described by the measures defined in LUV and LAB color space.

Acknowledgement: DFG 879/9

63.4009 A comparison of display technologies for accurate reproduction of colour stimuli

Caterina Ripamonti[1] (c.ripamonti@crsltd.com), Mark Hodgetts[1], Jakob Thomassen[1]; [1]Cambridge Research Systems Ltd

When measuring colour discrimination, it is crucial that a display device is able to reproduce colour accurately. In this study, we characterised the performance of LCD and CRT displays to reproduce a set of chromatic stimuli, and calculated the just noticeable difference between the measured and requested colour using the delta E value (DE) developed in the CIEDE2000 formula. A value of DE bigger than one represents a visible difference between the measured and requested colour. It is a com-

 See page 3 for Abstract Numbering System

monly held belief that CRT displays have superior colour reproduction compared to LCDs; we wanted to investigate this empirically and, if true, determine a technique to improve the colour reproduction of LCDs so as to be equivalent to CRT displays. We made a series of systematic measurements which confirmed that the native performance of LCDs was not as good as the native performance of CRT displays: more than 50% of the colours reproduced by LCDs had a DE bigger than one, compared to only 15% of the colours reproduced by CRT displays. There appear to be several factors that can contribute to this inaccuracy, including (i) variations in the transmittance properties of the LCD due to changes in temperature; (ii) chromatic shift that occurs within the LCD primaries across different intensity levels; (iii) the goodness of the opto-electronic transfer function characterisation and its linearisation; (iv) the contribution of the dark light; and (iv) the colour resolution of the LCD. We developed an optimised colorimetric correction which can significantly improve the colour reproduction of a calibrated LCD to a point that its performance becomes superior to the native colour reproduction of a CRT display.

63.4010 **Color-Concept Consistency Helps Observers Infer Meaning from Visual Displays** Charlotte Walmsley[1] (charwalmsley@gmail.com), Karen Schloss[2]; [1]Department of Biology, Brown University, [2]Department of Cognitive, Linguistic, and Psychological Sciences, Brown University

This study tested whether systematic associations between colors and concepts can be used to infer meaning from visual displays. It is well-known from the Stroop Effect that people are faster at reading a color word when displayed in a congruent text color than in an incongruent color (e.g. "RED" in red ink vs. green ink). However, it is unknown whether this type of facilitation/interference generalizes to abstract associations in ecologically valid domains. We addressed this question within the domain of recycling. We first tested whether participants have systematic associations between colors and to-be-discarded items: paper, glass and trash (Experiment 1). For each object, participants rated how strongly they associated it with each of the Berkeley Color Project 37 colors. White was systematically associated with paper, light blue with glass, and black with trash. In Experiment 2, we tested whether a different group of participants was better at discarding trash/recyclables in bins whose colors were consistent with empirically-derived mappings from Experiment 1 (color-concept consistent) than in bins whose colors were determined from ecologically-based mappings of trash/recycling bins in their environment (Brown University). During each trial participants saw a display of three bins colored in an empirically-based or an ecologically-based color scheme, along with the name of an object (paper, glass or trash). They were instructed to choose which bin was appropriate for discarding the object. The bins were not labeled so participants could only rely on their color intuitions to complete the task. Trials included all combinations of each object (paper/glass/trash) with each color scheme (color positions counterbalanced). Participants were faster and more accurate at discarding objects in the empirically-based colored bins scheme than in ecologically-based bins. The results suggest that not only do people have strong color-concept associations, but color-coding according to those associations facilitates inferring meaning from visual displays.

Acknowledgement: Center for Vision Research, Brown University

Perception and Action: Walking

Wednesday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

63.4011 **Visual information for the control of walking over complex terrain** Brett Fajen[1] (fajenb@rpi.edu), Sean Barton[1], Jonathan Matthis[2]; [1]Cognitive Science Department, Rensselaer Polytechnic Institute, [2]Center for Perceptual Systems, University of Texas at Austin

Which regions of the ground surface do humans need to see to control walking over complex terrain? Previously, we offered an answer to this question rooted in the biomechanics of walking: To efficiently exploit their inverted-pendulum-like structure, walkers should use information about potential target footholds for an upcoming step during the last part of the preceding step. That is, the last part of each step is the critical phase for the visual control of the upcoming step. The aim of the present study was to determine the nature of the visual information used during this critical control phase. To efficiently exploit their biomechanical structure, walkers must initialize each step with a pushoff force from the trailing foot that is properly tailored to the position of the next target relative to the previous target. This leads to the hypothesis that walkers rely on information about the relative position of pairs of consecutive targets. To test this hypothesis, we instructed subjects to walk along a path of irregularly spaced target footholds (small circular patches of light projected onto the floor) while their movements were tracked by a motion capture system. On some trials, the visibility of a subset of targets was manipulated such that they were only visible for a brief period. The duration of the period of visibility varied such that consecutive targets were simultaneously visible in some conditions (leaving relative position information intact) but not others. We found no significant differences in stepping accuracy between conditions in which relative position information was available and a control condition in which all targets were always visible. However, stepping accuracy degraded in conditions in which relative position information was unavailable. We conclude that walkers rely on relative position information and that such information facilitates energetically efficient walking over complex terrain.

Acknowledgement: NSF 1431078

63.4012 **Eye, head, and foot tracking during locomation over real-world complex terrain** Jonathan Matthis[1] (matthis@utexas.edu), Mary Hayhoe[1]; [1]Center for Perceptual Systems, University of Texas at Austin

Successful locomotion over complex terrain such as a rocky trail requires walkers to place each step on a safe foothold with high spatiotemporal precision while also taking the future terrain into account. We have previously shown that humans guide foot placement using a visual control strategy that exploits the physical dynamics of the bipedal gait cycle (e.g. Matthis, Barton & Fajen, 2014). However, this work was limited to locomotion over virtual terrain projected onto flat surfaces within the laboratory. In the current project, we develop a research protocol to allow accurate and integrated tracking of the eye, head, and feet during locomotion over real-world complex and rocky terrain, a protocol that has been previously limited by numerous technical challenges. This protocol allows us to test predictions derived from the results of previous lab-based studies on the visual control of foot placement in real-world terrains, and opens new opportunities to study the visual control of locomotion outside a laboratory setting. Our protocol utilizes a Positive Science mobile eye tracker with a GoPro scene camera and inertial measurement units (IMUs) attached to the head, trunk, and feet. Each IMU integrates the output of temperature-calibrated, tri-axial accelerometers, gyroscopes, and magnetometers to determine the sensor's orientation within a world-centered reference frame. The orientation quaternions produced by the head and trunk-mounted IMUs were used to rotate the gaze vectors recorded by the eye tracker in order to specify gaze fixations within a body-centered reference frame and relate gaze location to foot placement. In a pilot study, subjects walked across different types of real-world terrain while performing different distraction tasks. Preliminary results reveal that foot placement in complex terrain is highly demanding of attentional resources, and that the control strategies used to guide foot placement vary dramatically according to the difficulty of the terrain being traversed.

Acknowledgement: NIH EY 05729

63.4013 **How do the biomechanics of walking constrain the visual control of stepping over obstacles?** Melissa Parade[1] (melissa.parade@gmail.com), Brett Fajen[1]; [1]Rensselaer Polytechnic Institute

The normal human gait cycle is to a significant degree driven by the passive physical forces acting on the structure of the body, but must be adjusted on the basis of visual information when walking over complex terrain. Visual information about the layout of flat terrain features is picked up two steps ahead in order to enact adjustments that secure foot placement on the basis of passive physical forces, which suggests that the use of visual information is constrained by the biomechanics of walking. When the terrain also contains raised obstacles, foot placement must be controlled with respect to an obstacle's location ahead of time, but foot elevation, which depends on obstacle size, requires additional muscle activation in the lower limbs throughout the crossing steps. As such, information about an obstacle's size may be needed at a different time than information about obstacle location. In the present study, we tested this prediction by instructing subjects to step over obstacles in a virtual environment viewed through a head-mounted display and manipulating the availability of visual information about the obstacle's size. The obstacle's location was always visible, but its size was not apparent until subjects reached a visibility window located at different points during approach. The size of the obstacle and timing of the visibility window varied between trials. Performance measures and gait parameters from an initial experiment suggest that information about an obstacle's size is not necessary until just prior to obstacle crossing. As such, information about obstacle size may be picked up later than information about obstacle location in order to raise the feet on the basis of active adjustments to the gait cycle during crossing. We discuss how these findings support the broader theoretical claim that the use of visual information is constrained by the biomechanics of walking.

Acknowledgement: NSF 1431078

63.4014 The contributions of active and passive modes of control during walking over complex terrain Sean Barton[1] (bartos5@rpi.edu), Jonathan Matthis[2], Brett Fajen[1]; [1]Department of Cognitive Science, Rensselaer Polytechnic Institute, [2]Center for Perceptual Systems, University of Texas at Austin

When walking over complex terrain, humans use visual information about the upcoming ground surface layout to exploit the passive physical forces inherent to bipedal locomotion. We previously showed that visual information about potential target footholds for an upcoming step is critical for control during the end of the preceding step. Visual information about target position presented during this critical control phase was sufficient for subjects to accurately step to a target, while the same information presented before or after the critical phase resulted in less accurate foot placement. Although visual information about target position is not essential once the step to that target is initiated, it remains unclear whether humans are capable of using such information to improve stepping accuracy following a perturbation during that step. Reynolds and Day (2005) demonstrated that, when taking a single step, participants rapidly respond to changes in target position while the foot is in flight. However, it is not known whether humans exhibit such active corrections during continuous walking over longer stretches of complex terrain, when locomotion is largely under passive control. In the present study, subjects walked along a path of irregularly spaced targets projected onto the ground while their movements were recorded with motion capture. As subjects approached targets, each target briefly disappeared and then reappeared. On a subset of trials, the location of one of the six targets was perturbed in either a medial-lateral or anterior-posterior direction while invisible. Subjects' responses to the perturbation depended on the timing of visual information during that step. Discussion focuses on the contributions of active control, to respond to perturbations during the swing phase, and passive control, to efficiently adapt the gait cycle to upcoming terrain.

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63.4016 Persistent personal biases in walking Norbert Boeddeker[1] (norbert.boeddeker@uni-bielefeld.de), Simon Jetzschke[1], Marc Ernst[1]; [1]Cognitive Neuroscience & CITEC, Bielefeld University

Locomotion along a given path in the absence of vision and audition is known to be inaccurate. Here we ask about the nature of these inaccuracies. To this end, we analyzed the performance of participants in three walking experiments involving straight and angle-walking tasks. In the first experiment eight blindfolded participants were guided along paths of different lengths and asked to turn to a target location by an angle of ±90° in a sports hall (size: 25x45m). We found significant biases in turn angles, i.e. systematic deviations from the correct angle that were characteristic of certain participants, whereas varying path length had weak effects on turn accuracy and precision. To check whether this idiosyncrasy was persistent over time and present in another type of walking task, we performed a second experiment several weeks after the first. Here, the same participants were guided to walk turns with varying amplitude. We then asked them to judge whether they had walked an angle larger or smaller than 90° in a two-alternative forced-choice (2AFC) paradigm. Very surprisingly, the personal bias was highly correlated between the two experiments indicating that the sense of direction can be persistently and individually biased in the absence of external directional cues. In a third experiment the participants where asked to walk straight on slanted and level surfaces. Here, we again found persistent directional biases in most participants. The direction of surface inclination did not significantly influence these individual biases. We found systematic angular biases in several walking tasks that were persistent over weeks. The biases reported here for healthy participants are most likely counterbalanced during normal daily-life by using visual and auditory cues for spatial orientation.

63.4017 Individual differences in perception and control of walking direction Isabelle Poulain[1] (poulaini@essilor.fr), Charlene Gaignard[1,2,3], Gildas Marin[1], Bruno Mantel[2,3], Delphine Bernardin[1]; [1]International R&D Optics Department, Vision Science Department, Essilor, [2]Normandie Université, France, [3]UNICAEN, CesamS, F-14032 Caen, France

Introduction. There exists an abundant literature on navigation strategies for the visual guidance of goal-directed locomotion. Two main strategies have been documented: the optic flow strategy (OF) and the egocentric direction strategy (ED). OF is assumed to be mainly used when optic flow is densely structured (Harris and Carre, 2001; Wilkie and Wann, 2003), whereas ED would dominate when optical structure is reduced (Rushton et al., 1998; Harris and Bonas, 2002). Less is known about how one particular strategy is exploited depending upon the perceptual and motor history of each individual or upon the individual weighting of sensory information. Inter-individual differences have been found in the perception of self-rotation (Bruggeman et al., 2009) and reported, though not specifically investigated, in visually guided locomotion (Turano et al. 2005; Rusthon et al. 1998). In the present study, we aimed at examining the navigation strategy preferentially used while walking towards a visible goal. Method. 27 participants, from 22 to 44 years old (11 women, 16 men), participated in the study. They were asked to walk on a treadmill toward a virtual target, while optic flow was either deviated 10° to the right of actual walking direction, or not deviated. Targets were localised straight ahead, or 20° to the left or right. Heading Error was computed as the difference between instantaneous target direction and walking direction. K-means clustering method was used to examine whether heading distribution could be decomposed into participants relying on OF (Heading Error = OF deviation) and participants relying on ED (No Heading Error). Results. Results showed a large variability in the magnitude of OF's influence, independently of saliency and availability of visual structure. Conclusion. There exists important inter-individual variability in the perception and control of locomotion, with individuals forming a continuum, rather than distinct groups, from OF to ED.

63.4018 Evaluation of a Phantogram Groundplane for the Study of Visually Guided Walking Behavior Gabriel Diaz[1] (gabriel.diaz@rit.edu), Andrew Smith[1], Kamran Binaee[1], Rahul Gopinathan[2]; [1]Center for Imaging Science, Rochester Institue of Technology, [2]Computer Science, Rochester Institute of Technology

Humans in the natural environment are able to maintain efficient and stable gait across complex terrain. In part, this is because visual feedback is used to guide changes in heading, foot placement, and posture. However, the role of vision in the control of gait is not well understood. We present a novel methodology for the study of visually guided walking over complex terrain in a laboratory setting. A perceptually three-dimensional ground-plane is projected upon a physically flat laboratory floor, similar to a one-plane CAVE environment. The percept of height is reinforced through the use of stereoscopic shutter glasses, and by the dynamic updating of the projected image to maintain the coincidence of the accidental perspective with the subject's motion-tracked head position. The benefits of this "phantogram" groundplane are numerous. Obstacle height, shape, and location can be instantaneously manipulated. Because the groundplane is physically flat, the likelihood of falls is dramatically reduced. Because head position and object positions are known, the environment facilitates the computational analysis of eye-tracking data. The apparatus also opens the possibility of real-time manipulations of the environment that are contingent upon the participant's behavior. In summary, the apparatus facilitates rigorous hypotheses testing in a controlled environment, presumably, with minimal degradation to the visual experience. We have tested this assertion in a validation study. The subject was asked to approach and step over an obstacle of three possible heights, scaled in units of leg length, and randomized between trials. Between blocks, the obstacle was varied between a real-world or phantogram type. Data shows that subjects treat the phantogram and real-world obstacles similarly, thus validating the methodology for the study of naturalistic walking behavior.

63.4019 Can where we are tell us where to go? The role of positional cues in visual guidance of human walking. Danlu Cen[1] (cend@cardiff.ac.uk), Simon Rushton[1], Seralynne Vann[1]; [1]School of Psychology, Cardiff University

Warren et al.(2001) investigated the role of optic flow and egocentric direction in the visual guidance of walking. They dissociated perceived and walking direction and measured walking trajectories in four different scenes that ranged in complexity from a single target line to a textured room containing posts. Trajectories became progressively straighter, and so less compatible with the use of egocentric direction, as the scenes became more complex. They interpreted the change in trajectory as due to the increasing availability of optic flow. However, the complex scenes also introduced geometric cues, positional cues, and motion parallax. We sought to tease the contribution of these cues out. Using a VR system we first replicated two scenes in Warren et al.'s study, the single line scene and the room plus posts scene. Our data closely replicated their results, we found that trajectories were markedly straighter in the room condition. We then isolated optic flow so that we could evaluate its contribution. We used a single target line scene as before, an empty room, and an isolated cloud of dots that filled the volume of the room. The dot scene provides the same amount of optic flow as the room plus posts scene that was used previously. Therefore if the change in trajectories is due to an increased amount of optic flow then trajectories in the dot scene should be at least as straight as in the empty room scene. What we found was that the trajectories in the dot condition were more curved than in the empty room condition and similar to those obtained in the single line environment. These results suggest that geometric or positional cues play a previously unrecognised role in the visual guidance of walking.

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63.4020 **Man vs. Mouse: The act of walking does not alter spatial suppression in humans** Kait Clark[1] (clarkk3@cardiff.ac.uk), Simon Rushton[1]; [1]School of Psychology, Cardiff University

Recently, Ayaz et al. (2013) reported a remarkable finding: surround suppression, as measured by V1 activation in mice, is substantially reduced during locomotion (running in place). Does low-level visual processing change in humans when they are walking? Such a change would recast our understanding of the relationship between vision and action and might explain previously observed effects of walking on motion perception (e.g., Durgin, 2009). To assess how the findings of Ayaz et al. extend to behavioural effects in human vision, we tested participants during locomotion and used an established behavioural measure of perceptual suppression based on Tadin et al. (2003). Tadin et al. demonstrated that duration thresholds for detecting the motion direction of a high-contrast grating increase with stimulus size. Our participants completed a simple motion-discrimination task in two conditions (modelled after Ayaz et al.): (1) standing in a stationary position and (2) walking on a treadmill. We replicated the expected behavioural effects in the baseline (standing) condition (i.e., increased difficulty discriminating the direction of motion for larger stimuli); however, we also found identical performance in the walking condition. Our results may indicate that changes in early visual areas are not predictive of behavioural suppression effects, or they may reflect a fundamental difference between the structures of visual systems. In either case, as discrimination thresholds were indistinguishable between the standing and walking conditions, we do not find support for an interaction between locomotion and spatial suppression in humans.

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63.4021 **Nonvisual information contributes to flow parsing during walking** Jeffrey Saunders[1] (jsaun@hku.hk), Xing Xing[1]; [1]Department of Psychology, University of Hong Kong

To perceive the movement of an independently moving object during self-motion, visual motion caused by object movement must be distinguished from effects of self-motion. This has been termed flow parsing. Flow parsing could be accomplished from optic flow alone. During walking, nonvisual information about self-motion could also potentially contribute. In this study, we measured the relative influence of visual and nonvisual information on perception of object motion and movement control during walking. In a virtual environment, observers walked toward a distant target along a textured ground plane. An independently moving dot appeared briefly during movement, 0.9 m above the ground, and observers judged whether the object was moving leftward or rightward. The horizontal velocity of the object was varied across trials and responses were used to compute a point-of-subjective-equality representing the object motion that is perceived to be stationary. To dissociate visual and nonvisual cues, we presented conditions where the direction of self-motion indicated by optic flow differed from the physical direction of walking by ±5°. In this situation, the relative motion of an object that is stationary with respect to optic flow would not correspond to a stationary object when compared to the physical direction of self-motion, and vice versa. The object motion that is perceived to be stationary can therefore be used to infer the relative influence of visual and nonvisual cues. We also analyzed walking trajectories to estimate the relative influence of visual and nonvisual cues on movement control. We found that nonvisual information strongly influenced both object motion judgments and walking trajectories, with less weighting for object motion (60% vs. 90%). We also found trial-to-trial correlations between biases in walking direction and judgments of object motion. The results suggest that an integrated perception of heading contributes to both movement control and flow parsing.

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63.4022 **Behavioral dynamics of visually-guided heading alignment in pedestrian following** Gregory Dachner[1] (gregory_dachner@brown.edu), William Warren[1]; [1]Brown University

The collective behavior of human crowds is thought to emerge from the local interactions between individual pedestrians, such as the coordination of walking speed and direction (heading). This coordination is guided by visual information about the motion of one's neighbors. A critical interaction assumed by many models of collective behavior is the alignment of heading with neighbors. Using a behavioral dynamics framework, we simulated experimental data on pairs of pedestrians to formulate a dynamical model of heading alignment. On each trial, a "follower" either walked behind or beside a "leader" for 20m, while the leader made two unpredictable turns. The initial distance and position, turn sequence, magnitude, and timing varied. Head trajectories were recorded with a 16-camera motion capture system. Results show that the follower's heading direction was closely coordinated with that of the leader (mean cross-correlation r = 0.92, mean delay between pedestrians = 984 ms for behind; r = 0.93, delay = 219 ms for side-by-side). We tested four models against this data to characterize the follower's change in heading during alignment, using a least-squares criterion. In the simplest model, the follower's angular acceleration is proportional to the sine of the heading difference (mean r = 0.72, gain k = 0.81 for behind; r = 0.70, k = 0.69 for side-by-side); additional terms did not improve fit. An alternative model that incorporates the mean time delays yielded similar gains (mean r = 0.71, k = 1.17 for behind; r = 0.71, k = 1.21 for side-by-side), thus generalizing across different leader-follower positions. The results show heading alignment is controlled by nulling the difference in heading with a neighbor. This provides a cognitively-grounded model of heading alignment that may be generalized to larger-scale crowd dynamics. We are currently investigating the optical variables that control these interactions.

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63.4023 **Intercepting a learned moving target: On-line or model-based control?** Huaiyong Zhao[1] (huaiyong_zhao@brown.edu), William Warren[1]; [1]Brown University

When walking to intercept a moving target, occluding the target severely impairs performance, consistent with on-line control by the constant bearing strategy (Zhao & Warren, 2014). Alternatively, interception might be controlled by an internal model of the target's motion, which is updated by current information (Diaz, et al., 2013). Here we ask whether an internal model of target motion can be learned over multiple training trials, and then used to guide interception during occlusion. Participants (N=10) walked in a virtual environment (12m x 12m), and displays were presented stereoscopically in a head mounted display (63˚H x 53˚V, 60 Hz), while head position was tracked (60 Hz). The target initially moved at 0.6 or 0.8m/s, and after 3s changed speed by -0.3, -0.2, 0.0, +0.2 or +0.3m/s. Each participant performed five experimental sessions, with one speed change per session. A session consisted of a learning block of 40 trials in which the target was always visible, followed by a test block of 24 trials in which the target was occluded 2.5s after it started moving. Occluding the target significantly impaired interception accuracy and precision ($p< 0.01$). An analysis of heading adjustments prior to the occlusion point indicates that participants learned to anticipate the speed change: they turned more in sessions when the target would speed up and turned less in sessions when the target would slow down. However, heading adjustments after the occlusion point indicate that participants did not adaptively adjust their heading during occlusion, but made a stereotyped turn. The results suggest that an internal model of the target's motion is not learned or used to guide interception in the absence of visual information, rather, interception is normally controlled on-line. The target's motion can be anticipated, but only when it is visible, possibly by modifying the constant bearing strategy.

Acknowledgement: Supported by NIH R01 EY10923

Attention: Individual differences

Wednesday, May 20, 8:30 am - 12:30 pm

Poster Session, Pavilion

63.4024 **Keeners and Procrastinators: Investigating Individual differences in visual cognition between voluntary signup across school semesters** David Chan[1] (davidyt.chan@mail.utoronto.ca), Jason Rajsic[1], Jay Pratt[1]; [1]Department of Psychology, University of Toronto

University-based psychological research typically relies on the participation of undergraduate students for data collection. With such participants, circadian timing effects have been shown to modulate attention and cognitive control, with student participants showing greater attention control in the afternoon than in the morning (Blake, 1967). On a longer time scale, researchers have anecdotally commented that semester differences may produce different outcomes in attentional and cognitive studies, with participants that sign up early in the semester being more attentive and focussed than those that sign up at the end of the semester. The purpose of our study was to test this anecdotal claim, and investigate the effect of time of semester across a set of attentional and cognitive tasks. To do so, participants completed canonical versions of a visual working memory (VWM) task, a flanker task, and a multiple object tracking (MOT) task. Crucially, we tested students who signed up at the beginning of the semester (within the first 3 weeks of school), and at the end of the semester (within 3 weeks until the end of class). Our results demonstrate that students at the end of the semester did not show any significant differences in the MOT task and VWM task, even though both these tasks require high levels of effort and concentration. Interestingly, there was a significant difference in the flanker task, such that early semester students showed a stronger flanker effect. In other words, later semester students were less susceptible to inference from irrelevant peripheral distractors, suggesting differences in perceptual load across the early and later semester groups. Overall, it appears that there can be differences between participants who choose to sign up early in the semester from those near the end of the semester, but these differences may be limited to particular cognitive processes

Acknowledgement: NSERC

63.4025 **It's in the game: Exploring Cognitive Differences between Professional Gamers and Novices** Alyssa Hess[1] (alyssa.hess@knights.ucf.edu), Mark Neider[1]; [1]University of Central Florida

Is playing video games associated with increased cognitive and perceptual capabilities? Recent research aimed at answering this question has produced highly contested results on both ends of the spectrum. While some argue that cognitive abilities, such as working memory and attention, vary between video game experts and novices, others have had difficulty replicating the finding. One possibility as to why findings have been so variable might be related to the difficulty associated with defining exactly what constitutes video game players of various proficiencies. For example, does training someone for 50 hours on a particular game necessarily create an expert at that game? To address this, we conducted a study comparing novice video game players (NGPs) to competitive, professionally ranked fighting game players (FGPs), a distinction intended to compare game players on the most extreme ends of the expertise spectrum. NGPs and FGPs engaged in a broad ranging cognitive task battery. Interestingly, FGPs performed better than NGPs on a number of measures, including Useful Field of View (with FGPs ~223 ms faster and 9% more accurate than NGPs), Attentional Blink (with FGPs ~312 ms faster and 11% more accurate than NGPs), Mental Rotation (with FGPs ~1s faster than NGPs), Wisconsin Card Sorting (~3.8 more perseverative errors on average in NGPs) and Dual n-back (FGPs outscored the NGPs by >10% at all n-back levels). There were no differences found on other measures that have previously been shown to be sensitive to videogame play, including Visual Search, Flanker task, and Enumeration. These results suggest that, while many previous findings indicating differences between expert gamers and novices do extend to comparisons of gamers from extreme ends of the videogame expertise continuum, other measures do not. These data may be indicative of the distinction between playing games often and playing them well.

63.4026 **Cue-it? We say: Block-it!** Bart Cooreman[1], Iris Wiegand[1], Anders Petersen[1], Signe Vangkilde[1], Claus Bundesen[1]; [1]University of Copenhagen

A bilateral change detection paradigm is often used to measure lateralized ERP-components, such as the Contralateral Delay Activity (CDA), believed to be associated with visual short-term memory (e.g. Vogel and Machizawa, 2004; Alvarez and Cavanagh, 2004; McCollough et al., 2007). Recently, Wiegand et al. (2014) developed a similar whole report paradigm in which participants reported the identity of four letters, presented in a pre-cued hemifield, showing a correlation between CDA amplitude and visual short-term memory capacity when modeled using Bundesen' s Theory of Visual Attention (TVA) (Bundesen, 1990) – in line with earlier findings suggesting that individuals with larger visual working memory capacity have larger CDA amplitudes than lower-capacity individuals (Vogel and Machizawa, 2004). In our EEG-study, we modeled healthy participants' visual attention performance in two versions of a five-letter whole report: a pre-cued version, similar to the paradigm used in Wiegand et al. (2014) in which a hundred percent valid symbolic cue preceded the letter display, and a blocked version, in which all letters in a given block were shown on the same side of the screen. The behavioral data were modelled by TVA, providing an estimate of perceptual threshold, processing speed, and visual short-term memory capacity for each participant. Our results show that the blocked design compared with the intermixed pre-cued design provided an equally good estimate of participants' TVA-parameters, and an equally prominent CDA. A clear advantage of the blocked design, however, is that participants seems to make less horizontal eye-movements compared with the intermixed design, and most important, the activity preceding our stimulus display is reduced in absence of a pre-cue, resulting in a more reliable baseline activity. A blocked design might therefore be considered a valid (and perhaps even slightly superior) alternative for cuing. We say: block it!

63.4027 **Stimulus strength and visual competition contribute to individual differences in Stroop-Task performance** Marnix Naber[1,2,3,4] (marnixnaber@gmail.com), Stephen Brown[1], Anneke Vedder[2,5], Sander Nieuwenhuis[1,4]; [1]Leiden University, Cognitive Psychology, The Netherlands, [2]Harvard University, Vision Sciences Laboratory, [3]Utrecht University, Experimental Psychology, The Netherlands, [4]Leiden Institute for Brain and Cognition, The Netherlands, [5]Utrecht University, Clinical and Health Psychology, The Netherlands

The Stroop task is a popular test for measuring executive control. In this task subjects are shown words describing a color in a font color that mismatches its description. The word's meaning distracts and slows reaction times when subjects have to report the word's font color. This is called Stroop interference. Popular computational models of the Stroop task indicate that a competition between words and colors underlies Stroop interference. It is possible that some of the variance in Stroop interference across individuals may be explained by differences in visual pathway strength and differences in competition between stimulus categories, independent of executive control. We designed an electrophysiological and psychophysical experiment to examine the effects of these variables on Stroop interference. In experiment 1, observers were presented with words and colors in isolation and event-related potentials (ERP) were measured to determine relative visual pathway strength. In experiment 2, observers reported target disappearances caused by motion-induced blindness as an indication of the strength of competition in the visual system. Observers also performed the Stroop task after experiment 1 and 2. In experiment 1 we found that the relative latencies of the P3 ERP component to words and colors highly predicted Stroop interference (50% variance explained). Furthermore, in experiment 2 the strength of motion-induced-blindness also predicted Stroop interference (40% variance explained). In neither experiment, these effects could be explained by trial-to-trial fluctuations in cognitive control. Hence, we conclude that the Stroop effect is largely determined by an individual's pre-set characteristics in visual processing and competition between feature categories.

63.4028 **Electrophysiological evidence for decreased top-down attentional control in adults with ADHD** Irina Nesterovsky[1], Lilach Shalev[1,2], Roy Luria[2,3], Keren Saar[1], Pnina Stern[1], Baruch Styr[4], Carmel Mevorach[5]; [1]Constantiner School of Education, Tel-Aviv University, Israel , [2]Sagol School of Neuroscience, Tel-Aviv University, Israel , [3]School of Psychological Sciences, Tel-Aviv University, Israel , [4]Maccabi Healthcare Services, Israel , [5]School of Psychology, University of Birmingham, UK

One of the characteristics of adults with Attention Deficit/Hyperactivity Disorder (ADHD) is deficient executive functioning; however the underlying mechanism is unclear. In the present study we investigated the neural substrate of executive attention in 35 adult participants with and without ADHD using a derivative of the Global-Local task, while recording a continuous EEG from participants' scalp. The demand for executive attention was invoked by including both congruent and incongruent displays (so that participants had to resolve a perceptual and response conflict) and by manipulating the relative salience of the global and local information (by using small and large display sizes). At the behavioral level, participants with ADHD performed significantly worse than the control group. Interestingly, we found two ERP components (latency of N1 at parieto-occipital electrodes and mean amplitude in a late component measured across 350-450ms time window at midline electrodes) that differentiated between the groups. Critically, both components exhibited a similar pattern whereby differences between target and distractor salient conditions (representing top-down control) that were evident for the controls were substantially attenuated for the ADHD group. In addition, N1 peak amplitude also differed between the groups: for the ADHD group the amplitude reflected the difference between small and large display sizes while for the controls the difference was substantially smaller. Taken together, these data highlight both reduced top-down signature (smaller difference between target and distractor salient conditions) as well as increased bottom-up signature (larger difference between small and large displays) in the ADHD group. All three ERP measures that differentiated between the groups were correlated with ADHD symptoms (Adult ADHD Self-Report Scale-ASRS). We therefore suggest that adults with ADHD are less efficient at applying pro-active top-down executive control and that this may represent a core difficulty in ADHD.

 See page 3 for Abstract Numbering System

63.4029 Enhanced pro-active distractor filtering in adults with high autistic traits Carmel Mevorach[1] (c.mevorach@bham.ac.uk), Mayra Muller Spaniol[1], Lilach Shalev[2,3]; [1]School of Psychology, The University of Birmingham, UK, [2]Constantiner School of Education, Tel-Aviv University, Israel, [3]Sagol School of Neuroscience, Tel-Aviv University, Israel

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition involving a variety of impairments including impaired social interaction and restricted and repetitive interests and activities. While ASD is heterogeneous in its presentation, a number of studies have attempted to highlight core impairment in attention in ASD. However, such studies have reported somewhat conflicting findings. For instance, it has been suggested that ASD is often accompanied by impaired attention disengagement but also improved ability to ignore irrelevant distractors. In two experiments we investigated performance of typically developed adults with or without high autistic traits (AQ, Baron-Cohen et al., 2001) in tasks highlighting distractor filtering in a pro-active manner. In the first experiment participants had to select the global or local aspect of a hierarchical letter under conditions where the target or the distractor level is more salient; in the second, we measured performance threshold when participants identify a face in a morphed face continuum superimposed on an irrelevant distractor. Across the two experiments we found that adults with high AQ were better at ignoring distractors than adults with low AQ. In the global/local task the high AQ group exhibited smaller congruency effects and in the morphed faces task they exhibited increased thresholds. Critically however, there were no overall differences in either the global and local conditions or in the morphed face categorization functions across the groups, precluding differences in low-level perceptual processes. The data support the notion that autistic tendencies are associated with increased attention filtering. We hypothesize that this enhanced filtering represents a bias towards pro-active control of attention (when the task set should be invoked in advance of stimuli presentation). This bias may in turn compromise re-active control, which might be called upon in situations where attention must be disengaged and reoriented.

63.4030 Amblyopic adults demonstrate intact endogenous spatial attention Mariel Roberts[1] (mariel.roberts@nyu.edu), Marisa Carrasco[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Background. Amblyopia is a developmental disorder characterized by a wide array of visual deficits following abnormal binocular childhood experience. Neuroimaging and behavioral studies have argued that amblyopia results in abnormal allocation of endogenous attention, but none have directly manipulated it and assessed its perceptual consequences. In visually-intact adults, endogenous attention increases performance in orientation discrimination tasks mediated by contrast sensitivity. Purpose: We explored whether and how the modulatory effects of endogenous attention on orientation discrimination differ (1) between the eyes of amblyopic adults and (2) compared to the corresponding eyes of visually-intact controls. Methods. 11 amblyopic (7-strabismic; 4-anisometropic) and 11 age- and gender-matched control adults were monocularly tested on a 2-AFC orientation discrimination task. Four Gabor patches (independently and randomly tilted ±20° from vertical) appeared at isoeccentric diagonal locations. Participants were presented with a central precue (60% valid; 20% invalid; 20% neutral) indicating the possible target location(s). In the valid condition, precue and postcue locations matched, in the invalid condition they did not. Stimulus contrast was adjusted in the neutral condition to equate task difficulty between eyes within observers and across observers. Results. In both groups, deployment of endogenous attention resulted in a significant performance benefit (valid–neutral condition) and cost (neutral–invalid condition). The magnitudes of these effects did not differ between the two eyes within each group or between the groups. RT analysis followed the same pattern of results, ruling out speed-accuracy tradeoffs. Conclusions. Despite their characteristic low-level vision impairments, endogenous attention remains functionally intact in human amblyopic adults. This finding, in conjunction with studies of exogenous attention in amblyopic human adults (Carrasco et al., VSS 2014) and of endogenous attention with amblyopic monkeys (Kiorpes et al., VSS 2014), show that covert attention is intact in amblyopes.

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63.4031 Tonic and Phasic Alertness Training Enhances Executive Function, Working Memory, and Skill Acquisition in Older Adults Thomas Van Vleet[1,2] (tomvanvleet@gmail.com), Joseph DeGutis[4,5], Michael Merzenich[2,3]; [1]Department of Veteran Affairs, VA Medical Center, Martinez, [2]Brain Plasticity Institute at Posit Science, [3]Department of Physiology, University of California, San Francisco, [4]Department of Veteran Affairs, VA Medical Center, Boston, [5]Harvard Medical School

The ability to sustain attention gradually declines with age, exacerbating normal decays in performance across multiple cognitive domains. In addition, poor sustained attention may impair efficient learning of new information and skills. Previous studies have shown that it is possible to enhance sustained attention in patients with severely impaired abilities, such as hemispatial neglect and traumatic brain injury, and that this generalizes to improvements in spatial attention and more global cognitive improvements (DeGutis & Van Vleet, 2010; Van Vleet et al., 2014). However, it is unclear whether 1) sustained attention can be enhanced in less impaired, healthy aging individuals and 2) whether these sustained attention improvements can transfer to improvements in relevant outcomes such as executive functioning and visuospatial skill learning. In experiment 1 we sought to test, in older adults, whether tonic and phasic attention training (TAPAT) can improve sustained attention and if this transfers to improvements on validated neuropsychological tests of executive functioning. In experiment 2, we sought to replicate these effects and further examine whether TAPAT can enhance skill learning on a visuospatial divided attention task which has shown to be related to driving performance (useful field of view task, UFOV). The results demonstrate that, compared to active control training, TAPAT enhanced sustained attention and that this transferred to improved executive functions. We also found that TAPAT, compared to active control training, enhanced rates of learning on the UFOV task. This novel approach to enhance sustained attention may serve to facilitate greater benefit across a wide range of learning tasks.

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63.4032 Aging effects on expectancy use in driving scenes as assessed by the ideal observer Steven Shimozaki[1] (ss373@le.ac.uk), Eleanor Swan[1], Claire Hutchinson[1], Jaspreet Mahal[1]; [1]School of Psychology, College of Medicine, Biological Sciences, and Psychology, University of Leicester

Aging can cause several issues affecting driving, including visual and attentional loss (e.g., UFOV). However, one aspect of ageing effects upon attention that seems less clear is the use of expectancy, or prior information (e.g., cueing tasks). This study assessed expectancy use in naturalistic driving scenes employing an ideal observer analysis developed for cueing tasks (Eckstein, Drescher, & Shimozaki, 2006). A pilot online study first asked 172 participants where (in 150 driving scenes, greyscale) certain driving-related stimuli (cars, pedestrians, cyclists, signs) would appear. From these responses expectancy 'heat maps' were generated by summing and normalizing the Gaussian-blurred responses (σ=1.41°). Then for 75 of the scenes (36.9°x28.1°),driving-related targets were artificially inserted in high- and low-expectancy locations, and 46 older UK drivers (61-85 years) and 49 younger UK drivers (19-29 years) performed a yes/no detection task. Stimuli were presented either in the full scene, or within ellipses removing the scene context (extending 1.41° beyond the vertical and horizontal extents of targets) for either 50ms (young) or 200ms (old). When the younger participants viewed the full scene, they saw a scene without the target (150ms), a blank grey screen (50ms), then the stimulus (50ms), similar to a flicker task (change blindness). For the targets presented without context (ellipses), performance was slightly better in the high-expectancy locations (d'-young-high=1.33, se =0.08; d'-young-low=1.18, se=0.08; d'-old-high=1.35, se=0.12; d'-old-low=1.05, se=0.09). In the full scenes there were also expectancy effects (high-expectancy - low-expectancy hit rates) for both young (0.123, se=0.013) and old (0.075, se=0.018) observers. However, ideal observer analyses found that this expectancy effect could be explained by the d' difference in the ellipse conditions for the old (but not the young) observers. This suggests that the young (but not the old) observers were using expectancy, and that one potential issue for aging effects in driving is expectancy use.

63.4033 Neural and Behavioral Markers of Inter- and Intra- hemispheric Communication Stephanie Simon-Dack[1] (slsimondack@bsu.edu); [1]Department of Psychological Sciences, College of Sciences and Humanities, Ball State University

This study examined correlates between a behavioral measure of interhemispheric transfer (IHT), performance on tasks targeting right and left hemispheric functions, and resting electroencephalography (EEG). IHT was measured using the Poffenberger Paradigm, a reaction time (RT) task based on the inference that participants will have speeded RTs to a visual target ipsilateral to the responding hand compared to a contralateral target. The neural processes indexed by this crossed-uncrossed difference (CUD) is debated in the literature due to its high variability. This study utilizes the individual variability of the CUD to examine individual differences in behavioral and neural measures of hemispheric function. The resting EEG data of 28 participants were recorded. Participants completed the Poffenberger Paradigm, a temporal discrimination task, line bisection task, and the Remote Associates Task (RAT). Right minus left average spectral power (ASP) for theta, alpha, beta, and gamma EEG frequencies across 8 equivalent scalp locations were regressed onto task performance. Location F3/4 emerged for the beta band: larger beta ASP in the right versus left hemisphere predicted faster right-to-left IHT, while larger beta at F3/4 in the left hemisphere correlated with left-to-right IHT. For the RAT, smaller alpha and larger beta in the right hemisphere at location F7/8 predicted better performance. For temporal sensitivity, location P3/4 for beta and location T7/8 for the theta loaded significantly, with higher ASP in the left electrodes predictive of better performance. Participants with slower right-to-left IHT demonstrated, via Pearson's correlations, significantly larger pseudoneglect. Participants with faster right-to-left IHT demonstrated marginally significant increases in performance on the RAT and temporal sensitivity. Findings demonstrate individual differences in lateralized neural function in conjunction with IHT and behavior and will be discussed in terms of characterizing the relationship between individual neural activity and behavioral performance, with an emphasis on implications for clinical populations.

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Attention: Reward and affective influences

Wednesday, May 20, 8:30 am - 12:30 pm

Poster Session, Pavilion

63.4034 Visuocortical changes during discriminant aversive conditioning: Effects of inter-individual differences in contingency awareness and autonomic engagement

L. Forest Gruss[1] (lforest@ufl.edu), Andreas Keil[1]; [1]Psychology, College of Liberal Arts and Sciences, University of Florida

Contingency learning of a noxious stimulus can be systematically studied in humans using classical fear conditioning. Conditioning studies utilizing the steady state visually evoked potential (ssVEP) have shown CS discrimination to occur as far downstream as lower-tier visual cortex, but the temporal evolution and inter-individual differences contributing to this process remain unclear. We implemented an uninstructed, differential fear-conditioning paradigm in which two orientations of a rapidly phase-reversing Gabor grating served as the conditioned stimuli (CS), only one of which (CS+) was ever paired with a 96db white noise (US, unconditioned stimulus). After a brief habituation phase, participants (n=20) were informed that a loud noise would occur at the end of some trials and were asked after every trial to indicate the likelihood of hearing the loud noise when viewing a specific Gabor grating. Acquisition consisted of an initial 100% CS+/US contingency followed by partial pairing (66%) and one re-exposure trial presented halfway through extinction. Preliminary results indicate that one group of participants (n=11) demonstrated rapid and sustained CS discrimination in their contingency ratings lasting throughout extinction, whereas the other group (n=9) showed gradual or no discrimination during acquisition. In terms of ssVEP data, observers with rapid and sustained discrimination learning demonstrated strong selective amplification of the CS+ grating, which habituated late in acquisition. By contrast, observers with little behavioral discrimination displayed later and smaller discrimination effects at the level of visual cortex. This suggests that behavioral responses to the conditioning regime are reflected in temporal dynamics of visual electrocortical facilitation.

63.4035 Proactive deprioritization of emotional distractors enhances target perception

Briana Kennedy[1] (b.kennedy@student.unsw.edu.au), Steven Most[1]; [1]School of Psychology, University of New South Wales

In the competition for perceptual priority, emotional stimuli often dominate, with one result being an impaired ability to report non-emotional targets that appear in close spatiotemporal proximity. Some evidence suggests that priority can shift in favor of targets when people are given detailed information about the targets (thereby enabling more effective preparatory visualization; Most, Chun, Widders, & Zald, 2005). But can people achieve a similar result by proactively deprioritizing emotional distractors when forewarned that they will appear? To assess this possibility, we tested whether participants could overcome "emotion-induced blindness" when forewarned about the nature of the distractor. On each trial, participants searched for one target (a rotated picture) presented within a rapid serial visual stream of upright images. Also within each stream, a high-arousal negative, high-arousal positive, or neutral distractor could precede the target by either 200- or 400-msec. At the start of half of the trials, participants were informed which kind of distractor would appear on that trial; on the other half, they received no such information. Results revealed that the provision of distractor information significantly improved target perception following both negative and positive distractors at the early lag, and following negative distractors at the later lag. Based on prior findings that individuals with depression have difficulty applying proactive control (Vanderhasselt et al., 2014), we further probed whether individual differences in depression modulated this effect; we found that those with high depression scores exhibited the greatest improvement when trials were preceded by information about the distractor. In sum, people can give targets a competitive edge in perceptual processing by proactively deprioritizing emotional distractors, but there may be predictable differences in the effectiveness of such a strategy.

63.4036 Task-irrelevant reward-learning elicits value-driven attentional capture

Chisato Mine[1] (mine.chisato.68m@st.kyoto-u.ac.jp), Jun Saiki[1]; [1]Graduate School of Human and Environmental Studies, Kyoto University

Rewards shape the deployment of visual attention to particular objects. Growing evidence indicates that the stimulus previously associated with reward involuntary captures attention (value-driven attentional capture; VDAC, e.g., Anderson, 2013). However, little is known about what properties of the reward-associated feature elicit VDAC, even if this feature no longer predicts reward outcome. In the present study, we conducted the flanker task in reward leaning, in which target was defined by location, to manipulate the color-reward association (training phase) and then tested the effect of this association in a visual search task with no reward outcome (test phase). Because attentional capture occurs under spatial uncertainty, first, we tested a hypothesis that the reward-associated feature needs to be utilized for target localization. Results showed that RTs were significantly slower in the high-reward than low-reward and control conditions during visual search with no reward outcome (Experiment 1), suggesting that stimulus features not useful for localizing a target are sufficient for VDAC. We also observed a significant VDAC in reward learning bound to distractors (Experiment 2), indicating that target-reward association is not critical. Next we put the same color to both the target and distractors in the flanker display to examine whether the feature should be useful in target-distractor discrimination to produce VDAC. A significant VDAC in Experiment 3 suggested that target-distractor discrimination by reward-associated features is not necessary for VDAC. Finally, we obtained a significant VDAC (Experiment 4) even when color rectangular frames around the letters were associated with reward. These results indicated that the stimulus previously associated with reward induced VDAC even when this stimulus feature no longer predicts reward outcome, suggesting that the association between task-irrelevant stimulus feature and reward is sufficient for VDAC.

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63.4037 High Susceptibility to Stress Associated with Increased Value-Driven Attentional Capture

Evan Palmer[1] (evan.palmer@wichita.edu), Andrew Miranda[1], Maria Chaparro[2], Amanda Hood[1], Joseph Keebler[1]; [1]Department of Psychology, Wichita State University, [2]Department of Psychology, University of South Florida

In this study, we are seeking to identify factors predicting value-driven attentional capture in the normal population. Previous research has shown that high levels of stress lead to addictive behaviors such as substance abuse (Sinha, 2001), and also that recovering substance abuse addicts show more attentional capture for rewarded stimuli than the normal population (Anderson, Faulkner, Rilee, Yantis, & Marvel, 2013). We hypothesized that there may be a relationship between susceptibility to stress and potential for attentional capture from rewarded stimuli in the normal (non-clinical) population. A sample of over 450 participants filled out the Susceptibility to Stress scale (Miller, Smith, & Mehler, 1988) online and 23 also independently participated in a gamified visual search training experiment which has previously been shown to lead to value-driven attentional capture (Miranda & Palmer, 2014). Results indicate that higher scores on the Susceptibility to Stress scale were associated with larger amounts of attentional capture for both the low-reward ($r2 = .24$, $F(1,21) = 6.54$, $p < .05$) and high-reward ($r2 = .19$, $F(1,21) = 5.05$, $p < .05$) conditions. Therefore, individuals with high stress susceptibility may be more vulnerable to reward-system engagement. These findings also coincide with previous research demonstrating that stressful conditions can lead to an increase in dopamine levels in the prefrontal cortex (PFC), which disrupts PFC regulation and thereby the executive control of attention, producing more bottom-up and less top-down attentional control (Arnsten, 2009). We hypothesize that individuals with greater stress susceptibility may have an overactive dopamine presence in the PFC leading to greater attentional capture from previously rewarded stimuli. We are currently investigating the relationship between participants' current stress levels and the amount of attentional capture they exhibit.

63.4038 **"Wishful seeing" in non-human primates: can reward shape size perception?** Samy Rima[1,2] (rima@cerco.ups-tlse.fr), Benoit Cottereau[1,2], Jean-Baptiste Durand[1,2]; [1]Université de Toulouse, Centre de Recherche Cerveau et Cognition, Toulouse, France, [2]Centre National de la Recherche Scientifique, Toulouse Cedex, France

Reward seeking shapes our interactions with the environment, but whether it also influences how we perceive it remains controversial. Notably, there is currently a debate on whether objects that are more likely to provide high reward might be perceived bigger than those associated with low reward. The aim of this study is to test this « wishful seeing » hypothesis in non-human primates. Two macaque monkeys performed a two-alternative forced choice (2 AFC) size discrimination task during several weeks. Following an initial fixation period, the animals were required to make a saccade towards the biggest of two simultaneously displayed discs, located in diametrically opposite positions relatively to the fixation point (7° eccentricity). Correct trials were followed by a liquid reward. The disk positions determined the probability of receiving a high versus a low amount of fluid (5/1 ratio). In half of the trials, the 2 discs appeared in positions with equal probability of high reward (neutral conditions, p=0.5/p=0.5) while in the other trials, the probability of high reward was asymmetric (reward-biased conditions, p=0.8/p=0.2). Preliminary results indicate that the saccade latencies are directly related to the probability of getting a high reward (i.e. saccades toward more rewarded positions are significantly shorter that saccades toward less rewarded positions), in agreement with previous reports. Our results also reveal massive differences in the psychometric curves associated with the neutral and reward-biased conditions. Monkeys tend to choose highly rewarded positions irrespective of the sensory evidence, which suggests a reward-induced change in strategy rather than in perception. However, we also observe an interaction between reward probability and sensory evidences that might indicate reward-induced changes in perceived size, in agreement with the wishful seeing hypothesis.

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63.4039 **Explicit awareness mediates reward-based prioritization of spatial attention** Li Sha[1] (lixx3632@umn.edu), Roger Remington[2], Yuhong Jiang[1]; [1]Department of Psychology, University of Minnesota, [2]Department of Psychology, University of Queenland

A rapidly expanding literature has shown that monetary reward modulates visual attention, often in the absence of explicit instructions. A tenet is that the effect is implicit, with subjects unable to report the relative values of rewarded stimuli. Yet conditions under which reward implicitly guides spatial attention are unclear. Here we tested the effects of monetary reward on the allocation of spatial attention in visual search under incidental learning conditions. We compared these effects to intentional learning of reward and to location probability, an established form of implicitly learned attention. Participants searched for the letter T among letter Ls to uncover monetary reward hidden behind the T. Although the T was randomly located, monetary reward was three times higher in one visual quadrant than in any of the other visual quadrants. Contrary to recent findings, participants did not develop an implicit spatial bias toward the high-reward quadrant. Search RT was equivalent for targets in the high-reward and low-reward quadrants. These results were found both when reward was given without considering RT and when reward was given only when RT was faster than a stringent deadline. However, monetary reward became a powerful source of top-down attention under explicit learning conditions. Specifically, when participants were told that one quadrant was associated with greater reward, those who successfully identified the high-reward quadrant showed faster RT for targets in the high-reward quadrant. Thus, locations associated with higher monetary reward were prioritized under explicit but not implicit learning conditions. In contrast, locations that more frequently contain the search target received priority even in the absence of monetary reward or explicit awareness. We conclude that experience-driven attention is a dual-system supported by explicit goals and implicit learning. Monetary reward affects spatial attention primarily by changing explicit goals and occurs under more limited conditions than previously thought.

Acknowledgement: NIH 102586

63.4040 **Reward- and space-based repetition priming is weighted by task relevance.** Beth Stankevich[1,2] (bstankevich@ucdavis.edu), Arni Kristjánsson[3], Joy Geng[2,4]; [1]Department of Neuroscience, University of California, Davis, [2]Center for Mind and Brain, Davis, California, [3]Department of Psychology, School of Health Sciences, University of Iceland, Reykjavik, Iceland, [4]Department of Psychology, University of California, Davis

Reward-associated features are prioritized during attentional selection. This priority is long-lasting even when task-irrelevant (Anderson et al., 2013) suggesting that reward associations are a particularly potent attentional cue that operates through selection history (Awh et al., 2012) and is separate from typical top-down and bottom-up cues (Posner, 1980). Reward-associated features have also been shown to magnify repetition priming effects (Kristjánsson et al., 2010). We investigated whether repetition priming for rewarded and non-rewarded dimensions would be modulated by top-down knowledge of current task goals. We employed a target discrimination task consisting of two phases, an initial rewarded phase (participants learned a color-reward mapping) followed by an extinction phase (learned color-reward mapping became invalid). Consistent with Kristjánsson et al., the repetition priming effect was bigger for rewarded than non-rewarded targets, but only during the rewarded phase. The novel finding was an interaction between repetition priming of the reward-associated color and target location: the priming effect was similar in size during the rewarded phase, but increased for location repetitions and decreased for reward-associated color repetitions in the extinction phase. This suggests that repetition priming is sensitive to the contextual relevance of task information. To ascertain whether the observed interaction was due to changes in reward-associated mapping or specific to changes in top-down knowledge of reward relevance, we performed a second study where the color-reward mapping reversed in alternating blocks. Priming for rewarded color and target location was comparable in all blocks, suggesting that simply changing reward mapping does not alter the magnitude of repetition priming for either information type. These results suggest that repetition priming is modulated by the contextual knowledge of task-relevant dimensions. The selection history of multiple features results in repetition priming effects, the magnitude of which is weighted according to task-relevance.

63.4041 **Generalization of value to visual statistical associates during reinforcement learning** Timothy Vickery[1] (tim.vickery@gmail.com), Kyle Friedman[1]; [1]Department of Psychological and Brain Sciences, University of Delaware

Humans are adept at learning from reinforcement history to make more rewarding choices. When the values of two options are correlated, such contingencies are detected and exploited by human decision-makers (Wimmer, Daw, & Shohamy, 2012). We examined whether learned, purely visual contingencies also interact with reward learning mechanisms to guide behavior. Subjects completed a "4-armed bandit" choice task that consisted of 600 choice trials. On each trial, they were presented with 4 shapes placed on a 3x3 grid. They clicked on a shape and then received either a reward or no reward. Subjects were told, truthfully, that each shape was independently related to a separate probability of reward, and that this probability drifted slowly over time and independently for each item. Unbeknownst to subjects, we also paired shapes into two groups. One pair always appeared in a fixed horizontally adjacent configuration, while the other always appeared in a fixed vertically adjacent configuration, thus creating the conditions for visual statistical learning to occur. Two reinforcement-learning algorithms were fit to choice histories – one in which rewards modified only the chosen item's value function, and another in which rewards additionally modified the value function of the chosen item's statistical associate. Despite the fact each item's value was truly independent of its paired associate's values, the model that included generalization to the associated item was a better predictor of participant choices than the more basic, nested model (likelihood ratio test, $p < .001$). Subjects thus showed a tendency to generalize learned value to visual statistical associates, even though such generalization was not valid or helpful in this task. These results imply that humans may have a tendency to generalize value estimates based on extrinsic statistical associations.

63.4042 **Reward-based involuntary capture interacts with voluntary attentional control during search** Gisella Diaz[1] (gisella@umail.ucsb.edu), Mary MacLean[2], Barry Giesbrecht[1,2]; [1]Psychological & Brain Sciences, University of California Santa Barbara, [2]Institute for Collaborative Biotechnologies, University of California Santa Barbara

Non-salient task-irrelevant features previously associated with reward can involuntarily capture attention (Anderson et al., 2011). Here we investigated the interaction between this reward-associated involuntary capture effect and voluntary attentional control. In a training task, participants (n=17) learned to associate two target colors (red and blue) with monetary reward (high/low). In a visual search task conducted one week later, target letters and distracter numbers, contained within differently colored circles, were briefly (232 ms) presented and then masked. Participants were then probed to indicate which of two letters had been presented in the search array. To manipulate voluntary attention, the search arrays were preceded by valid spatial cues (x or v) that indicated which hemifield would contain the target letter (left or right) or by neutral cues (=) that did not provide information about the target location. On half of the trials, one circle containing a distracter number was rendered in a previously rewarded color. Neutral trials did not contain a reward-associated color. Overall, there was a reward-associated capture effect, such that accuracy was significantly lower when a high, but not a low, reward-associated distracter was presented in the hemifield opposite the target. There was also a voluntary cueing effect, such that accuracy was greater in the cued condition than in the uncued condition. However, the cueing effect was diminished when the location of the reward-associated distracter was incongruent with the cued location, particularly on cued trials. The role of reward magnitude was examined by subtracting performance on neutral trials from performance on cued trials containing a reward-associated feature. Cue-distracter congruency only influenced performance on cued trials with high, but not low, reward-associated features. Our findings suggest that the involuntary capture by task-irrelevant and physically non-salient reward-associated features interacts with the voluntary control of attention to mediate visual search performance.

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63.4043 **Reward history enhances working memory precision in a continuous partial report task** Mary MacLean[1] (mary.maclean@psych.ucsb.edu), Barry Giesbrecht[1,2]; [1]Institute for Collaborative Biotechnologies, University of California Santa Barbara, [2]Psychological & Brain Sciences, University of California Santa Barbara

Features previously associated with reward capture attention, even when task-irrelevant and physically non-salient. We investigated the effect of such reward-associated features on the precision of working memory representations. We hypothesized that reward-associated features would enhance the precision of WM representations for items presented with that feature. Participants first learned to associate two colors with different magnitudes of reward ($0.01 or $0.05). One week later participants completed a partial report task where they remembered the orientations of three or six masked gratings presented for either 232 ms (Exp.1, n=18) or 1,800 ms (Exp.2, n=11) and then estimated the target orientation on a continuous scale. WM precision for the probed item was measured as the standard deviation of error (degree offset) in the estimation of orientation (SD_{error}). Importantly, on some trials a task-irrelevant and physically non-salient reward associated feature surrounded either the probed item or a non-probed item. On neutral trials no reward-associated feature was present. The presence of a reward-associated feature affected SD_{error} only for short exposures (Exp.1), such that SD_{error} was greater when the high, but not the low, magnitude reward-associated feature surrounded the probed target as compared to neutral trials (Mdiff = 2.74 SD, p = .019) and trials with a low magnitude reward-associated feature (Mdiff = 2.72 SD, p = .002). This effect was only reliable for set size six. There was no significant effect of the reward-associated feature when it surrounded a non-probed item. These results support our hypothesis that irrelevant, and physically non-salient reward-associated features improve WM precision for the stimuli towards which they direct attention, especially when WM load was high, but only when data was limited by short exposure. However, we did not find evidence that the WM precision for a given item was diminished when attention was directed elsewhere by a reward-associated feature.

Acknowledgement: This work was supported by a Postdoctoral Fellowship from the Natural Sciences and Engineering Research Council of Canada to the first author, and by the Institute for Collaborative Biotechnologies through grant W911NF-09-0001 from the U.S. Army Research Office. The content of the information does not necessarily reflect the position or the policy of the Government, and no official endorsement should be inferred.

63.4044 **More than distractor devaluation: The emotional boost of grasping a real object** Nathan Wispinski[1,2] (nathanjwispinski@gmail.com), Bruce Nip[1], James Enns[1], Craig Chapman[2]; [1]Department of Psychology, University of British Columbia, [2]Faculty of Physical Education and Recreation, University of Alberta

How we attend to visual images influences their subsequent affective evaluation, such that images we ignore are evaluated more negatively than those we actively attend (Raymond & Fenske, 2006). Here we ask whether this also applies to real objects, specifically those we must avoid (obstacles) and those we must grasp (targets), when reaching in three-dimensional space. To answer this question, we combined the attend-ignore factor of previous attention research with the obstacle-target factor that is relevant when reaching in personal space. Each trial in the experiment involved presenting different images of abstract art on two objects (iPods) resting upright on a tabletop. Participants were cued to reach and grasp one of the two objects based on the class of artwork being presented. Thus, the art presented on each trial could be classified as belonging to the grasp target, the grasp obstacle, or a neutral distractor (an object that did not impede limb movement). Following each successful grasp of the target object, an abstract art image was displayed on one of the two objects and participants rated its cheeriness–the affective evaluation dimension in most distractor devaluation research. The results indicated large grasp target enhancement effects. Namely, abstract art images appearing on the grasp target were rated more positively than the same art when it appeared on a distractor, on an obstacle, or was novel art that had not been previously displayed. This finding contrasts sharply with previous research on the emotional consequences of attention, which have been largely distractor devaluation effects. This also implies that the emotion-attention link is different during action tasks than in studies of covert attention. Specifically, it implies there are stronger positive emotional tags associated with attending and acting on an object than merely attending to it.

Acknowledgement: NSERC

63.4046 **The detection of fearful and angry expressions in visual search** Alisdair Taylor[1] (alisdairt@eyecarecentre.org), Jason Barton[1]; [1]Departments of Medicine (Neurology), Ophthalmology and Visual Sciences, Psychology, University of British Columbia

Background: The "anger-superiority hypothesis" states an angry facial expression is detected faster than a non-threatening facial expression when either is embedded in a crowd of neutral faces. Presumably, this occurs because an angry face signals impending direct-threat to the observer. However, it is not known whether angry facial expressions are detected more efficiently than other negative expressions that signal danger. Objective: In this study we compared search efficiency for angry and fearful expressions. Methods: Subjects completed a visual search task in which the goal was to detect either an angry or fearful facial expression amid a crowd of neutral expression distractor faces. Crowd size (small vs. large) and view (frontal vs. side) were manipulated. As an angry face signals direct-threat, but a fearful face only signals indirect threat, we expected better search efficiency for angry expressions. Furthermore, we hypothesized angry faces would be more efficiently detected in frontal-view, given that this signals a direct threat from the image to the observer, but that there would be no effect of view on fearful faces. Results: Subjects were faster and more efficient in detecting fearful than angry faces. Target interacted with crowd size: performance declined with increasing crowd size for angry targets, crowd size did not affect performance for fearful targets. We confirmed that angry targets were detected more efficiently in frontal-view, but view had no effect for fearful targets. Conclusions: Contrary to the anger-superiority hypothesis, we found even better performance for fearful faces. This may indicate paradoxically that an indirect threat, possibly shared by the subject and observer, is more salient than a direct-threat. Detection of direct threat is greatest in a view where the threat can be perceived as directed at the observer, but a similar view effect is not seen for the indirect-threat represented by fearful faces.

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Visual Search

Wednesday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

63.4048 The Importance of Slow Consistent Movement when Searching for Hard-to-Find Targets in Real-World Visual Search

Charlotte Riggs[1] (c.a.riggs@soton.ac.uk), Katherine Cornes[1,2], Hayward Godwin[1], Richard Guest[3], Nick Donnelly[1]; [1]Centre for Vision and Cognition, Psychology, University of Southampton, [2]Defence Science and Technology Laboratory, [3]School of Engineering and Digital Arts, University of Kent

Various real-world tasks require careful and exhaustive visual search. For example, searching for forensic evidence or signs of hidden threats (what we call hard-to-find targets). Here, we examine how search accuracy for hard-to-find targets is influenced by search behaviour. Participants searched for coins set amongst a 5m x 15m (defined as x and y axes respectively) piece of grassland. The grassland contained natural distractors of leaves and flowers and was not manicured. Coins were visually detectable from standing height. There was no time limit to the task and participants were instructed to search until they were confident they had completed their search. On average, participants detected 45% (SD=23%) of the targets and took 7:23 (SD=4:44) minutes to complete their search. Participants' movement over space and time was recorded as a series of time-stamped x, y coordinates using a Total Station theodolite. To quantify their search behaviour, the x- and y-coordinates of participants' physical locations as they searched the grassland were converted into the frequency domain using a Fourier transform. Decreases in dominant frequencies, a measure of the time before turning during search, resulted in increased response accuracy as well as increased search times. Furthermore, decreases in the number of iterations, defined by the total search time divided by the dominant frequency, also resulted in increased accuracy and search times. Comparing distance between the two most dominant frequency peaks provided a measure of consistency of movement over time. This measure showed that more variable search was associated with slower search times but no improvement in accuracy. Throughout our analyses, these results were true for the y-axis but not the x-axis. At least with respect to the present task, accurate search for hard-to-find targets is dependent on conducting search at a slow consistent speed where changes in direction are minimised.

63.4049 Investigating Confirmation Bias in Overt Visual Selection

Jason Rajsic[1] (jason.rajsic@mail.utoronto.ca), Daryl Wilson[2], Jay Pratt[1]; [1]Psychology, University of Toronto, [2]Psychology, Queen's University

In visual search, attention is biased towards stimuli that confirm a target's presence. Although advantageous in present/absent target searches, we have shown that search can be arbitrarily biased towards one of two target stimuli, indicating a confirmation bias for the target conjunction framed as the search template. This conclusion, however, assumes that participants performed a simple, serial visual search in our task. To test this assumption, we measured behavioral and oculomotor performance in standard and gaze-contingent versions of our dual-target search task. Searches consisted of eight colored circles, seven containing distractor letters, and one with a target letter. Participants were instructed to press one key if the target letter appeared on a circle with a specified color, and to press another key if the target letter appeared on a circle in the non-specified color. We varied the number of circles that matched the specified color and the color that the target letter appeared on. We predicted that circles matching the specified color would be attended first, as these circles would confirm the presence of the target conjunction. In the standard condition, eye positions were simply recorded to measure spontaneous search patterns. In the gaze contingent condition, letters were only shown when circles were fixated. This allowed us to assess search strategy when searches were necessarily serial. The results of the standard search demonstrated confirmation bias in oculomotor selection; both search time and number of fixations increased as more circles in the specified color were present on a trial. However, the gaze contingent condition did not exhibit confirmation bias, either in total fixations or search time. We conclude that gaze contingent search leads to different selection dynamics than search when all stimuli are visible, weakening the bias towards confirmatory stimuli.

Acknowledgement: NSERC

63.4050 Memory is Necessary in Visual Search with Limited Guidance

Chad Peltier[1] (peltie11@gmail.com), Mark Becker[1]; [1]Michigan State University, Department of Psychology

There has been an ongoing debate in the visual search literature on whether or not visual search has memory. One manipulation to test if memory is used in visual search has been to randomize the location of stimuli in an image every 111ms, which prevents observers from tracking the locations of previously inspected items. Horowitz and Wolfe (1998) used this method and found no significant differences in search slopes between static and random conditions, leading to the conclusion that visual search has no memory. Here we revisit this claim. We reason that memory in search should only be necessary for a search where there is little guidance. Thus search may appear memoryless when the search task allows for adequate guidance, but search may rely on memory in more difficult search tasks when guidance is ineffective. In Experiment 1 we replicated Horowitz and Wolfe's findings when observers searched for a T among Ls. But when we made the task a search for the same T among offset Ls observers in the random presentation condition were very close to chance performance, making it difficult to interpret search slopes. However, error rates suggest that presentation type (static v. random) interacted with stimulus type (easy v. hard) suggesting a role for memory with the harder search. In Experiment 2 we sought to increase overall accuracy to avoid chance performance. We decreased the set sizes in Experiment 2 from 8, 12, and 16, to 4, 6, and 8, while increasing the stimulus presentation duration from 111 to 160ms. Again we found that poorer accuracy in the difficult stimuli condition is moderated by the presentation type. The data suggest that memory is not necessary in searches where guidance to the target is efficient, but memory is necessary for high performance in searches with limited guidance.

63.4051 Coactivation in Peripheral Triple Conjunction Search

Ada Mishler[1] (ada_mishler@knights.ucf.edu), Mark Neider[1]; [1]Psychology Department, College of Sciences, University of Central Florida

The triple conjunction effect (TCE) is characterized by faster response time (RT) when a target is defined by a conjunction of three features than when it is defined by two features. One possible, but unaccounted for, explanation of this finding is feature coactivation, in which information from multiple features combines to reach a response threshold more quickly than separate single features. The purpose of the current study was to determine if the TCE could be attributed to feature coactivation; in addition, we explored whether or not the TCE occurs in peripheral visual search. Participants searched for the presence of a target letter in 6 counterbalanced blocks, with 4 blocks of conjunction searches (2 of color and orientation, and 2 of form and orientation) and 2 blocks of triple conjunction searches (color, form, and orientation). Each trial contained 4 or 8 letters subtending 2° by 2° on an invisible circle 8° from the center of the display. Trials were terminated if participants moved their eyes more than 2.75° from the center or did not respond within 4 seconds. Each conjunction search had 4 types of distractors, and each triple conjunction search had 3 types of distractors. A second experiment had 3 distractor types in all search conditions, to rule out distractor homogeneity effects. In both experiments, RT was faster in triple conjunction (~206 ms) than conjunction search. The Townsend Bound, a race model prediction about the redundant target RT distribution, was violated at several quantiles (5-16 of 18 quantiles, depending on experiment, set size, and target), providing evidence for coactivation when RTs were averaged across participants. Anderson-Darling tests indicated that most participants individually violated the Townsend Bound, providing further evidence for coactivation. The results suggest that the peripheral TCE is at least partially due to coactivation of target-relevant features.

63.4052 Singleton search performance predicts performance on heterogeneous displays: Evidence in support of the Information Theory of Vision

Anna Madison[1] (amadiso2@illinois.edu), Simona Buetti[1], Alejandro Lleras[1]; [1]Psychology, University of Illinois

Feature singleton search tasks have been characterized as being independent of the number of non-target elements in the display (Treisman and Gelade, 1980; Wolfe, 1994). Previous work from our lab has shown that reaction times on feature singleton search tasks in fact increase logarithmically with the number of non-target (lure) elements in the display and that the steepness of the logarithmic function is modulated by lure-target similarity (Madison, Buetti & Lleras, 2014). Duncan and Humphreys (1989) proposed an effect of distractor heterogeneity on search performance such that distractor-distractor similarity modulates search efficiency, and that distractor rejection is facilitated by the repetition of identical distractors (a mechanism called spreading suppression). Here we challenge those claims and demonstrate that in parallel search, we find no evidence for distractor-distractor effects, nor for spreading suppression (grouping of distractors). We tested search performance in displays containing multiple types of lures simultaneously (e.g., a red target amongst yellow, blue and orange lures). To evaluate performance on these mixed displays, we

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first computed estimates of logarithmic processing costs for each type of lure (obtained from a different set of subjects) when the target was presented amongst uniform fields of each type of lure (e.g., a red target amongst only orange distractors). We then used those estimates to predict what reaction times in mixed displays ought to be if (a) each item in the display was processed independently from one another and (b) the processing of all items was performed in unlimited capacity parallel fashion. In two separate experiments, with different combinations of lures, this model (a simple linear addition of logarithmic processing costs), was able to account for 95.67% and 94.41% of the variance of reaction times in mixed displays. These results argue strongly against both distractor-distractor interactions as well as spreading suppression effects in parallel search.

63.4053 **Through The Looking (Google) Glass: Attentional Costs in Distracted Visual Search** Joanna Lewis[1] (joanna.lewis@knights.ucf.edu), Mark Neider[1]; [1]University of Central Florida

Devices using a Heads-Up-Display (HUD), such as Google Glass (GG), provide users with a wide range of informational content, often while that user is engaged in a concurrent task. It is unclear, however, how such information might interfere with attentional processes. Here, we evaluated how a secondary task load presented on GG affects selective attention mechanisms. Participants completed a visual search task for an oriented T target among L distractors (50 or 80 set size) on a computer screen. Our primary manipulation was the nature of a secondary task via the use (or non-use) of GG. More specifically, participants performed the search task while they either did not wear GG (control condition), wore GG with no information presented on it, or wore the GG with a word presented on it. Additionally, we also manipulated the instructions given to the participant regarding the relevance of the information presented on the GG (e.g., useful, irrelevant, or ignore). When words were presented on the GG, we tested for recognition memory with a surprise recognition task composed of 50% new and old words following the visual search task. We found an RT cost during visual search associated with simply wearing GG compared to when participants searched without wearing GG (~258ms) and when secondary information was presented as compared to wearing GG with no information presented (~225ms). We found no interaction of search set size and GG condition, nor was there and effect of GG condition on search accuracy. Recognition memory was significantly above chance in all instruction conditions; even when participants were instructed that information presented on the GG should be ignored, there was still evidence that the information was processed. Overall, our findings suggest that information presented on HUDs, such as GG, may induce performance costs on concurrent tasks requiring selective attention.

Acknowledgement: National Science Foundation

63.4054 **When is stereopsis useful in visual search?** Emilie Josephs[1] (ejosephs@partners.org), Matthew Cain[1,2], Barbara Hidalgo-Sotelo[3,5], Gregory Cook[4], Nelson Chang[4], Krista Ehinger[1], Aude Oliva[5], Jeremy Wolfe[1,6]; [1]Visual Attention Lab, Brigham and Women's Hospital, [2]US Army Natick Soldier Research, Development & Engineering Center, [3]University of Texas, Dept of Communication Sciences and Disorders, [4]Hewlett-Packard Labs, [5]Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology, [6]Departments of Ophthalmology & Radiology, Harvard Medical School

Does stereoscopic information improve visual search? We know that attention can be guided efficiently by stereopsis, for example, to the near target among far distractors (Nakayama and Silverman, 1986), but, when searching through a real scene, does it help if that scene is presented stereoscopically? Certainly, scenes appear to be more vividly real in 3D. However, we present three experiments in which the addition of stereo did not alter scene search very much. In Experiment 1, 12 observers searched twice for 10 target objects in each of 18 photographic scenes (a 'repeated' search task). Note that observers were not cued to search for a target at a specific depth, stereopsis simply added to the vividness of the scene. Reaction time and accuracy did not differ significantly in stereoscopic and monoscopic conditions. In Experiment 2, using similar images, we found no differences between 2D and 3D conditions on time to first fixation on the target or on the average length of saccades. However, gaze durations were significantly shorter in 3D scenes. Since gaze durations are typically taken to measure processing time, this may suggest that it was easier to disambiguate surfaces and/or objects in 3D, although this advantage did not translate to benefits in search times. In a final experiment, we reduced the stimulus array to a set of colored rendered objects distributed in depth against a plain background. In this task, the addition of stereo produced shorter reaction times, even though stereo information was not predictive of target location. Our real scenes may have contained such a rich array of cues to target location that the addition of stereo may not have contributed much additional information. It may be in more difficult searches, including more challenging real world tasks, that stereopsis will be an asset.

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63.4055 **Prior knowledge of objects improves efficiency during hybrid visual search** Aaron Johnson[1] (aaron.johnson@concordia.ca), John Brand[1,2], Yvette Esses[1], Bianca Grohmann[3], H. Onur Bodur[3]; [1]Dept. Psychology, Concordia University, Montréal, Canada., [2]Cornell University, Ithaca, US, [3]John Molson School of Business, Concordia University, Montréal, Canada.

In our daily lives, visual search often involves looking for items that we have in memory, such as in the search for products to purchase in a supermarket. Previous work has shown that this type of search (termed Hybrid Visual Search) becomes less efficient – as assessed by increases in reaction time – as a function of set size of objects in the search array, and set size of the objects that are memorized. This previous work involved the memorization of random objects. But what would happen if participants already had prior knowledge of the object? For example, searching for a popular brand of cola among other products on a grocery shelf may be faster, as the participant already knows that the target object is red and white. This prior knowledge may therefore improve the efficiency of hybrid search. To test this hypothesis, we ran a hybrid visual search task on 100 participants for known North American brands, versus unknown European brands. Known and unknown brands were matched in terms of product category (i.e. each group of objects contained the same type of products). Brand knowledge (or lack thereof) was confirmed post-experiment via a questionnaire. We manipulated set size (4, 8, 16) for both items memorized, and for number of objects on the screen. All distractors were random objects. Similar to previous studies, we found set size effects for both items memorized, as well as the number of items on the screen for both known and unknown brands. Furthermore, we observed a statistically significant ($p< .01$) increase in reaction times across all set sizes for the unknown (versus known) objects. In addition, search slopes are steeper for unknown versus known objects. We therefore conclude that prior knowledge of items helps to make hybrid visual search more efficient.

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63.4056 **Guidance of Attention by Multiple Feature Values in Visual Working Memory** Andrew Hollingworth[1] (andrew-hollingworth@uiowa.edu), Valerie Beck[1]; [1]Department of Psychology, University of Iowa

Many activities depend on directing attention to several goal-relevant objects (the butter, the knife, etc.), requiring flexible configuration of attentional guidance. Visual working memory (VWM) fulfills this role by maintaining features of the current target object. Although this basic framework is well accepted, there is debate over the architecture of guidance. Several researchers have claimed that only one feature from a dimension can interact with selection, whereas others hold that multiple features can interact simultaneously with selection. Supporting the former view, van Moorselaar et al. (2014) reported that memory-based capture (the delay produced by a memory matching distractor during visual search) was eliminated when participants held more than one color in VWM. They argued that multiple features fail to guide attention simultaneously and that such maintenance might eliminate memory-based guidance entirely. In the present study, participants held one or two colors in memory, searched for an orientation-defined target, then responded to a memory probe. In the search display, two colored distractors were present on some trials, with either both, one, or neither distractor matching a remembered color. The critical contrast was between a) one remembered color, one matching distractor and b) two remembered colors, two matching distractors. If only one feature can interact with selection, capture magnitude should be limited to that generated by a single color match; if multiple features can interact with selection, capture could plausibly increase with an increasing number of color matches. We found robust memory-based capture when either one or two colors was held in VWM. Critically, the magnitude of the capture effect was larger with two matching distractors than with one, indicating that both features interacted with selection. In contrast with van Moorselaar et al. (2014), these data provide clear evidence that multiple feature values can interact with and guide attention simultaneously.

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63.4057 **Visual search for shape singletons as a function of visual hemifield** Christophe Carlei[1] (christophe.carlei@unige.ch), Dirk Kerzel[1]; [1]University of Geneva

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Asymmetries between left and right as well as upper and lower visual hemifield were investigated using pop-out search. Participants searched for a shape singleton and reported the orientation of a line segment inside the shape singleton. The target's line orientation did not pop out, whereas its shape did. Our results showed that participants were faster to respond when targets were presented in the right compared to the left visual hemifield, which is opposite to a previous report that parallel search is better in the left visual hemifield (Poynter & Roberts, 2012). Our findings are also at odds with the idea that "global" or low-resolution processing is enhanced in the left visual field, which would predict faster singleton search on the left. Possibly, the requirement to report the line orientation inside the shape singleton implied "local" or high-resolution processing, which is supposed to be better in the right visual field, where we found reaction times to be shorter. Moreover, we also found shorter reaction times in the lower compared to the upper visual hemifield, which is consistent with previous reports of enhanced visual acuity in the lower visual hemifield. In sum, our findings show that both laterality and elevation affect reaction times in search for a shape singleton. Because our task required participants to report a visual detail after parallel search, presentation of shape singletons in the right and lower hemifields, which favor high-resolution processing, results in better performance.

63.4058 **Keep on rolling: Visual search asymmetries in 3D scenes with motion-defined targets** Matthew Cain[1,2] (matthew.s.cain6.civ@mail.mil), Emilie Josephs[2], Jeremy Wolfe[2,3]; [1]U.S. Army Natick Soldier Research, Engineering, & Development Center, [2]Visual Attention Lab, Brigham & Women's Hospital, [3]Departments of Radiology & Ophthalmology, Harvard Medical School

Many simple feature searches are asymmetric; that is, finding a target defined by feature value A among distractors with value B is more efficient than finding B among A. In motion, for example, finding moving targets among stationary distractors is more efficient than finding stationary among moving (but see Rosenholtz, 2001). Most previous work involves simple motions in the 2D plane including manipulations of speed (Ivry & Cohen, 1992), rotation (Thornton & Gilden, 2001), expansion, contraction (Takeuchi, 1997), and randomness (Horowitz, et al., 2007). Here, we extend this work to environments with depth, using objects rotating around different axes in 3D environments. Observers searched for targets that were "rolling" about a horizontal axis among distractors "spinning" about a vertical axis or vice versa. Objects appeared to rest on a slanted plane and did not translate along this surface. Set sizes were 4, 8, and 12. Search for rolling targets among spinning distractors was markedly more efficient than search for spinning among rolling (RT x set size slopes: 12 vs 36 msec/item). Half of observers had target-present slopes < 10 msec/item, suggesting that "rolling" may behave like a fundamental feature such as color or orientation. More broadly, these results suggest that more features that guide attention may be waiting to be discovered as we move beyond simple stimuli in the frontal plane. Horowitz, et al. (2007). Visual search for type of motion is based on simple motion primitives. Perception, 36, 1624-1634. Ivry & Cohen (1992). Asymmetry in visual search for targets defined by differences in movement speed. JEP:HPP, 18, 1045-1057. Rosenholtz (2001). Search asymmetries? What search asymmetries? Perception and Psychophysics, 63, 476-489. Takeuchi (1997). Visual search of expansion and contraction. Vision Research, 37(15), 2083-2090. Thornton & Gilden, (2001). Attentional limitations in the sensing of motion direction. Cognitive Psychology, 43, 23-52.

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63.4059 **The role of selective attention during visual search using random dot motion stimuli.** Zeinab Bolandnazar[1] (zbolandnazar@mednet.ucla.edu), Bianca Lennarz[1], Koorosh Mirpour[1], James Bisley[1,2,3]; [1]Dept. Neurobiology, [2]Jules Stein Eye Institute, David Geffen School of Medicine, [3]Dept. of Psychology and the Brain Res. Inst., UCLA, Los Angeles, CA

Finding objects among distractors is an essential everyday skill, which is often tested with visual search tasks using static items in the display. Although these kinds of displays are ideal for studying search behavior, the neural encoding of the visual stimuli can occur rapidly, which limits the analysis that can be done on the accumulation of evidence. Searching for a target among multiple random dot motion (RDM) stimuli should allow us to study the effect of attention on the accumulation of information during visual search. We trained an animal to make a saccade to a RDM stimulus with motion in a particular direction (the target). The animal began the task by fixating a central square. After a short delay, it changed to a dotted hollow square and one, two or four RDM stimuli appeared equally spaced in the periphery for 700 ms. The animal was rewarded for looking at the target, if present, or for maintaining fixation if the target was absent from the display. In the spread attention condition, all the dots in the RDM stimuli were the same color. In the focused attention condition, the color of the fixation square and the dotted hollow square matched the color of the dots in one RDM stimulus, which was a 100% valid cue. We varied the coherence of the RDM stimuli for each condition from 65 to 100% (100 ms limited lifetime). At the lower coherences, there were strong effects of set size and attention condition on both performance and reaction time. Our data show that using a RDM visual search task allows us to clearly illustrate the role of attention in the accumulation of perceptual evidence, which increases response accuracy and shortens reaction time.

63.4060 **Involuntary semantic bias during search for words and word pairs** Chia-Chien Wu[1,2] (cchienwu@gmail.com), Nada Attar[1], Marc Pomplun[1]; [1]Department of Computer Science, University of Massachusetts at Boston, [2]Center for Computational Neuroscience and Neural Technology, Boston University

Wu, Wang and Pomplun (2014) found that observers can use spatial dependency among objects for semantic guidance during natural scene inspection even when the scene gist is not available. This result suggests that observers are actively seeking semantic information to help visual performance. Here we investigate whether semantic association among objects is still used when there is no scene context, or even when using semantic information would not facilitate task performance. In Exp. 1, observers were asked to search displays of multiple object labels for the only repeated label. The objects referred by the labels could come from a single context set (ex. kitchen), from two context sets (ex. kitchen and bathroom) or from three context sets (ex. kitchen, bathroom and park). Subsequently, observers were asked whether a specified label was the repeated label or not. Interestingly, even though the task can be accomplished without accessing the meaning of each label, search accuracy improved and reaction time became faster when more context sets were shown. To test whether this bias was due to memory encoding which was indispensable in Exp. 1, we minimized the memory load in Exp. 2, which was a conventional search experiment with the target being indicated by either its label (label cue) or its image (image cue) before the search. The search displays were similar to Exp. 1 except that each label in the display only appeared once. The results show that, in the label cue condition, observers still had better search accuracy and shorter search duration (by up to 150 ms) when there were more context sets. Counterintuitively, this semantic association bias disappeared in the image cue condition. Our results demonstrate that the use of semantic association is not completely under voluntary control and operates differently in lexical and image processing.

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63.4061 **Intensity of Visual Search Asymmetry Depends on Physical Property in Target-Present Trials and Search Type in Target-Absent Trials** Yoshiyuki Ueda[1] (ueda@educ.kyoto-u.ac.jp), Shingo Kurosu[2], Jun Saiki[2]; [1]Kokoro Research Center, Kyoto University, [2]Graduate School of Human and Environmental Studies, Kyoto University

Visual search asymmetry is a phenomenon in which search efficiency changes in accordance with a swapping target and distractor, and which has been observed with a variety of target types. Previous studies assume that search asymmetry is achieved due to the difference of activation, which is calculated by considering each feature separately (e.g., color, orientation, and intensity). According to this prediction, for each participant, search asymmetry would be consistent across a target type, if the target is defined by the same feature dimension. In this study, we used four types of stimulus sets: circle/circle with line, vertical/tilted lines, longer/shorter lines, and familiar/mirror-reversed Chinese characters. Circle/circle with line search is based on the appearance of one element, vertical/tilted and longer/shorter line searches are based on the difference in the feature amount, and Chinese/mirror-reversed Chinese character search is based on familiarity. Moreover, the first two stimulus sets lead to pop-out search, whereas others lead to inefficient search. For the vertical/tilted line search and familiar/mirror-reversed Chinese character search, the target was defined by the difference of orientation of a line. The results indicated that although search asymmetry was observed in all stimulus types, personal performances were inconsistent across target types and target presence. An exploratory factor analysis and correlation analysis demonstrated that search asymmetries in target-present and absent trials were due to the different structures of the factors. Specifically, for target-present trials, asymmetries in orientation and Chinese character searches were correlated, whereas for target-absent trials, asymmetries in circle/circle with line and orientation searches, and those in line length and Chinese character searches were correlated, respectively.

These results suggest that i) consistency in the intensity of search asymmetry depends on the feature property in the target-present trials, and ii) the search asymmetry in target-absent trials is affected by the search strategy.

63.4062 **Search in actively organized spaces** Grayden Solman[1] (grayden@psych.ubc.ca), Alan Kingstone[1]; [1]University of British Columbia

The study of memory in search has emerged from the observation that real world environments possess an inherent temporal stability, whereby an object's past position is often predictive of its future position. Much work has explored the various factors which encourage or discourage observers from leveraging this stability to help guide search. A related, but comparatively understudied property of real search environments is that the arrangement of objects is frequently produced and actively modified by the searchers themselves. Here we introduce a novel task designed to study this interplay between organization and search. We demonstrate how order emerges in search environments through both incidental and deliberate behaviours, how the sequential statistics of target streams come to be reflected in spatial groupings, and how individual differences in organizational tendencies are related to performance.

Acknowledgement: NSERC

63.4063 **Interpersonal competitiveness and improvement in reaction time in a visual search task** Carissa Romero[1] (carissaromero7@live.com), Kandace Markovich[1], Yvonne Johnson[1], Eriko Self[1]; [1]Department of Psychology, California State University, Fullerton

The goal of this study was to seek the potential relationship between interpersonal competitiveness and improvement in reaction time in a visual search task. Interpersonal competitiveness is a desire to win or do better than others. The participants' interpersonal competitiveness was measured using the Competitiveness Index (CI), which measures interpersonal competitiveness at trait level. The stimulus consisted of multiple red or green circles (3.5° in diameter) or squares (3.2° per side) that were presented on a computer screen. Each shape contained a white line segment (1.5° x 0.2°) in its center. The spatial configuration of the shapes was always circular (aligned on an imaginary circle of 14° radius). The total number of shapes was 8, 12, 16 or 20. The participant's task was to judge the orientation of the line segment (vertical or horizontal) in a target shape that is unique and different from all the others as soon as possible. Reaction time and response accuracy were recorded. Accuracy was used as a criterion and set at a threshold of 90%. Participants ran a first session and were immediately shown their results. They then completed the CI. Participants were informed that their reaction time would be rank-ordered and compared among all the participants. Finally, the participants ran a second session. They were categorized into two groups based on their CI score: the competitive group and the noncompetitive group. We hypothesized that participants with a high CI score will show a greater improvement in reaction time from session 1 to session 2. A mixed ANOVA indicated that the competitive group (M = 273 ms) showed a significantly higher improvement of reaction time from session 1 to session 2 compared to the noncompetitive group (M = 205 ms), $F(1, 93) = 5.035$, $p = .027$, supporting our hypothesis.

63.4064 **For better or worse: Prior trial accuracy affects current trial accuracy in visual search** Jonathan Winkle[1] (jonathan.winkle@duke.edu), Adam Biggs[1], Justin Ericson[1], Stephen Mitroff[1]; [1]Center for Cognitive Neuroscience, Duke University

Life is not a series of independent events, but rather, each event is influenced by what just happened and what might happen next. However, many research studies treat any given trial as an independent and isolated event. Some research fields explicitly test trial-to-trial influences (e.g., repetition priming, task switching), but many, including visual search, largely ignore potential inter-trial effects. While trial-order effects could wash out with random presentation orders, this does not diminish their potential impact (e.g., would you want your radiologist to be negatively affected by his/her prior success in screening for cancer?). To examine biases related to prior trial performance, data were analyzed from airport security officers and Duke University participants who had completed a visual search task. Participants searched for a target "T" amongst "pseudo-L" distractors with 50% of trials containing a target. Four set sizes were used (8,16,24,32), and participants completed the search task without feedback. Inter-trial analyses revealed that accuracy for the current trial was related to the outcome of the previous trial, with trials following successful searches being approximately 10% more accurate than trials following failed searches. Pairs of target-absent or target-present trials predominantly drove this effect; specifically, accuracy on target-present trials was contingent on a previous hit or miss (i.e., other target-present trials), while accuracy on target-absent trials was contingent on a previous correct rejection or false alarm (i.e., other target-absent trials). Inter-trial effects arose in both population samples and were not driven by individual differences, as assessed by mixed-effects linear modeling. These results have both theoretical and practical implications. Theoretically, it is worth considering how to control for inter-trial variance in statistical models of behavior. Practically, characterizing the conditions that modulate inter-trial effects might help professionals searchers perform more accurately, which can have life-saving consequences.

63.4065 **An individual differences approach to multiple-target search errors: Errors correlate with attentional deficits** Stephen Adamo[1] (sha10@duke.edu), Matthew Cain[2], Stephen Mitroff[1]; [1]Department of Psychology & Neuroscience, Center for Cognitive Neuroscience, [2]U.S. Army Natick Soldier Research, Development, & Engineering Center

Multiple-target visual searches, where more than one target can be present within a single search array, are especially error-prone such that a second target is more likely to be missed after a first target has been detected. This is a serious concern for many critical searches (e.g., radiology, baggage screening) and also raises interesting theoretical questions. Increasingly, evidence supports a resource depletion account of these errors—a first target consumes attentional resources leaving less available to process additional targets. The current study tested this account by comparing 60 participants' multiple-target search performance to two other attention-demanding tasks: attentional blink (AB) and vigilance. The multiple-target search task had 1 or 2 targets per trial intermixed with distractors, and participants clicked on each target they found. The AB task presented two targets (letters) 100–800ms apart in a rapid serial visual presentation (RSVP) stream of distractors (numbers), and participants reported which targets they saw. The vigilance task presented targets (the letter O) in a RSVP stream with distractors (forward or backwards letter Ds) on top of a noise mask, and participants were to indicate every time the target appeared. Second target accuracy in the multiple-target search task significantly correlated with (1) a measure of how long it took second target accuracy in an AB task to recover from the blink, and (2) sensitivity (d') in the vigilance task. Participants who took longer to recover from an AB and who were less vigilant had more second-target misses in a multiple-target search task. Taken together, these results support a resource depletion account of multiple-target search errors in that they highlight an attentional underpinning; errors in AB and vigilance tasks are believed to reflect a deficit in attentional resources and the magnitude of these deficits significantly related to the magnitude of the multiple-target search errors.

Face Perception: Emotion 2

Wednesday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

63.4066 **Spatial integration and nonlinear transduction of emotional expression** Katie Gray[1] (k.l.h.gray@reading.ac.uk), Tessa Flack[2], Daniel Baker[2]; [1]Department of Psychology, University of Reading, UK, [2]Department of Psychology, University of York, UK

Basic visual features such as contrast are processed in a highly nonlinear fashion, resulting in 'dipper' shaped functions in discrimination experiments. Previous work has applied a similar paradigm to investigate the representation of higher level properties such as facial identity (Dakin & Omigie, 2009, Vision Res, 49, 2285-2296). Here we ask whether emotional expressions are processed nonlinearly by measuring discrimination thresholds for six emotions (angry, happy, sad, fear, disgust, surprise) morphed along a continuum relative to neutral. Using a 2IFC paradigm, we estimated discrimination thresholds relative to six 'pedestal' morph levels between 0% and 75%. The participants' (N=5) task was to indicate which of two faces (pedestal, or pedestal plus increment) conveyed the strongest expression. We found evidence of facilitation at low morph levels (~15%) and masking at higher levels (>60%), indicating the existence of a nonlinearity in the neural representation of expression, comparable to that reported for lower level visual features. We then asked whether facial features are integrated across the face before or after this nonlinearity by keeping the expression in one half of the face (top or bottom) fixed at neutral, and applying the pedestal and increment expressions to the other half. Sensitivity decreased by around a factor of two along the entire dipper function, relative to the whole-face condition, suggesting that facial expressions are integrated before nonlinear transduction. Finally we assessed the amount of interference between the two halves of the face, by fixing the expression in one half at a given level (the 'mask'), and applying the target increment to the other half. This produced a strong masking effect, such that target expressions

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needed to approach the level of the mask to be detected. This is evidence for competition between the neural representations of different facial features.

63.4067 **Individual differences in antisocial and prosocial traits predict perception of dynamic expression** Alison Campbell[1] (campbel1@uvic.ca), James Tanaka[1]; [1]University of Victoria, British Columbia

Successful everyday, social interactions are mediated by the accurate perception of dynamic facial expressions. For example, the decoding of distress cues have been shown to inhibit antisocial behaviour while simultaneously eliciting empathetic responses. The import of this recognition-behaviour connection has been revealed by psychiatric research demonstrating that disorders characterized by interpersonal deficits are associated with impairments in processing facial affect. This area of research has generated speculation that the neurocognitive mechanisms specific to social behaviour are also pivotally involved in expression recognition, but it is unknown whether this relationship also holds in nonclinical populations. To explore this question, we examined how individual differences in antisocial traits relate to the recognition of facial affect. Antisocial behaviour was assessed using the Inventory for Callous-Unemotional Traits (ICU, Kimonis et al., 2008), a scale which designates a subgroup of antisocial individuals who are more likely to show deficits in processing emotional stimuli relative to other antisocial individuals. Perceptual sensitivity to facial affect was probed using a Dynamic Expression Recognition Task (DERT, Deriso et al., 2012) in which participants were shown 75ms, 150ms, or 225ms reveals of a dynamic face morph progressing from neutral to one of sad, happy, angry, fear, surprise, or disgust. The main finding was that participants who scored higher in callous-unemotional traits were significantly less accurate in expression recognition compared to participants who scored low on the ICU. This result supports the hypothesis for a common mechanism underlying affect recognition and antisocial behaviour across clinical and nonclinical groups, while also highlighting the diagnostic potential of facial affect processing.

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63.4068 **Valence, expression and identity effects in the affective priming paradigm** Shanna Yeung[1] (shannayeung@gmail.com), Alisdair Taylor[1], Cristina Rubino[1], Jason Barton[1]; [1]Departments of Medicine (Neurology), Ophthalmology and Visual Sciences, Psychology, University of British Columbia

Background: In the affective-priming paradigm, a briefly-presented facial expression (prime) facilitates reaction time to identify a subsequent facial expression (target) if the prime and target are congruent in emotional valence (i.e. both positive or both negative). However, some studies have found that facilitation is more specific, only occurring when the prime and target share the same emotion (e.g. both angry). Objective: We investigated first whether reaction times to identify expressions showed valence priming effects that were modulated by whether the specific emotion was congruent between the prime and target. Second, we examined whether effects differed when the prime and target were faces of different people, a situation which minimizes low-level image effects. Methods: 22 subjects were asked to indicate if the valence of a target facial expression was positive or negative. A prime (no prime, angry, fearful, happy) was shown for 85ms, preceded and followed by masks, and then a target expression (angry, fearful, or happy) was shown for 100ms. We examined whether priming by negative emotions (angry or fearful) differed from positive emotions (happy). Next we assessed whether there was an interaction between specific expressions of the prime and of the target. Results: We replicated the valence effect of priming, showing that subjects were faster to respond to positive emotions with a positive prime, and negative emotions with negative primes. Similar effects were obtained when the faces of the prime and target differed in identity. Examination of effects on negative targets showed no interaction between prime and target, in either same or different-identity blocks. Conclusion: Expression-priming effects are related to emotional valence rather than specific expressions. Along with the finding that the effects do not depend on facial identity, this indicates a high-level origin of the priming effect, rather than an effect generated by low-level image properties.

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63.4069 **Blocking facial mimicry reduces perceptual sensitivity for facial expressions** Alberta Ipser[1] (alberta.ipser.1@city.ac.uk), Richard Cook[1]; [1]Department of Psychology, City University London

Built on models of 'action understanding', motor theories of expression perception propose that facial simulation, a process similar to covert imitation, aids perception and interpretation of others' facial expressions. As predicted by these accounts, some reports suggest that blocking facial mimicry impairs expression recognition. However, these reports have been criticized and motor theories remain controversial. Crucially, it remains to be determined whether the labeling errors observed reflect a loss of perceptual sensitivity - a genuine perceptual phenomenon - or whether they are a product of response bias. The current study addressed this question using a novel psychophysical paradigm, where observers judged whether smiles drawn from a morph continuum were sincere or insincere. In Experiment 1, we confirmed that cues from both the eye and mouth regions contribute to sincerity judgments. Experiment 2 measured discrimination of smile sincerity across free-viewing and blocked-mimicry conditions. In the blocked-mimicry condition, participants pronounced vowel sounds during stimulus presentation, thereby loading the motor system and preventing mimicry. Each participant's responses were modeled by fitting psychometric functions. Sensitivity to changes in smile sincerity and bias were inferred from the slope and the point of subjective equality (PSE), respectively. Motor interference significantly decreased sensitivity relative to baseline, but did systematically affect bias. Experiment 3 examined whether the motor manipulation has similar effects on judgments of facial gender, a task equated for difficulty but which is not thought to recruit motor processes. Neither slope nor PSE estimates for gender judgments were affected, indicating that the loss of sensitivity seen in Experiment 2 is relatively specific to judgments of expression and does not reflect generic distraction. These findings accord with the view that judgments of facial expression benefit from motor contributions to perception.

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63.4070 **Facial mimicry is modulated by implicit and explicit emotion consistency.** Alexander Kirkham[1] (alexander.kirkham@york.ac.uk), Amy Hayes[2], Steven Tipper[1]; [1]Dept. of Psychology, University of York, UK., [2]School of Sport, Health and Exercise Sciences, Bangor University, UK.

Adapting and integrating to our current environment through physical and social imitation of those around us, such as mimicking facial emotion, often seems to be an automatic and unconscious process. We examined whether the consistency of a person's emotional response can be learned and influence later emotional mimicry. For example, some individuals always express consistent emotions, such as smiling at a positive image whereas other people emote inappropriately, where their emotion is inconsistent, such as smiling at negative images. Is such individual consistency encoded in to memory influencing subsequent mimicry when these consistent and inconsistent people are encountered at a later time? In Study 1 participants implicitly learnt to associate 4 faces as showing consistent emotions, and 4 different faces as showing inconsistent emotions. In Study 2 participants explicitly associated all faces as showing either consistent (2a) or inconsistent (2b) emotions. In both studies participants had facial EMG responses recorded (taken from the corrugator supercilii and zygomaticus major muscles) whilst viewing and categorising each face as smiling or frowning. These recordings were taken to assess how much mimicry was shown toward each face, in relation to the expression and the emotion-consistency of that specific face. In Study 1 EMG results exhibited highly similar mimicry to both consistent and inconsistent emotion faces, despite implicit learning of individual identities and associated emotion consistency. EMG results in Study 2a showed traditional strong mimicry effects to all face emotions. In Study 2b mimicry towards frowns remained but was greatly reduced compared to 2a. No mimicry was shown toward smiles. We conclude that facial mimicry is an automatic process that is nevertheless influenced by context, especially if the context is explicitly created.

Acknowledgement: ESRC

63.4071 **Happiness is in the mouth of the beholder and fear in the eyes.** Louise Delicato[1] (Louise.Delicato@sunderland.ac.uk), Rosie Mason[1]; [1]Department of Psychology, University of Sunderland

A temporal two-interval forced-choice paradigm is used to evaluate the relative strength of the visual signals conveyed by the eyes and the mouth in happy and fearful facial expressions. Stimuli were black and white images of faces with a neutral, happy or fearful expression. The happy and fearful visual signals were conveyed by the eyes, the mouth or by the whole face. A range of signal strengths (0-100%) were created by morphing the neutral and expressive images. One interval contained the neutral face (0%) and the other the expressive face (varied from 0 – 100%, presented for 200ms).

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Observers indicated the interval with the more expressive image. Performance increased from chance (50%) to 100% correct as signal strength increased in all conditions. Psychometric functions for happy expressions were shifted to the left of those for fearful expressions indicating that observers are more sensitive to happy expressions. This suggests that the emotion signals conveyed by a happy face are more salient than those conveyed by a fearful face. For happy expressions, psychometric functions for conditions with an expressive mouth were shifted to the left of those in which only the eyes were expressive. For fearful expressions, psychometric functions for conditions in which the eyes were expressive were shifted to the left of those in which only the mouth was expressive. This suggests that the visual signals conveyed by the mouth are more salient for happy facial expressions and the visual signals conveyed by the eyes are more salient for fearful expressions. Future research is aimed at understanding the extent to which this perceptual difference can be explained by the nature of the low level visual signal or higher cognitive function.

63.4072 Detecting emotions is easier in less realistic faces.

William Kendall[1] (will.kendall@psych.ubc.ca), Alan Kingstone[1], Rebecca Todd[1]; [1]Department of Psychology, University of British Columbia

In investigations of emotional expression, schematic faces are attractive stimuli because they can be precisely controlled. However, these stimuli are then often treated as comparable to real faces, which could be problematic. Previous research has shown that schematic faces are processed less holistically than naturalistic faces (Prazak, E.R., & Burgund, E.D., 2014) and that the deficits autistic patients have in emotion detection may not extend to cartoon faces (Rosset, D.B., Rondan, C., Da Fonseca, D., Santos, A., Assouline, B., & Deruelle, C., 2008). These examples suggest that in some cases, cartoon faces are processed differently. We hypothesized that higher levels of schematization increase communicability of emotion. Here we tested participants in a discrimination task with emotional faces presented with varying degrees of schematization: in addition to unmanipulated greyscale photos, we applied rotoscoping software to generate two heavy outlined "cartoon" versions of the same photographs with high vs. low contrast. To vary featural complexity, simple cartoon faces underwent the same treatment to create two schematic stimulus types. The resulting stimulus set contained five types of faces - three photo-based and two schematic - which non-linearly spanned a range from photos to simple cartoons. In each trial, participants were presented with a rapidly presented face (17, 33, 50, and 66 ms) and instructed to identify which emotion was present. At 17 ms, expressions in photos were detected above chance. However, for every stimulus type moving away from photos towards cartoons, accuracy increased. That is, at shorter presentation times, as contrast increased and featural complexity decreased, discrimination became more successful. These results suggest that, as faces are represented less realistically, their informational content is more easily accessed. Moreover, our data also suggest that both contrast and featural complexity influence how easy it is to detect emotions in an image.

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63.4073 A Comparison of Perceptual and Emotional Expression Processing Between Real and Line-drawn Faces

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Face processing and recognition has been one of the most productive research areas in cognitive science over the past four decades, and in most studies images of real faces are the focus of inquiry. Due to the proliferation of technology in social media in recent years, we have witnessed a significant surge of using line-drawn faces and expressions along with their real-face counterparts for purpose of communication. In two experiments we examined how line-drawn faces may differ from real faces in terms of perceptual and emotional expression processing. In Experiment 1, we used the part-whole task and showed that, compared to real faces, line-drawn faces were processed in a part-based manner similar to non-face objects (i.e., houses). In Experiment 2, we tracked participants' eye movements while they were asked to perform a delayed matching-to-sample task, in terms of expressed emotion, where images of either real or line-drawn faces were used as sample. The results indicated that while participants were more efficient at extracting expression-related information from real than from line-drawn face, the manner in which that information was extracted was actually quite similar between real and line-drawn faces. These findings might explain why it has become a common practice to exaggerate portrayed expression in line drawn faces: To overcome the inherently vague signals of emotional expression.

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63.4074 Impact of Peripherally Presented Emotional Expressions on Subsequent Target Detection

Brandon Coffey[1] (brandon.coffey972@topper.wku.edu), Siera Bramschreiber[2], Andrew Mienaltowski[1]; [1]Department of Psychological Sciences, Ogden College of Science and Engineering, Western Kentucky University, [2]Department of Psychology, College of Education and Behavioral Sciences, Western Kentucky University

Emotional stimuli have the ability to capture our attention and influence how we perceive our surroundings. Previous research demonstrates that fearful facial expressions can impair the perception of elementary visual features of a subsequent visual target while simultaneously improving the perception of the target's rapidly varying temporal features. These results have been attributed to amygdalar enhancements of magnocellular visual inputs. The current study extends prior research by examining the extent to which angry and happy facial expressions enhance or inhibit the detection of a temporal or spatial gap in a Landolt circle stimulus. Participants (N = 38, ages 18-23) were presented with angry and neutral facial cues or with happy and neutral facial cues followed by a variation of a Landolt circle target. Facial cues appeared at 8 to 10 degrees away from a central fixation point in the periphery, and Landolt circle targets appeared at 4 degrees from fixation. Some participants monitored the circle target for a temporal gap (or flicker), and others monitored the circle target for a spatial gap (or absent segment). Participant perception was tracked across gap and no gap trials using a signal detection measure of discriminability. Overall, participants displayed an emotion-related enhancement in detecting a spatial gap in a Landolt circle target when it was proceeded by an angry cue relative to a neutral cue, and they displayed an emotion-related enhancement in detecting a timing gap in a Landolt circle target when it was proceeded by a happy cue relative to a neutral cue. These findings suggest that the impact that emotional stimuli presented in the periphery can have on subsequent target detection varies as a function of emotion and as a function of the type of perceptual judgment being performed. Consistency and inconsistency of findings with prior research will be discussed.

63.4075 The impact of an acute social stress on the use of visual information in facial expression categorization

Camille Daudelin-Peltier[1] (dauc04@uqo.ca), Caroline Blais[1,2], Hélène Forget[1], Andréa Deschênes[1], Daniel Fiset[1,2]; [1]Département de psychologie, Université du Québec en Outouais, [2]Centre de recherche en neuropsychologie et cognition

Langner et al. (2009) investigated the impact of social anxiety on the use of visual information in angry vs. neutral emotion recognition using Bubbles (Gosselin & Schyns, 2001). They found that both groups used mostly the same facial features in higher spatial frequencies, but that socially anxious participants relied more than nonanxious participants on low spatial frequencies. Here, we investigated if inducing an acute social stress alters the visual strategies for facial expression categorization using the Bubbles method. Twenty-five men were first submitted to a social stress (i.e. Trier Social Stress Test for Groups) or a control condition (i.e. identical setting save for the socio-evaluative threat component) in a counterbalanced order. Sparse versions of emotional faces (angry, fearful, happy or disgust) were created by sampling facial information at random spatial locations and at four spatial frequency bands. Following the stress induction (or control) phase, participants categorized 500 sparsed stimuli on average. The accuracy was maintained at 62.5% for each facial expression by adjusting the number of bubbles on a trial-by-trial basis. The visual information useful for the task was determined using an analysis procedure that amounts to a multiple linear regression on the bubbles masks and on the participant's response accuracy. This analysis was performed for each condition separately. The facial features useful in high spatial frequencies were similar for both conditions (e.g. the eyes for fear and angry, the mouth for happy). However, the stress condition induced a bias for the use of lower spatial frequencies for angry, fear and happy. For disgust, we replicated Smith et al. (2005) in the control condition, i.e. the importance of the nose winkler. However, in the stress condition, this bias disappeared in favour of the lips. Our results show that an social stress alters the perception of facial expressions of emotions.

63.4076 Facial expression recognition impairment following acute social stress

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Recently, von Dawans et al. (2012) showed that stress exposure increases facial trustworthiness judgements. Given the relation between trustworthiness and the presence/absence of subtle visual features related to happiness and anger (Oosterhof & Todorov, 2008), we verified if social stress modulates the visual perception of facial expressions. Twenty-nine men were submitted to a social stress (i.e. Trier Social Stress Test for Groups) or a control condition (i.e. identical setting save for the socio-evaluative threat component) in a counterbalanced order. Facial expression recognition was then measured using a homemade version of the 'facial expression megamix' (Young et al.,1997) in which each of the six basic facial expressions plus neutrality were morphed with each other at seven different percentages (from 14/86 in intervals of 12%). The task was to decide which expression the image most resembled. Recognition accuracy for each facial expression when it was dominant in the morph (i.e. over 50%) was first computed. We found that social stress modulates accuracy scores only for disgust (Mstress= 81%; Mcontrol=89%; t(28)=-3.20, p=0.028; bonferroni corrected). We also verified if the emotion signal necessary to detect each facial expression when they were part of the morph was modulated by stress. For each facial expression, we calculated, separately for each percentage level, the proportion of times that it was correctly identified as being part of the morph. This produced a curve on which we fitted a cumulated gaussian to find at what percentage level an expression was detected 50% of the time. Our results show that stress decreased the sensitivity to disgust (t(28)=3.55, p=0.007; bonferroni corrected). These results indicate that an acute social stress alters the perception of facial expressions, more specifically it decreases the sensitivity to the disgust expression.

63.4077 **Pubertal Development and Emerging Sensitivity to Complex Facial Expressions** Natalie V. Garcia[1] (nvg109@psu.edu), K. Suzanne Scherf[1,2]; [1]Psychology, The Pennsylvania State University, [2]Social Science Research Institute, The Pennsylvania State University

Complex facial expressions provide critical social signals about nuanced social emotional behavior (Baron-Cohen et al. 1997). Given the increasing evidence of heightened sensitivity to social signals during adolescence, we evaluated the influence of adolescent development, and pubertal development specifically, on emerging perceptual sensitivity to detect complex expressions. Using an existing model (Scherf et al, 2012), we hypothesized that pubertal development would disproportionately influence sensitivity to perceive complex compared to basic emotional expressions. To evaluate this hypothesis, we tested prepubescent children (6-8 years), adolescents matched on age who varied in pubertal development (11-14 yrs), and sexually mature adults (18-25 yrs) in a perceptual sensitivity paradigm to determine the just noticeable difference in expression between two versions of the same face identity. For each of four expressions (two positively and two negatively valenced), we created 13 morphed versions of the face that included increasingly more perceptual cues to the expression. Participants were presented with pairs of faces (original face vs. morphed face) in a staircase procedure and they determined which of the two faces was more expressive. For both positively and negatively valenced expressions, pre-pubescent children and early pubertal adolescents exhibited higher thresholds for the complex compared to the basic expressions (see attached figure), meaning that they required significantly more perceptual cues to detect complex than basic expressions. However, age-matched adolescents in later puberty and sexually mature adults exhibited comparable thresholds for both types of expressions. These findings support our hypothesis that emerging perceptual sensitivity to detect complex expressions is fundamentally influenced by pubertal development.

Acknowledgement: National Science Foundation Graduate Research Fellowship

3D Perception: Neural mechanisms

Wednesday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

63.4078 **Adaptation decorrelates object representations: Evidence from Multivoxel Pattern Analysis** Marcelo Mattar[1] (mattar@sas.upenn.edu), Maria Olkkonen[1], Geoffrey Aguirre[2], Russell Epstein[1]; [1]Department of Psychology, University of Pennsylvania, [2]Department of Neurology, University of Pennsylvania

The neural response to visual stimuli is typically attenuated when similar or identical items have been recently encountered—an effect known as neural adaptation. It has been suggested that adaptation may serve to decorrelate neural responses across the set of representational channels. Empirical evidence for this idea, however, is sparse. Here we used multivoxel pattern analysis to test whether adaptation induces decorrelation for object representations. We constructed a parametric 3D shape-space whose axes corresponded to different frequencies and orientations of sinusoidal modulations of a sphere. Two distinct reference shapes (A and B) were selected from this space, along with a "cloud" of fifty stimuli around each reference. BOLD fMRI data were collected over 8 runs. Each run started with a pre-adaptation phase (60s), where subjects were presented with an RSVP stream of stimuli drawn randomly from one of the clouds (cloud A in 4 runs; cloud B in 4 runs; counterbalanced). Afterwards, each of the 16 trials started with a top-up adaptation phase (5s) followed by a test stimulus (1s) at a jittered (4-7s) ISI. The test stimuli throughout all runs were four items, two drawn from cloud A, and two drawn from cloud B. To quantify decorrelation, we extracted the patterns for these four items in each scan run and performed a similarity analysis. Results indicate that the patterns evoked by two similar shapes (e.g. A1 and A2) were less correlated when these shapes were preceded by stimuli from the corresponding cloud than when they were preceded by stimuli from the other cloud, in both anterior and posterior portions of the Lateral Occipital Complex (defined by an independent functional localizer). These results demonstrate that adaptation decorrelates representations in object-selective regions.

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63.4079 **Cortical responses to congruent and incongruent stereo cues for objects on a collision path with the observer** Jac Billington[1] (j.billington@leeds.ac.uk), John Wann[2]; [1]School of Psychology, University of Leeds, Leeds, LS2 9JT, United Kingdom., [2]Department of Psychology, Royal Holloway, University of London, Egham Hill, Egham, Surrey, TW20 0EX, United Kingdom.

It has been established that binocular motion and visual looming are two primary sources of information for judging object motion. These cues are normally congruent when viewing motion in natural scenes. We explored the cortical responses to visual collision events that were presented via stimuli that changed in size (looming) or stereo-depth (binocular motion), or both. In particular we examined the differences in cortical response when the looming and binocular cues were congruent or incongruent in the collision information they provided. A stereoscopic goggle system was used within the fMRI environment and allowed us to present looming and disparity cues in isolation, or in congruent and incongruent combinations. Following univariate analysis it was found that incongruent looming and binocular motion cues elicited additional activation in cortical areas known to process error and locate objects in spatio-topic coordinates. Visual regions which showed high predictor values using multivariate pattern analysis concurred with research which has highlighted areas V1 - V3 and V6 in disparity processing. Results are discussed in terms of visual, cognitive and motor responses to seeing incongruent cues.

Acknowledgement: BBSRC

63.4080 **Vergence, accommodation, and apparent viewing distance in the perception of depth from motion parallax** Mark Nawrot[1] (mark.nawrot@ndsu.edu), Brian Connelly[1], Keith Stroyan[2]; [1]Center for Visual and Cognitive Neuroscience, Department of Psychology, North Dakota State University, [2]Math Department, University of Iowa

For fixed binocular disparity (BD), the relationship between viewing distance and relative depth is well known, the distance-square law. Similarly, perceived depth from motion parallax (MP) varies with viewing distance. Here, depth of a non-fixated object (d) varies with distance to the point of fixation (f), the retinal image velocity of the object (dθ), and velocity of the pursuit eye movement required to maintain fixation (dα). The relationship, termed the motion/pursuit ratio, is: $d = d\theta/d\alpha * f$. Here we investigated how the cues of vergence and accommodation contribute to apparent viewing distance in MP by assessing perceived depth magnitude. Participants viewed translating random-dot MP and stationary BD stimuli at 36, 54, and 72 cm, with each stimulus type depicting a range of motion/pursuit ratios and disparities. MP stimuli were presented monocularly to the right eye and to ensure correct vergence the fixation spot of this stimulus was fused with a lone fixation spot presented to the left eye. In both conditions vergence was manipulated with a mirror stereoscope and calibrated to simulate a particular vergence angle with a dual-laser system. Accommodative load was manipulated with trial lenses. Perceived depth magnitude was indicated by the distance between the participant's thumb and forefinger measured with a linear potentiometer. This method of perceived depth measurement was characterized by both large inter-observer differences and large intra-observer variability. Perceived depth magnitudes varied linearly with disparity, and with motion/pursuit ratios having the same pursuit velocity. Changes in vergence changed perceived depth magnitude, but less than the equivalent change in actual viewing distance. Adding a concomitant change in accommodative load did not appear to change perceived depth. Perceived depth from MP is linked to apparent viewing distance, which is not determined solely by vergence and accommodation. Furthermore, inter-digit-distance is a noisy estimator of perceived depth.

Acknowledgement: NIH COBRE P20 GM103505

63.4081 Alcohol intoxication does not increase the temporal processing interval for the perception of depth from motion parallax

Shanda Lauer[1] (Shanda.Lauer@my.ndsu.edu), Mark Nawrot[1]; [1]Center for Visual and Cognitive Neuroscience, North Dakota State University

The unambiguous perception of depth from motion parallax (MP) occurs with very brief temporal processing intervals. Observers require MP stimulus presentation durations on the order of 30 msec, which is increased to 75 msec with a high-contrast pattern mask. Since MP relies on an extra-retinal signal from the pursuit eye movement system, this later interval (with the mask) likely represents the time required to generate an internal signal regarding the impending pursuit signal. Alcohol intoxication is known to affect the pursuit eye movement system, the basis for a roadside sobriety test. Alcohol intoxication also increases MP thresholds, presumably due to pursuit dysfunction disrupting the integration of internal pursuit and retinal motion signals. Here we explored an alternative explanation: ethanol intoxication increases the temporal processing interval necessary for the unambiguous perception of depth from MP. To investigate this hypothesis, 16 participants completed a series of motion parallax and motion perception tasks while sober and moderately intoxicated (mean peak BAC = 0.084). These computer-generated tasks were used to assess the minimum temporal interval required to determine depth sign, stimulus window movement, and stimulus dot movements, with and without a subsequent stimulus mask. To avoid threshold issues, MP stimuli depicted stimulus geometry of about 28 cm. A step-ramp stimulus was used to assess pursuit gains and latencies at the stimulus velocities used in the psychophysical tasks. The temporal integration interval required for each of these tasks was not affected by alcohol intoxication. Curiously, while participants required the same stimulus presentation durations in both sober and intoxicated conditions, pursuit onset latency was affected by alcohol intoxication. We conclude that the ethanol intoxication does not affect the time it takes the visual system to create and integrate the component signals required for the unambiguous perception of depth from MP.

Acknowledgement: Centers of Biomedical Research Excellence (COBRE) grant: NIH P20 GM103505

63.4082 Studying the cortical response to binocular disparity using EEG temporal frequency tagging

Zoltán Derzsi[1] (zoltan.derzsi@ncl.ac.uk), Ghaith Tarawneh[1], Kai Alter[1]; [1]Institute of Neuroscience, Newcastle University

Frequency tagging exploits the high temporal resolution of electroencephalography (EEG) to identify cortical mechanisms responding to a given stimulus, usually varying in luminance. Here, following pioneering work by Norcia & Tyler (1984) and others, we experiment with frequency tagging using binocular disparity. Each trial was a dynamic random-dot stereogram lasting 4s. For 1s, the dots had zero disparity, i.e. in the screen plane. For 3s, disparity was +/-0.065°. On "frequency-tagged" trials, the dots formed a horizontal disparity square-wave grating of spatial frequency 0.25 cycles/deg. The disparities were inverted with a temporal frequency of either F=5Hz or F=8Hz. On "control" trials during this 3s, two transparent planes were formed, one behind the other. We obtained data from 12 subjects, with an average of 68 good trials per condition, and EEG traces were band-pass filtered from 1 to 30 Hz before averaging. We see clear Event Related Potentials (ERPs) shortly after both the onset of the dot pattern (t=0s) and the onset of the disparity change (t=1s). Both ERPs show a N100-P200 complex, here a small negative peak at around 75ms followed by a larger positive peak at around 150ms. In the frequency domain, Fourier power is proportional to 1/sqrt(frequency) between 1 and 30Hz. The frequency-tagged conditions both show additional peaks at F and 2F, the first and second harmonics of the disparity modulation frequency, relative to the control condition. This confirms that a frequency-tagged signal can be observed in the disparity domain. However, the signal's strength was much weaker than in previous studies, perhaps because we used a disparity grating rather than a plane. Surprisingly, we also found strong power in the alpha-band in all disparity conditions compared to the zero-disparity baseline. References Norcia AM, Tyler CW. 1984. Temporal frequency limits for stereoscopic apparent motion processes. Vision Res 24:395-401.

Acknowledgement: Wellcome Trust

63.4083 Position shifts of fMRI-based population receptive fields induced by the Ponzo illusion

Ce Mo[1] (mocheck@sina.com), Dongjun He[2], Fang Fang[1,2,3]; [1]Peking-Tsinghua Center for Life Sciences, Peking University, [2]Department of Psychology and Key Laboratory of Machine Perception (Ministry of Education), Peking University, [3]IDG/McGovern Institute for Brain Research, Peking University

Murray, Fang and colleagues (2006, 2008) demonstrated that the Ponzo illusion was reflected in the spatial pattern of activity in primary visual cortex (V1). They presented two rings at close and far apparent depths in a 3D scene (Fang et al. 2008). When subjects fixated its center, the far ring appeared to be larger and occupy a more eccentric portion of the visual field, relative to the close ring. Using fMRI, they found that the spatial distribution of V1 activity induced by the far ring was also shifted toward a more eccentric representation of the visual field, whereas that induced by the close ring was shifted toward the foveal representation. However, the nature of the V1 activity shifts remains largely unknown. A possible explanation is the position shift of receptive field of V1 neurons. Here, we used the fMRI-based population receptive field (pRF) mapping technique to test this possibility. We used the same stimuli as those in Fang et al. (2008). The magnitude of the Ponzo illusion was measured with a method of constant stimuli. The far ring appeared to be 0.17 degrees larger than the close ring. In the pRF mapping experiment, flickering checkered rings with various sizes were presented in the 3D scene and their center coincided with that of either the far ring or the close ring. Subjects were required to detect occasional, brief pauses of flickering. We found that, relative to the close ring, the pRF positions of the voxels in V1 and V2 responding to the far ring were closer to fixation, consistent with the perceptual appearance of the far and close rings. Furthermore, the pRF position shift in V1 significantly correlated with the illusion magnitude across individual subjects. These findings make headways towards unraveling the neural mechanisms of the Ponzo illusion.

63.4084 Cortical representations of object motion trajectories in 3D space

Hiroshi Ban[1,2] (ban.hiroshi@gmail.com), Yuji Ikegaya[1,3]; [1]Center for Information and Neural Networks, National Institute of Information and Communications Technology, Osaka, Japan, [2]Graduate School of Frontier Biosciences, Osaka University, Osaka, Japan, [3]Laboratory of Chemical Pharmacology, Graduate School of Pharmaceutical Sciences, The University of Tokyo, Tokyo, Japan

One of the fundamental challenges of our visual system in tracking moving objects is to identify their dynamically changing locations in a three-dimensional (3D) space reconstructed from two-dimensional (2D) retinal inputs. The binocular disparities, differences of retinal inputs between left and right eyes, are known to play a key role in reconstructing 3D structures. However, even without binocular disparities, human can perceive 3D from monocular (pictorial) depth cues alone. For instance, we can identify object 3D locations based on shadows of the objects casted on the floor. Despite recent advances of neuroscience, the cortical processing of such pictorial cues has remained unclear. Here, we investigated how and where in the brain pictorial casting shadow cues are represented and converted to depth. To this end, we measured and compared fMRI responses (Siemens 3T MR, TR: 2000 ms, voxel size: 3x3x3 mm3, n=10 healthy adults) evoked by object motion trajectories in 3D defined by casting shadows on the floor (SHADOW) and by binocular disparities interposed on the target motions (DISP). The object motions caused strong retinotopic responses over the occipital cortex, but detailed analyses showed that a few specific regions represented the trajectories in 3D. More specifically, a multi-voxel pattern transfer classification analysis (e.g. we trained the classifier with SHADOW dataset whereas we tested the decoder performance with DISP dataset) revealed that the 3D trajectories defined by SHADOW were translated into those defined by DISP in V1, especially in its retinotopic sub-region corresponding to the trajectories, as well as in middle-temporal motion-sensitive area MT. The results indicate that V1 has capabilities to represent the visual target 3D locations irrelevant to depth cue types, contrary to a general assumption that V1 represents 2D space retinotopically. The fine-scale 3D representations in V1 may help us to interact with moving objects in dynamic visual environments.

Acknowledgement: JSPS KAKENHI (26870911)

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