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Organizer: George Sperling, University of California, Irvine

ABSTRACTS
1/15/13

Tom Busey
Indiana University

The Utility of Intermediate-Level Feature Representations
Authors: T. Busey, C. Yu, & J. Vanderkolk

Identification tasks often require the specification of the diagnosticity of individual features. This in turn requires a specification of the feature set. Rather than rely on global technique such as principle component analysis (PCA), we have computed an intermediate-level feature representation using independent component analysis (ICA) on small regions of image detail. Our particular application is fingerprints, although the methods are general enough to apply to a variety of identification tasks.

The intermediate-level representation allows for a number of different computations, including automatic clustering of different regions and region matching. More importantly, the activations from the basis set can be combined with information theory (first proposed by Bruce and Tsotsos, 2009) to provide estimates of diagnosticity for individual features. These diagnosticity maps are then validated against eye gaze data from fingerprint examiners.

The ICA representations also allow explorations of the relation between temporal and spatial information. Examiners often report combining together several individual features into 'target groups' to increase the diagnosticity of the impression. We explore this using temporal and spatial clustering algorithms that are built on hidden markov modeling and coding theory.

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Patricia Cheng
University of California, Los Angeles

Causal Reasoning

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Lawrence Cormack
The University of Texas at Austin

The Processing of 3-Dimensional Motion: What We Know, What It Means, and Future Directions

The visual system uses many ways to recover three-dimensional (3D) information from the retinal images. For static images, none produces a percept so qualitatively compelling as stereopsis, which uses the retinal disparities created by the two eyes' differing vantage points to create a striking sense of 3D position. In the natural world, an obvious and necessary goal is to encode the trajectories of things moving in 3D space and to evaluate, for example, whether a thing is likely to hit one's own head or not. When things move through depth, the retinal images change as do perforce the depth estimates provided by stereopsis. Given the vivid positional sense that stereopsis yields, it would be natural to assume that these estimates could be simply fed into subsequent mechanisms, ones with receptive fields oriented in disparity-time (just as motion sensitive mechanisms are oriented in space-time) to estimate 3D motion. Surprisingly, this is not how the human visual system rolls. Converging evidence from a number of laboratories indicates that the visual system has an alternate mechanism for encoding motion through depth. This mechanism does not use the output of stereopsis, but rather uses velocity signals from each eye as an input to a binocular comparator. It is, if you prefer, a binocular form of motion processing rather than a dynamic form of stereopsis. In this talk, I will summarize the evidence for this mechanism, discuss

some of the implications thereof, and speculate on where we might go from here.

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James Cutting
Cornell University

Perceiving Event Dynamics and Parsing Hollywood Films
Authors: J. E. Cutting, K. L. Brunick, & A. Candan

Most of the psychological literature on event segmentation focuses on viewers understanding the intents and goals of actors. To test this in another domain we selected 24 Hollywood movies released from 1940 through 2010 to serve as a film corpus. Eight viewers, three per film, parsed them into events, which are best termed scenes and subscenes. While watching a film a second time, viewers scrolled through frames and recorded the frame number where each event began. Without consultation they agreed about 90% of the time. We then analyzed the data as a function of a number of variables: shot transitions, shot duration, shot scale, motion, luminance, color, music, and a code that noted changes in place or time. We modeled viewer parsings across all shots of each film and found that, as an ensemble, the physical variables accounted for about 30% of the variance in the data. Adding a code recording place and/or time change increased this variance to about 50%. We conclude that there is ample collateral perceptual information for viewers to parse films into events without inherently following the intentions and goals of the actors, although these are certainly needed to understand the story of the film.

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Peter Dixon
University of Alberta

Visual and Verbal Codes in the SNARC Effect

The SNARC effect is a stimulus-response compatibility effect in which responses to large digits are faster when made with the right hand while responses to small digits are faster with the left. Historically, the effect has been attributed to the activation of a spatial representation of a mental number line in which large digits are on the right and small digits are on the left. In contrast, I will describe several lines of evidence that implicate verbal rather than spatial codes. The implications for processing models of the SNARC effect will be discussed.

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Barbara Dosher
University of California, Irvine

Perceptual Learning

Collaborator: Zhong-Lin Lu, The Ohio State University

Perceptual learning -- the improvement of performance through practice or training -- has been observed over a wide range of perceptual tasks in adult humans. The extensive plasticity in adult perceptual systems suggests its importance in the study of perception. This talk reviews some major functions and mechanisms of perceptual learning, including specificity and transfer of perceptual leaning, the law of practice in perceptual learning, mechanisms of perceptual leaning, the level and mode of perceptual learning and its relation to feedback, and computational models of perceptual learning. Studies of perceptual learning have improved our understanding the information processing limitations of the human observer, and how the state of the observer changes with training, and has implications for the development of training methods for perceptual expertise in normal populations and amelioration in challenged populations.

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James Elder

York University

Perceptual Organization of Shape

Humans are very good at rapidly detecting salient objects such as animals in complex natural scenes, and recent psychophysical results suggest that the fastest mechanisms underlying animal detection use contour shape as a principal discriminative cue. How does our visual system extract these contours so rapidly and reliably? While the prevailing computational model represents contours as Markov chains that use only first-order local cues to grouping, computer vision algorithms based on this model fall well below human levels of performance. Here we explore the possibility that the human visual system exploits higher-order shape regularities in order to segment object contours from cluttered scenes. In particular, we consider a recurrent architecture in which higher areas of the object pathway generate shape hypotheses that condition grouping processes in early visual areas. Such a generative model could help to guide local bottom-up grouping mechanisms toward globally consistent solutions. In constructing an appropriate theoretical framework for recurrent shape processing, a central issue is to ensure that shape topology remains invariant under all actions of the feedforward and feedback processes. This can be achieved by a promising new theory of shape representation based upon a family of local image deformations called formlets, shown to outperform alternative contour-based generative shape models on the important problem of visual shape completion.

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Casper Erkelens
Utrecht University

Phenomena in Picture Perception Explained by Linear Perspective

Reverspectives are paintings of perspective-rich scenes whose perspective opposes the physical orientation of the canvas on which the scenes are painted. Research on reverspectives has demonstrated that linear perspective is a powerful cue in picture perception. How perspective-related cues compete with binocular disparity and other canvas-related cues is not well understood. Perceived slants of well-defined perspective-rich stimuli depicted on a rotatable screen were measured as a function of depicted slant and screen slant in both monocular and binocular viewing conditions. Slants computed on the basis of a linear-perspective hypothesis provided quantitative predictions for the measured slants. Perceived slant was well explained by the linear-perspective hypothesis although slants were generally underestimated. Contributions of screen-related cues were small and mainly limited to small slants. Binocular disparity did not have any effect on perceived slant. The linear-perspective hypothesis explains various perceptual phenomena that occur when observers move relative to pictures and reverspectives.

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Mark Gluck
Rutgers University

Hippocampal Dysfunction Leads to Generalization Deficits in Alzheimer’s Disease, Post-Traumatic Stress Disorder and Depression

Damage to the medial temporal lobe, including the hippocampus, is a common feature of many neurological and psychiatric disorders including Alzheimer's disease, post-traumatic stress disorder, schizophrenia and depression. In neuropsychological studies conducted at clinics around the world using a battery of our Rutgers computer-based learning tasks, we and our colleagues have shown that hippocampal-dysfunction can lead to subtle but consistent changes in transfer generalization and contextual sensitivity as was predicted by our prior computational models of cortico-hippocampal function in associative learning and conditioning (Gluck & Myers, 1993, 2001). These computer-based neuropsychological tests -- all of which involve category learning, discrimination, and transfer generalization -- suggest common information-processing deficits that underlie cognitive, personality and emotional aspects of diverse neurological and psychiatric disorders. The Rutgers battery of learning and decision making tasks offers a novel tool for expanding our understanding of the cognitive changes that result from even modest degrees of hippocampal dysfunction and damage, especially those that do not lead to obvious declarative memory deficits.

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Justin Halberda
Johns Hopkins University

An Interface Between Vision, Numerical Cognition, and Word Meanings

Whereas the limits of visual processing are interesting in their own right, these limits take on a deeper meaning where vision integrates with other cognitive systems. It is at this point that limits within vision become limits that can affect the whole of cognition. In this talk I present evidence for one such case: an interface between vision, numerical cognition and the semantics of quantifier terms (e.g., "there are more students than teachers"). Across several behavioral tasks we find evidence that the way speakers of English understand a sentence affects how they search for relevant evidence in a visual scene. For example, English speakers presented with a scene of side-by-side, paired-off blue and yellow dots failed to use these obvious one-to-one relations when evaluating the sentence "most of the dots are blue." Instead, they relied on an approximate sense of numerosity that was less accurate than one-to-one. Using such tasks, we are beginning to reveal some ways in which visual constraints may have shaped the word meanings that speakers understand.

Hynek Hermansky
Johns Hopkins University

Dealing With Unknown Unknowns in Speech

The talk discusses an approach for dealing with unexpected acoustic elements in speech. The approach is motivated by observations of human performance on such problems, which indicate the existence of multiple parallel processing streams in human speech processing cognitive system, combined with the human ability to know when the correct information is being received. We review some of our currently active research in multistream ASR, focusing mainly on feedback-based techniques involving fusion of information between individual processing streams. The difference between the system behavior on its training data and during its operation is proposed and studied as a substitute for the human ability of "knowing when knowing."

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Xiaoping Hu
Emory University

Scale-Dependent and Scale-Invariant Dynamics of Resting State Brain Activity Measured by fMRI
Authors: K. Li, G. Desphande & X. Hu

Resting state fMRI measurements have been used widely to ascertain functional brain connectivity, mostly based on synchronous low-frequency fluctuations in the fMRI signal. These studies focus on low-frequency and assume temporal stationarity in the signal. With high-temporal resolution fMRI data, we have investigated the dynamic evolutions of the functional connectivity in a range of frequency bands and identified scale independent and dependent structures, both of which are temporally evolving. Our results revealed important brain networks that dynamic evolving and will be of significance in assessing the brain dynamics in normal and disease subjects.

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Kerry Jordan
Utah State University

Multiple Cues Enhance Quantitative Discrimination in Infancy
Authors: K. Jordan, J. Morath, & J. Baker

My lab investigates numerical cognition in humans and nonhuman animals. Our studies show that number can be

represented without language and that these representations extend across different senses. Infants possess basic capabilities to assess various quantitative properties such as number, size, and time. Preverbal discriminations are approximate, however, and are similarly limited across these dimensions. We have found that redundant, multisensory stimuli boost numerical cognition during infancy and early childhood. In past years at this conference, we have discussed how this intersensory redundancy accelerates performance especially for more difficult mathematical problems. We now review more recent studies from my lab outlining other ways of sharpening early numerical representations. Specifically, we show evidence that multiple sources of quantitative unisensory information, namely, simultaneous visual cues to same-directional changes in both number and surface area, accelerate six-month-olds' quantitative competence. When provided with such visual cues to multiple quantitative properties, infants make more precise discriminations than when they receive information about a single cue alone. Such sensory input may be more salient than single-source information, which could better recruit attention and result in more precise learning and remembering. In sum, data from this series of studies suggest that our early developing system of approximate nonverbal quantity representation may be enhanced when receiving multiple redundant sources of information about quantity.

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Phil Kellman
University of California, Los Angeles

Unifying and Applying Perceptual Learning

What is the relation between perceptual learning (PL) in basic sensory discriminations and in more complex tasks, including real-world learning tasks? Most recent PL work focuses on the former, using simple sensory dimensions and a few specific stimulus values. In contrast, other PL research and virtually all real-world tasks involve discovery of invariance amidst variation, and may also involve PL working synergistically with other cognitive abilities. In this talk I will suggest that, despite superficial differences, low- and high-level PL tasks draw upon -- and reveal -- a unified type of learning. I will present data and arguments that suggest that rather than being confined to early receptive field changes, PL typically has an abstract character and depends on unifying notions of discovery and selection. I will relate this unified view of PL to direct practical applications. Learning technology based on PL -- Perceptual Learning Modules (PLMs) -- can address elusive aspects of learning, including pattern recognition, transfer, and fluency even in high-level, symbolic domains, such as mathematics learning. Due to their practical focus, evaluations of such interventions have tended to focus on domain-relevant tests, such as high-stakes mathematics assessments. In the final part of the talk, I will present recent data showing that PLM interventions in complex domains also produce large changes in basic information extraction tasks, such as visual search.

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Shaw Ketels
University of Colorado at Boulder

Training Away Anchoring in a Weighted Centroid Judgment Task
Authors: S. L. Ketels, C. D. Wickens, A. F. Healy, C. J. Buck-Gengler, & L. E. Bourne, Jr.

In information integration tasks, anchoring is a prominent heuristic, such that the first few arriving information sources (cues) tend to be given greater weight on the final integration product than those cues following. Such a bias may be particularly problematic when the situation is dynamic, such that earlier arriving cues are more likely to have changed, and hence are less reliable for the final integration judgment. Such is often the case in military intelligence, when enemy intentions are inferred from multiple sources. We describe results of a simulation of such intelligence gathering in which anchoring is prominently manifest, in the processing of seven sequentially delivered cues bearing on enemy threat. In Experiment 1 an anchoring bias was present. In Experiment 2 a simple "debiasing" wording, inserted in the instructions and emphasizing the age of intelligence information, induced more optimal weighting of the most recent cues, but did not eliminate anchoring.

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Lynne Kiorpes
New York University

Perceptual Learning in Amblyopia

Perceptual learning is gaining recognition as a potentially beneficial treatment for adults with amblyopia. However, it is unclear how consistent the training benefit is across subjects and tasks. We investigated this question in amblyopic non-human primates (Macaca nemestrina). We used an integrative training stimulus: random dot motion direction discrimination at a range of directions and dot speeds. We then tested for improvement in performance on a range of motion and form tasks post-training: coherent motion detection, Glass pattern discrimination, contrast sensitivity, and Vernier acuity. As a control, we assessed the untrained fellow eye for any changes in performance. Five amblyopic monkeys and one visually-normal control were tested. Our results showed that in most cases perceptual learning improved performance for the amblyopic eye. Learning transferred within the motion domain to a non-practiced motion task, but there was less transfer to spatial tasks. Contrast sensitivity improved in one-half of the cases but was poorer after training in the other cases; in several cases, serendipitous improvement in the untrained fellow eye negated any benefit to the amblyopic eye. Finally, long-term follow-up showed no lasting benefit from the training. These results show that there is a wide range of individual variation and hence an unreliable outcome.

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Michael Lee
University of California, Irvine

Bayesian Reanalyses of Inferences in the Psychological Literature

It is very useful to be able to speak fluent French when you're dining in Brussels. The menus can be subtle, the waiters disinterested, and fluency is needed for the best culinary and social experience. But understanding French is more a curse than a blessing riding the crowded metro to get to the restaurant, because it renders comprehensible the inane surrounding conversation. Being a Bayesian in psychology is much like this. As a researcher, understanding the Bayesian approach is a joy. It makes it possible to draw inferences about models and data in complete, principled, flexible, coherent and intuitive ways. But reading the literature from a Bayesian perspective is often a depressing or annoying experience. What psychologists routinely do to understand their data and models comes across as ad-hoc and unsatisfactory, inefficient at best and pathological at worst. This talk gives some concrete examples from the literature where inferences have been botched, and presents Bayesian reanalyses. The basic problem always stems from a failure to acknowledge the uncertainty inherent in scientific inference that a Bayesian approach can correct, but the theoretical and practical consequences vary from application to application.

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Zhong-Lin Lu
Ohio State University

Perceptual Learning in Adults with Amblyopia

Amblyopia, also known as “lazy eye,” is a spatial vision disorder that is characterized by reduced visual acuity in one or both eyes without any organic origin. Although conventional wisdom on visual development suggests that spatial vision becomes hard-wired after the critical period (6–8 yrs of age) and only young child amblyopes are treated in current clinical practice, a number of recent studies suggest that perceptual learning might be a potential treatment for adult amblyopia. In this talk, I will review evidence of perceptual learning, transfer of perceptual learning, and mechanisms of perceptual learning in adults with amblyopia.

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Laurence T. Maloney
New York University

Distortions of Probability Information in Perception, Action and Cognition

In "classical" decision under risk, decision makers choose between lotteries. They typically overweight small probabilities and underweight large. I'll first briefly describe recent experiments (Wu et al., 2009, 2011; Zhang et al, 2012; Warren et al., 2012) in which we examine human failure in visual and motor tasks that are equivalent to decision under risk or ambiguity.

Similar patterns of distortion are found in visual frequency estimation, frequency estimation based on memory, and in the use of probability in decision making under risk. I'll show that probability distortions in all cases (so far) can be approximated by a linear transformation of the log-odds of probability or relative frequency (Zhang & Maloney, 2012). The slope and intercept of the linear transformation control probability distortion. Researchers have not been able to predict or explain the values of slope and intercept observed in experiments across tasks or across participants.

In Zhang & Maloney (2012), we focused on one method for presenting probability, the relative frequency of items of one kind in a visual array of N items. We developed a model of human distortion of relative frequency and demonstrated in two experiments that we can separately control slope and intercept with high accuracy. Our results support the conjecture that probability is systematically "adapted" to particular tasks much as perceptual information concerning lightness or loudness is transformed. Wild speculation follows.

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Danielle McNamara
Arizona State University

Interactive Features Impact on Student Attention and Performance Within an ITS
Authors: E. Snow, T. Jackson, & D. S. McNamara

Goal maintenance and attention control are important constructs for researchers developing Intelligent Tutoring Systems (ITSs). Scientists engineering these environments are frequently incorporating interactive features as a way to increase student engagement. Although studies have shown that the addition of these features relates to decreased boredom, relatively little work has investigated how they impact overall performance by influencing goal maintenance within students. A game-based ITS, called iSTART-ME, incorporates several types of interactive features within an educational game context. This system allows students to earn points by completing educational games. These points are saved both as total iSTART points (an indicator of system achievement) and as iBucks (a form of system currency used to activate various features). A group of 40 high school students recently interacted with iSTART-ME over a series of 11 sessions (pretest, 8 training sessions, posttest, and a delayed retention test). The current work examined how students' behavior within the system was impacted by their interactions with game-based features. Specifically, we investigated how the proportion of available resources each student spent on interactive features impacted goal maintenance and performance within the system. Analyses indicated that students who spent a lower proportion of their resources on interactive features performed significantly higher at posttest and retention compared to students who spent a higher proportion on the same features (even after controlling for initial reading skill and prior motivation). Additional analyses demonstrated that a low proportion of time related to an increase in total points (iBucks) earned and higher system achievement levels. These results revealed that higher proportions of resources spent on interactive features had a profound and persistent negative effect on goal maintenance, which impacted overall performance. We hypothesize that these features impact student performance by acting as seductive distracters that pull students' attention away from the learning task.

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Timothy McNamara
Vanderbilt University

Environmental geometry and retrieval from long-term memory
Authors: B. E. Riecke & T. P. McNamara

People commonly need to adopt perspectives in imagination that differ from their actual perspectives in the environment, as when planning a route in advance or giving directions to another person. Such perspective-taking tasks are typically

easier in a remote environment than in the immediate environment. Consider, for example, the following task: Imagine standing in your kitchen, facing the sink; point to the nearest door. Most people will find this judgment of relative direction (JRD) easy to perform, especially when allowed to close their eyes to remove potentially interfering visual cues. Contrast that judgment with the following one: Without actually turning, imagine facing the door of the room in which you are currently located; point to the nearest window. Why is it more difficult to imagine a perspective switch in the immediate environment than one in a remote environment? Both local and remote perspective switches require us to establish an additional reference frame of the to-be-imagined environment in the to-be-imagined orientation. For local perspective switches, however, there is an additional challenge as the to-be-imagined perspective seems to conflict or somehow interfere more strongly with one's actual orientation in the environment, leading to so-called sensorimotor interference costs (Avraamides & Kelly, 2008; May, 1996, 2004; May & Wartenberg, 1995; Presson & Montello, 1994; Wang, 2005). In this study, we demonstrated that specific interference between actual and to-be-imagined orientation can occur even if the to-be-imagined environment is remote and participants do not know their physical orientation with respect to the to-be-imagined orientation. This has implications for our understanding of facilitation and interference effects in human spatial memory, and suggests that specific facilitation or interference effects might occur both in psychological testing of human spatial memory and in applications such as virtual environments.

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Cory Miller
University of California, San Diego

Auditory Attention in a Marmoset Cocktail Party

One of the primary functions of the auditory system is to parse meaningful information from the nearly continuous stream of acoustic information. Despite its complexity, this process occurs nearly effortlessly due to a myriad of perceptual mechanisms that evolved to segment the acoustic scene. One of the more widely studied aspects of auditory scene analysis is known as the cocktail party problem (Cherry 1953), the ability to direct attention towards a specific source from high levels of background noise. Although the phenomenon is based on a natural communicative context, the majority of the related work has taken a more reductionistic approach with experiments focusing on individual lower-level auditory mechanisms rather than the more dynamic processes necessary for perception in natural cocktail party settings. In the current study we developed a naturalistic, experimentally controlled acoustic environment in which we examine the cocktail party problem in common marmosets. The aim here was to simulate natural communicative exchanges between marmosets while manipulating aspects of the acoustic scene in order to examine the key mechanisms underlying the cocktail party problem, such as auditory attention- and feedback-mediated vocal control.

When visually occluded from conspecifics, marmosets engage in antiphonal calling. This vocal behavior is the reciprocal exchange of long-distance contact calls, known as phee calls. Our experiment consists of a multispeaker set-up in which two or four speakers (each simulating individual marmosets) are occluded from the subject and are broadcasting phee calls at different latencies and probabilities in response to subject calls. Subjects must use the specific behavioral cues to determine which speaker is willing to engage in vocal interactions and those that are not. In essence, the subject must attend to one speaker - the primary - while simultaneously ignoring calls from the other speakers (i.e. the distractors). Our initial experiments in this paradigm indicate that marmosets are readily able to parse the calls from the primary caller and selectively ignore the distractors by withholding calling behavior. Current experiments build on this finding by manipulating background noise, type, and sound level, and expanding the complexity of the acoustic scene.

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Tony Movshon
NYU

Cortical and Perceptual Processing of Naturalistic Visual Structure
Authors: J. Freeman, C. Ziemba, E. P. Simoncelli, & J. A. Movshon

The perception of complex visual patterns emerges from neuronal activity in a cascade of areas in the primate cerebral cortex. Neurons in the primary visual cortex (V1) represent information about local orientation and spatial scale, but the role of the second visual area (V2) has been enigmatic. We constructed synthetic images that contain complex features found in naturally occurring visual textures, and used them to stimulate macaque V1 and V2 neurons. Most V2 cells

responded better to these stimuli than to matched control stimuli lacking naturalistic structure, while V1 cells did not. Parallel fMRI measurements in humans revealed differences in V1 and V2 responses to the same textures that were consistent with the neuronal measurements. Neuronal and fMRI responses in V2 depended reliably and similarly on the particular texture types used. The ability of human observers to detect naturalistic structure also varied with texture type, and was well predicted by the strength of the neuronal and BOLD responses in V2 but not in V1. These results reveal a novel and particular role for V2 in the representation of natural image structure.

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Jeff Mulligan
NASA Ames Research Center

Reflexive and Voluntary Control of Smooth Eye Movements

An understanding of visually evoked smooth eye movements is required to predict the visibility and legibility of moving displays, such as might be encountered in vehicles like aircraft and automobiles. We have studied the response of the oculomotor system to various classes of visual stimuli, and analyzed the results separately for horizontal and vertical version (in which the two eyes move together), and horizontal and vertical vergence (where they move in opposite directions). Of the four types of motion, only vertical vergence cannot be performed under voluntary control, and we found that certain stimuli (all having relatively long latencies) were incapable of evoking it. In another experiment, we instructed observers to track one of two targets, and measured weak but reliable responses to the unattended target, in which the long-latency component of the response is abolished. Our results are consistent with a system containing two distinct processes, a fast reflexive process which responds to a restricted class of stimuli, and a slower voluntary process capable of following anything that can be seen, but incapable of controlling vertical vergence.

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Tatiana Pasternak
University of Rochester

Defining the Role of Prefrontal Cortex in Sensory Decision Making

I am going to document the existence of generalized sensory comparison mechanisms within dorsolateral prefrontal cortex (DLPFC), shedding light on top-down influences this region is likely to provide to the upstream sensory neurons during comparison tasks. We recorded the activity of individual neurons in the DLPFC while monkeys performed a memory-guided decision task in which they compared the direction or speed of two sequentially presented motion stimuli and reported whether a current stimulus was the same or different from another held in working memory. Many neurons, both putative local interneurons and putative pyramidal output cells, were selective for the speed and direction of motion, with tuning reminiscent of that observed in motion processing area MT. Throughout the delay, putative pyramidal projection neurons were more active, showing anticipatory rate modulation and transient periods of speed or direction selectivity reflecting the preceding stimulus. During the comparison stimulus, responses of both cell types were often modulated by the speed and direction of the first stimulus, and their activity was highly predictive of the animals' behavioral report. These results provide evidence for the existence of generalized neural mechanisms in the DLPFC sub-serving all stages of sensory comparison tasks.

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Misha Pavel & Holly Jimison
National Science Foundation, Oregon Health & Science University

Revolutionizing Neuropsychological Assessments with Computational Modeling Approaches
Authors: M. Pavel & H. Jimison

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Zygmunt Pizlo

Purdue University

Solving 3D Symmetry Correspondence in 2D Asymmetrical Images
Authors: Z. Pizlo & Y. Li

Before a 3D mirror symmetry constraint (prior) is applied to a 2D perspective retinal image in order to recover the 3D shape, the visual system has to figure out what goes with what in the retinal image. Specifically, which pairs of points and lines are perspective images of mirror symmetrical pairs of points and lines "out there." Symmetry correspondence problem is analogous to, but more difficult than stereo and motion correspondence problems. The extra difficulty results from the fact that mirror symmetry is a spatially global characteristic, which implies global search for corresponding features. Furthermore, features that are symmetrical "out there," are not symmetrical in the 2D retinal image. Solving symmetry correspondence problem depends on exact and approximate invariants of perspective projection of 3D symmetrical shapes. It also depends on additional simplicity constraints (priors) of 3D shapes. We will describe the first successful solution of symmetry correspondence problem and illustrate our model with real images of real scenes and objects. Unlike conventional Bayesian approaches to modeling visual inferences, our model never updates its priors.

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Nicholas Port & Bryan Redick
Indiana University

Title
Authors: N. L. Port, B. Redick, J. Howell, D. Westfall, B. F. O'Donnell, & W. P. Hetrick

For individuals diagnosed with schizophrenia, deficits in oculomotor smooth pursuit and cerebellar-like extra-skeletal motor control have been noted for approximately a century (Diefendorf & Dodge, 1908; Kraepelin, 1919). While models of schizophrenia postulating cerebellar dysfunction make predictions about several aspects of neurological and psychiatric dysfunction, to date only smooth pursuit deficits have received much investigation. Within the saccadic system, the circuit that maintains saccadic calibration is entirely contained within the cerebellum. The classic saccadic adaptation task breaks calibration and a full functioning cerebellum is essential in both humans and monkeys for recalibration (Hopp & Fuchs 2004; Prsa & Thier, 2011). Our experiment tests whether subjects with schizophrenia who exhibit smooth pursuit dysfunction will also exhibit saccadic adaptation impairment. *Methods*: We studied 19 subjects with schizophrenia, 7 healthy relatives, 13 matched controls, and 10 OD student control subjects. Subjects tracked a simple white dot on a black background while we recorded eye movements with an eye tracker. "Main sequence" and center-out visually guided saccade paradigms were utilized to assess the health of each subject's saccadic system. *Results:* There were no differences among groups for saccades to traditional stimuli, including the "main-sequence." However, subjects with schizophrenia exhibited significant impairment in saccadic adaptation (gain of 0.4) compared to healthy subjects (gain of 0.8). In our sinusoidal and step-ramp pursuit tasks, subjects with schizophrenia showed impaired pursuit gain. There was a positive correlation between saccadic adaptation and pursuit gain, meaning subjects with poorer saccadic adaptation also had poorer pursuit eye movements. *Conclusions:* Our results support the cerebellar model of schizophrenia and also fit with the model of saccadic eye movements of Quaia and colleagues (1999). By integrating our results with these models, we can make testable anatomical predictions about underlying dysfunctional oculomotor neural circuits in subjects with schizophrenia.

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Roger Ratcliff & Gail McKoon
Ohio State University

A Diffusion Model Analysis of Number Processing
Authors: R. Ratcliff & G. McKoon

The diffusion model for two-choice decisions was fit to accuracy and response time distribution data from college adults and first, second/third, fourth/fifth and seventh/eighth graders. Participants completed a numerosity discrimination task (was the displayed number of asterisks greater than 50?), a number discrimination task (was the displayed number greater than 50?), memory for two- and three-digit numbers (did the number appear on a just-presented list of numbers?), and

arithmetic verification (does 2+3=4?). Adult and children's drift rates, the quality of evidence extracted from the display, on the numerosity, discrimination and number discrimination tasks were correlated as were adult drift rates on the two memory tasks. Children extracted lower quality evidence, set wider decision criteria, and took longer to encode and execute responses than adults. We also report relationships between IQ and achievement scores and diffusion model parameters.

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John Reynolds
Salk Institute

A Precise and Minimally Invasive Approach to Optogenetics in the Awake Primate

Optogenetics has proven to be a powerful tool for understanding the function of specific cell types and circuits within the central nervous system and establishing a causal link between their activity and behavior. Its application in non-human primates has been slow to develop. One challenge has been the damage caused by transdural delivery of viruses and light to the brain. I will describe optogenetic activation of neuronal responses in the alert and behaving monkey after replacement of the native dura with a transparent artificial dura. This approach enables the use of fine glass micropipettes to inject virus with minimal damage and transdural illumination, obviating the damage that would otherwise occur as a result of lowering optical fibers into the brain. It also permits visualization of the underlying cortical micro-vasculature, which has proven to be helpful in targeting electrodes and laser illumination to the virus location. This approach promises to greatly assist in the dissection of cortical circuits underlying visual perception and behavior.

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Matthias Scheutz & Richard Veale
Tufts University

A Biologically Plausible Embodied (Robotic) Model of Infant Word-Referent Association Learning

We present a novel biologically plausible, embodied computational model of word-referent association learning, which elucidates crucial social aspects of the parent/teacher role. In particular, variations of three parameters---word length, visual attention length, and word presentation offset---can account for several learning effects seen in empirical studies where words are presented to infants either synchronously or asynchronously with the movement of objects. We also introduce a more abstract mathematical formulation of the essential properties of word-referent association learning in the computational model that can be used to make predictions about learning in infants for scenarios that have not yet been investigated empirically.

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Keith Schneider
York University

Attention Biases Decisions But Does Not Alter Appearance

Attention enhances our perceptual abilities and increases neural activity. Still debated is whether an attended object, given its higher salience and more robust representation, actually looks any different than an otherwise identical but unattended object. One might expect that this question could be easily answered by an experiment in which an observer is presented two stimuli differing along one dimension, contrast for example, to one of which attention has been directed, and must report which stimulus has the higher apparent contrast. The problem with this sort of comparative judgment is that in the most informative case, that in which the two stimuli are equal, the observer is also maximally uncertain and therefore most susceptible to extraneous influence. An intelligent observer might report, all other things being equal, that the stimulus about which he or she has more information is the one with higher contrast. (And it doesn't help to ask which stimulus has the lower contrast, because then the observer might just report the less informed stimulus!) In this way, attention can bias the decision mechanism and confound the experiment such that it is not possible for the experimenter to differentiate this

bias from an actual change in appearance. Ten years ago I proposed a solution to this dilemma—an equality judgment task in which observers report whether the two stimuli are equal in appearance or not. This paradigm has been supported in the literature and has withstood criticisms. In this talk I will review these findings and will also present new experiments that show that salience and increased information are the causal factors mediating the effect.

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Michael Shadlen
Columbia University

A Connection Between Time and the Neural Computation of Probability

I will discuss the neural mechanisms that underlie the speed and accuracy of a decision, how the same mechanism incorporates prior knowledge of the probabilistic outcomes (and costs) and how the brain attaches confidence to a decision. All revolve around the same basic principle: the conversion of spike rate to belief exploits knowledge of elapsed decision time.

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Richard Shiffrin
Indiana University

How Are Multiple Calls for Attention Adjudicated?
Authors: R. Shiffrin, K. Kumar, & S. Chandramouli

Donkin and Shiffrin developed a model for serial search whose order of comparisons is determined both endogenously (planned order) and exogenously (perceptual singletons and targets demanding attention due to consistent training). The heart of the model is the way that the various factors, that often conflict, are resolved. The present studies explore this issue in easy visual search in which the target "pops out" of the display. Twelve green circles are arranged as a clock face. Each contains a vertical or horizontal Gabor. For a given session one of the circles is either red, square, or larger. Study 1: The observer finds the one target object (e.g. red) and reports the orientation of the Gabor. Study 2: The observer reports the presence or absence of the target object (e.g. red). The critical trials have one or two distractor singletons that call for attention (e.g. red target, and square, large or both distractors). Jan Theeuwes and others have many studies showing slowing of response caused by a singleton distractor. One question: Do two distractors cause more or less slowing than one? We analyze accuracy and full response time distributions, report a variety of interesting results, and (hopefully) report models for the way that multiple calls for attention are adjudicated.

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George Sperling
University of California, Irvine

Attention Filters

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Mark Steyvers
University of California, Irvine

Calibrating and Aggregating Forecasts about World Events
Authors: M. Steyvers, B. M. Turner, E. C. Merkle, D. V. Budescu, & T. S. Wallsten

It is known that the average of many forecasts about a future event tends to outperform the individual assessments. With the goal of further improving forecast performance, we develop and compare a number of models for calibrating and

aggregating forecasts that exploit the well-known fact that individuals exhibit systematic biases during judgment and elicitation. The empirical data are from the Aggregative Contingent Estimation System, an online environment for forecasting world events (http://www.forecastingace.com/). All of the models recalibrate judgments or mean judgments via a two-parameter function, linear in in log-odds, that relates subjective estimates to outcome relative frequencies. The various models differ in terms of whether (1) the calibration function is applied before or after the averaging, (2) averaging is done in probability or log-odds space, and (3) individual differences are captured via hierarchical modeling or not. We compared the models against simple averaging and against each other in terms of both mean Brier scores (a quadratic scoring rule) and the number of forecasting problems on which each is better than the other. All of our models are superior to simple averaging, with percentage improvement in the Brier score ranging from 8.0% to 28.2%. Of the non-hierarchical models, the one that first recalibrates the individual judgments and then averages them in log-odds is overall the best relative to simple averaging, with 26.7% improvement in Brier score and better performance on 86% of the individual problems. The hierarchical version of this model does slightly better in terms of mean Brier score (28.2%) and slightly worse in terms of individual problems (85%).

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Bosco Tjan
University of Southern California

Effects of Image Content and Content-Selective Attention on the Form-Evoked BOLD Response in the Ventral Visual Areas: A Linear Sum-of-Components Model
Authors: B. S. Tjan & P. Bao

The neural activity along the ventral vision pathway is modulated by attention and the category of the attended image content. Unattended content also affects the neural activity. While the interaction between attention and image content can be convoluted, we found that an exceedingly simple relationship underlies the fMRI blood oxygenation level dependent (BOLD) response and the content of a complex image. We conducted three complementary experiments in which observers had to compare either the face or scene component of a pair of briefly presented images, each being an amalgamation of face, scene and random noise pattern. We found that the BOLD response to each non-noise image component (face or scene) is linear in the "signal proportion" of the component, defined as the ratio of the contrast energy of the component to the contrast energy of the entire image. For a cortical area along the ventral visual pathway, the slope of this linear function depends on whether the component is attended and if it is preferred by the cortical area. The net BOLD response of a cortical area is a simple sum of the responses to all of the non-noise components. We validated this linear sum-of-components model by showing that a model fitted to the data from any two of the three experiments can accurately predict the empirical results of the third. The model is consistent with the biased competition theory of attention and embeds a common form of divisive normalization.

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John K. Tsotsos
York University

Still Revisiting Visual Routines

This presentation will continue where I left off at AIC-2012. For everyday function, the visual system must do more than simple feature detection or object classification. A mechanism is needed to represent and guide the interaction of sensed information and higher order processes that regulate task performance. Such visual problem solving was addressed by Ullman's (1984) theory of visual routines, where tasks are solved by sequences of elemental operations. Although a seminal conceptualization, this theory requires re-examination.

The Selective Tuning (ST) model of visual attention has received strong experimental support (Tsotsos 2011) and has been extended to interact with visual recognition. A critical missing component is the executive controller for attention, and indeed for visual behavior as a whole. How can ST accept task requirements and construct the proper sequence of operations (sensing, selection, gaze/viewpoint changes, classification, localization, etc.) to fulfill that task? Ullman's visual routines (VRs) looked at closely related questions, focusing on reasoning about spatial relations. However, Ullman based VRs on knowledge of human vision and attention of the early 1980's, and most followers do the same. Among them, Ballard & Hayhoe (2009) make strong arguments about the need for nonsaliency methods for attention but do not propose

an alternative. Against this backdrop, we ask: 1) How do Ullman's VRs fare with a current understanding of human visual processing and attention? 2) Can ST play the role of attention as Ballard & Hayhoe describe? 3) How must VRs be updated given current understanding of vision and attention? 4) Can the updated VRs be defined using neural circuit elements? 5) Given the new definition, can useful routines be developed and tested, and shown to have robust properties? 6) Can these new VRs be learned and if so how? 7) Can the new VRs be mapped onto a neurally-based executive controller for ST?

We have studied the visual routines framework and identified elements that need to be reconsidered in order to provide the same functionality, yet conform with our modern understanding of visual processes (Kruijne & Tsotsos 2011). The updates help shape a new framework for visual cognition integrating visual pathways, peripheral visual processing, inhibition of return, visual working memory processes, the attentional mechanisms that interact with these components, and higher order cognitive rules. The operations are expressed both as general methods and applied scripts. Example problems using the classical visual routines framework are used to illustrate how this new framework operates. The result is a new theory of a dynamic, moment-to-moment task-modulated, visuomotor process.

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Laurie M. Wilcox
York University

What We Perceive From What We Don't See
Authors: L. M. Wilcox, I. Tsirlin, & R. S. Allison

Under natural binocular viewing conditions there is a considerable amount of the visual environment that is seen by only one eye due to monocular occlusion. Occlusion of part of an object or background from one eye's view, but not the other's, is common at object boundaries and within volumetric objects which can self-occlude. Once believed to be a source of noise for the high-resolution stereoscopic system, we now know that these occluded regions contribute significantly to depth perception and interact with stereoscopic signals to help provide accurate relative depth signals. I will review some of our basic research in this area and how it relates to the stereoscopic 3D film industry.

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