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Organizer: George Sperling, University of California, Irvine

ABSTRACTS

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Florent Autrusseau  
University of Nantes

Chromatic and Wavefront Aberrations: Estimates of Typical and Individual Variation in Retinal Images  
Authors: F. Autrusseau & S. Shevell

The first physiological process influencing visual perception is the optics of the eye. The retinal image is affected by diffraction at the pupil and by several kinds of optical imperfections. A model of the eye (Thibos & Bradley, 1999), which takes account of pupil aperture, chromatic aberration and wavefront aberrations, was used to determine polychromatic point-spread functions, which can be convolved with any stimulus specified by its spectral distribution of light at each point. The resulting retinal spectral distribution of light reveals the spatial distribution of stimulation for each of the three cone types (S, M and L). In addition, individual differences in retinal-image quality were assessed using Thibos, Bradley & Hong's (2002) estimates of population variance of Zernike coefficients, which characterize the eye's optical imperfections. The median and relatively extreme (5th and 95th percentile) modulation transfer functions (MTFs) for the S, M and L cones were determined for equal-energy-spectrum (EES) 'white' light. The results show that full consideration of wavefront aberrations gives a typical MTF for S cones that is more similar to the MTF for L and M cones, compared to usual optical models that exclude higher order aberrations. Even with these aberrations included, however, the S-cone MTF typically was below the M- or L-cone MTF by about a factor of 10 (one log unit). The results also highlight the poor estimate of image quality from population means of Zernike coefficients, which underestimate the typical loss of human image quality. More generally, the model can estimate the population range of retinal-image quality for any stimulus.

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Benjamin Backus  
SUNY College of Optometry

Properties of Learned Perceptual Bias

Cue recruitment studies by Backus and colleagues have shown that the visual system can be trained to resolve perceptual ambiguities according to added visual signals. In other words, perceptual appearance can to some extent be made contingent on a signal that was not previously effective as a visual cue. A number of additional results can now be described. These include: that the visual system is able to recruit an invisible cue (vertical disparity) to control the apparent rotation direction of a 3D cylinder; that visual attention to spatial location greatly speeds the rate at which long-term retinal-position-dependent biases are acquired for rotating Necker cubes; that practice on uninformative (formally ambiguous) stimuli creates a stronger long-lasting bias than does doing the same task on informative (disambiguated) stimuli; and that presenting a block of ambiguous stimuli prior to training is immediately effective at reducing subsequent learning. These results suggest that perceptual biases, which are needed to instantiate prior belief during perception, can ordinarily be learned during seeing under difficult conditions.

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Thomas A. Busey  
Indiana University

On the Nature of Age-Related Changes in Visual Temporal Order Judgment Performance

In this talk I will describe the results of a large-scale multimodal study of temporal processing in 150 healthy elder, 20

middle aged and 40 young participants. I will focus on visual temporal order judgments and address the degree to which performance on these tasks is related to perceptual measures such as temporal contrast sensitivity, as well as cognitive measures such as the WAIS III set of measures. We find significant differences between young and elder participants in virtually all measures, and correcting for letter discriminability reduces but does not eliminate group differences. Thus there seems to be an age-related effect that is specific to temporal processing. We use factor analyses and structural equation modeling to look for common latent factors across tasks, and regression analyses to look for predictors from other tasks.

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Lawrence Cormack  
The University of Texas at Austin

Motion Processing With Two Eyes in Three Dimensions  
Authors: L. K. Cormack, A. C. Huk, B. Rokers, & T. Czuba

The most obvious binocular cue to motion through depth is the change in retinal disparities over time. Theoretically, however, monocular velocity information could be compared across the eyes to yield the same information. While the latter idea is not new, convincing evidence for its implementation in the human visual system is. In this talk, we will show recent psychophysical and neuroimaging evidence for such a mechanism, and discuss the implications of these results for canonical models of motion processing and binocular combination.

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Barbara Doshier  
University of California, Irvine

Task Precision in Visual Attention

Visual attention often improves the accuracy of perceiving and judging an object. Surprisingly, it has not been documented whether attention is especially important for fine judgments. Here we demonstrate that spatially cued attention improves accuracy of pattern orientation judgments (for a given contrast) for all levels of judgment precision, but is somewhat more effective for low than high precision judgments. Attention effects are especially large for visually noisy stimuli, illustrating an important role for attention in extracting signal from noise.

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Valentin Dragoi  
The University of Texas at Houston

Noise and Correlated Variability in Visual Cortical Networks

The responses of cortical neurons are known to be 'noisy'. Neuronal noise is manifested both as spontaneous fluctuations in neuronal responses and as response variability when identical stimuli are presented. I will describe our research examining the two major sources of noise in neuronal networks, ongoing fluctuations in neuronal responses and trial-by-trial variability, and their impact on population coding in primary visual cortical networks (V1). We found that spontaneous fluctuations in neuronal responses in V1 are correlated, and that the distribution of spontaneous states across a network of cells can shape the accuracy of population coding in real time. In addition, strong noise correlations in the neurons' evoked responses to random stimuli influence network performance. Importantly, rapid adaptation, or exposure, to a stimulus of fixed structure reorganizes the distribution of noise correlations across the entire network engaged in stimulus processing by selectively reducing their mean and variability. The post-adaptation changes in neuronal correlations are associated with specific, stimulus-dependent, changes in the accuracy of the population code, and are consistent with changes in perceptual performance.

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Wilson S. Geisler  
The University of Texas at Austin

### Consequences of Noise for Neural Encoding and Decoding

Sensory stimuli are encoded by populations of neurons in early sensory areas and subsequently decoded by other populations of neurons into behavior. To gain an understanding of the consequences of stimulus and neural variability for encoding and decoding, we derived and evaluated optimal encoders and decoders for specific tasks. In the examples presented, stimuli are assumed to be encoded by a population of neurons having Gaussian response variability, with a variance that may depend on the mean response, and with correlation that may be non-zero. (However, no such constraints are assumed for stimulus variability.) In one type of application, we characterize from direct neurophysiological measurements the mean responses and variability of a given sensory neural population in a specific behavioral task, and then derive and evaluate the performance of the optimal decoder for the task. In a second type of application, we assume typical neural-noise properties of visual cortical neurons and then determine the optimal encoder (set of receptive fields) and associated optimal decoder, for randomly-sampled natural stimuli that arise in a given natural task. We demonstrate that this general approach of deriving and evaluating optimal encoders and decoders can provide deep and sometimes surprising insight into population encoding and decoding, and into natural stimuli and natural tasks.

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Hynek Hermansky  
Johns Hopkins University

### Multistream Recognition of Speech

Fletcher and his colleagues provided experimental evidence for processing information in a number of parallel information streams and proposed a model in which probabilities of errors in classification in the individual streams multiply to yield the probability of the final error. The model elegantly accounts for robustness of human perception where the low-error information streams dominate the outcome and appears to be general enough to apply to different intra and inter modal streams of human perception. It implies conditional independence of errors in the individual information streams and requires that the human information processing chain identifies correctly recognized items, thus eliminating false alarms, so that the only errors come from the lack of sufficient information for making a decision [Pavel, Slaney, Hermansky, ICASSP 2009]. We discuss implications of this concept in machine recognition of speech.

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Xiaoping Hu  
Georgia Institute of Technology and Emory University

### Functional and Effective Connectivities in Resting State Brain Networks Derived from fMRI Data Author(s): X. Hu, G. Deshpande, & P. Santhanam

We have investigated functional connectivity (FC) based on instantaneous correlation and effective connectivity (EC) based on Granger causality of four important networks at resting state derived from functional magnetic resonance imaging data – default mode network (DMN), hippocampal cortical memory network (HCMN), dorsal attention network (DAN) and fronto-parietal control network (FPCN). The use of correlation-purged Granger causality (CPGC), a measure recently introduced by us, not only enabled the simultaneous evaluation of FC and EC of all networks using a single multivariate model, but also accounted for the interaction between them resulting from the smoothing of neuronal activity by hemodynamics. FC was visualized using a force-directed layout upon which causal interactions were overlaid. FC results revealed that DAN was very tightly coupled compared to other networks while the DMN formed the core network around which the other networks amalgamated. Bidirectional causal interactions showed that posterior cingulate and posterior inferior parietal lobule of DMN acted as major transit hubs for information exchange. The unidirectional causal paths revealed that hippocampus and anterior prefrontal cortex (aPFC) received major inputs, indicating memory encoding and cognitive integration, respectively. Major outputs emanated from anterior insula and middle temporal area which were directed at aPFC, and might carry information about interoceptive awareness and external environment,

respectively, into aPFC for integration. This supports the hypothesis that aPFC-seeded FPCN may act as a control network. Finally, even though circumstantial evidence has given rise to networks with different nomenclature, there was high degree of interaction (especially causal) between different networks.

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Petr Janata  
University of California, Davis

#### Probability Structure in Music and the Coordination of Brain Networks Across Multiple Timescales

The system of major and minor keys on which Western tonal music is based defines a music-theoretical, perceptual, and statistical space that can be represented on the surface of a ring (torus). Keys are defined by probability distributions across the twelve possible pitch classes (the notes C, C-sharp, D, etc.). Local regions on the torus represent key regions (tonal centers) that are identified with similar probability distributions across the pitch classes. Keys that are close to each other in a music theoretical and perceptual sense, e.g. C major and G major, are situated close to each other on the toroidal surface because their pitch probability distributions are similar. A piece of music creates a pattern of movement on the toroidal surface. The pattern of movement is governed by the time window over which the occurrence probabilities of the 12 pitch classes are integrated. Using a leaky integrator with a 200 ms time constant, the transitions between notes in a melody or between chords are emphasized, whereas longer time constants of 2 or 10 s emphasize short cord sequences and the established sense of key. As we engage with music, different psychological processes transpire at various timescales. Sensorimotor processes, such as moving or singing along with a piece of music, are well-characterized at the shorter timescales, whereas mnemonic and emotional effects are more characteristic of the longer timescales. I will describe results from a functional magnetic resonance imaging (fMRI) experiment seeking to understand how music-evoked autobiographical remembering experiences are manifested in the brain. Using the model described above, I identify networks of brain areas that track the tonality changes at each of the timescales. The networks partially overlap and consist of brain areas whose known functions correspond to different facets of hearing a familiar song that evokes memories and positive emotions. Given the brain's penchant for extracting probability structures in its sensory inputs and responding to violations of expectations based on those probabilities, the sensitivity of brain regions to the time-varying probability structures that define music's movement in tonal space across multiple timescales is auspicious for our understanding the way in which the human brain couples complex musical stimuli with the many psychological processes they engender.

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Kerry Jordan  
Utah State University

#### Intersensory redundancy enhances early numerical abilities

We have recently found that multisensory stimuli facilitate numerical performance in infancy and early childhood. The first experiment I will present employed a habituation–dishabituation paradigm and showed that providing redundant, multisensory numerical information allowed preverbal infants to make more precise numerical discriminations than when they were provided with numerical information in the visual modality alone. Furthermore, in the face of perceptually redundant information, six-month-old infants attained a level of discrimination previously thought attainable only after additional months of development. I will then outline our recent experiment that extended this line of work to preschool children, who performed more accurately in a numerical matching task when given multisensory rather than unisensory information about number. In this study, three- to five-year-old children learned to play a numerical matching game on a touchscreen computer, which asked them to match a sample numerosity with a numerically equivalent choice numerosity. Samples consisted of a series of visual squares on some trials, a series of auditory tones on other trials, and synchronized squares and tones on still other trials. Children performed at chance on this matching task when provided with either type of unisensory sample, but improved significantly when provided with multisensory samples. Taken together, the data from this series of studies suggests that intersensory redundancy may boost early cognitive abilities such as numerical competence.

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Chi-Hung Juan  
National Central University, Taiwan

The Antisaccade Cost is Modulated by Contextual Experience of Location Probability

Authors: C.-H. Juan, C.-L. Liu, H.-Y. Chiau, P. Tseng, N. G. Muggleton, D. L. Hung, & O. J. L. Tzeng

It is well known that pro- and antisaccades may deploy different cognitive processes. However, the specific reason why antisaccades have longer latencies than prosaccades is still under debate. In three experiments we investigated the factors contributing to the antisaccade cost by taking attentional orienting and target location probabilities into account. In Experiment 1, using a new antisaccade paradigm, we directly tested Olk and Kingstone's hypothesis (2003), which attributes longer antisaccade latency to the time it takes to re-orient from the visual target to the opposite saccadic target. By eliminating the re-orienting component in our paradigm, we found no significant difference between the latencies of two saccade types. In Experiment 2, we varied the proportion of prosaccades made to certain locations (Geng and Behrmann, 2005) and found that latencies in the high location-probability (75%) condition were faster than those in the low location-probability condition. Moreover, antisaccade latencies were significantly longer when location-probability was high. This pattern can be explained by the notion of competing pathway for pro- and antisaccades in Kristjánsson and colleagues' findings (2001, 2004, 2007). In Experiment 3, we further explored the degrees of modulation of location probability by decreasing the magnitude of high-probability from 75% to 65%. We again observed a similar pattern as we did in Experiment 2, but with smaller modulation effects. Together, these experiments indicate that the re-orienting process is a critical factor in producing the antisaccade cost. Furthermore, the antisaccade cost can be modulated by probabilistic contextual information such as location probabilities.

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Adam Kohn  
Albert Einstein College of Medicine

Relating Response Variability Across Stages of Cortical Processing

Authors: A. Kohn & A. Zandvakili

Neurons in sensory cortex respond in a variable manner to repeated presentations of a stimulus. This variability is thought to constrain the accuracy of sensory encoding and, ultimately, perceptual decisions. Central to this issue is the degree to which variability is propagated along the cortical hierarchy: if variability in higher cortex arises primarily from local circuits, variability in lower areas will ultimately have little impact on perceptual decisions. To determine the relationship of variability at successive stages of processing, we performed simultaneous recordings from populations of single neurons in the upper layers of primate V1 and from their downstream targets in the middle layers of V2. We used a generalized linear model to predict trial-to-trial fluctuations in V2 responsivity from spike- and LFP-based measures of V1 population responses. We find that a simple model can explain a substantial portion of V2 variability and is moderately successful at predicting the timing of individual spikes in V2. Together these measurements suggest that much variability is shared, or perhaps propagated, across stages of cortical processing.

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Ulman Lindenberger  
Max Planck Institute for Human Development

Heterogeneity in Cognitive Aging: Genetic and Imaging Evidence

Authors: U. Lindenberger, I. Nagel, S.-C. Li, H. Heekeren, & L. Bäckman

Individual differences in cognitive performance increase from early to late adulthood. In this talk, I will examine this heterogeneity at genetic and neural levels of analysis. First, I will present the hypothesis that losses in neurochemical and anatomical brain resources in normal aging modulate the effects of common genetic variations on cognitive functioning. This hypothesis is based on the assumption that the function relating brain resources to cognition is nonlinear, so that genetic differences exert increasingly large effects on cognition as resources recede from high to medium levels in the course of aging. I will present empirical support for this hypothesis involving the effects of the COMT and BDNF genes on working memory and episodic memory. Second, I will note that performance heterogeneity generally has been largely

neglected in fMRI aging studies so that age differences in activation patterns are often confounded with individual differences in performance level. I will report data addressing this issue by comparing younger and older low and high performers in an event-related fMRI study. Specifically, 30 younger (20-30 years) and 30 older (60-70 years) healthy adults were tested on a spatial WM task with three load levels. In both age groups, a region-of-interest (ROI) analysis revealed marked differences in the activation patterns between high and low performers in both age groups. Critically, among the older adults, a more "youth-like" load-dependent modulation of the BOLD signal was associated with higher levels of spatial WM performance. These results underscore the need of taking performance level into account when studying changes in functional brain activation patterns from early to late adulthood. In the outlook, connections between genetic differences, structural and functional connectivity, and performance, and their implications for cognitive aging, will be discussed.

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Zhong-Lin Lu  
University of Southern California

#### Binocular Combination in Normal and Amblyopic Vision

Extending a suprathreshold binocular summation paradigm of phase perception developed by J. Ding and G. Sperling (2006, 2007) for normal observers, we investigated suprathreshold cyclopean perception of both phase and contrast in normal and amblyopic vision. In this paradigm, two suprathreshold sinewave gratings of the same spatial frequency but different spatial phases are presented to the left and right eyes of the observer. The perceived phase and contrast of the binocularly-combined cyclopean image is measured as a function of the contrast ratio between the images in the two eyes. We found that both eyes contributed equally in normal subjects. However, stimulus of equal contrast was weighted much less in the amblyopic eye relative to the fellow eye in binocular combination. We developed a mathematical model of binocular combination to account for cyclopean perception of both phase and contrast, and determined the mechanism of binocular deficits in amblyopia.

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Donald G. MacKay  
University of California, Los Angeles

#### Error Detection, Binding and the Medial Temporal Lobe: Evidence from Amnesic HM

This paper reviews evidence for a strong and previously unsuspected link between the medial temporal lobe (MTL) and error detection in visual cognition, language production, reading sentences and low frequency words aloud, sentence comprehension, and object naming. The evidence comes from ten studies conducted during 1998-1999 on errors, error detection and error correction in HM, an amnesic with MTL damage but virtually no neocortical damage. Two studies required detection of other-produced errors: objects "planted" in impossible contexts in complex visual scenes, e.g., a bird flying in a fish bowl, and anomalous word substitutions in otherwise grammatical sentences, e.g., I helped themselves to the birthday cake. In both studies, HM detected fewer errors than carefully matched memory-normal controls. Eight other studies examined self-produced errors, using error correction as an index of error detection in spoken discourse, reading sentences and low frequency words aloud, visual cognition, and object naming. Three features characterized HM's errors in all eight studies: anomaly, e.g., HM's errors rendered his sentences anomalous (incoherent, incomplete or ungrammatical); omission, e.g., HM tended to omit (rather than substitute) one or more words in self-produced sentences; and non-correction, e.g., HM corrected his errors reliably less often than the controls. I show that binding theory readily explains the link between error detection and the MTL, together with HM's episodic memory deficits, and the three features of his self-produced errors (anomaly, omission and non-correction).

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Ulrich Mayr  
University of Oregon

## Capturing the Dynamics of Control Via Eye Movements

Authors: U. Mayr, D. Kuhns, & M. Rieter

Important models of attentional control try to explain the dynamic recruitment of control, both within and across individual trials (Botvinick et al., 2001; Gilbert & Shallice, 2004). Yet, model predictions are almost never tested on that level, probably because of a lack of reliable information about how attention is allocated on a trial-by-trial basis. In the context of a task-switching paradigm we used eye tracking to assess task-congruent versus task-incongruent allocation of attention on the level of individual trials. Combined with hierarchical linear modeling this information can be used to characterize actual control dynamics (e.g., how attentional settings on trial  $n$  are coupled with attentional settings on trial  $n+1$ ). We demonstrate that such an approach allows us to distinguish between competing models of task selection (carry-over models versus configuration models) and of how inhibition is used during flexible task control (proactive versus reactive inhibition).

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Danielle S. McNamara  
University of Memphis

Linguistic Features of Writing  
Authors: D. S. McNamara & S. Crossley

This talk will describe recent research in which we have used Coh-Metrix to examine linguistic features that are correlated with essay quality. The results indicate that Coh-Metrix indices of cohesion do not discriminate between good and poor essays when written by native speakers of English. Indices of cohesion are weakly correlated with essay quality in texts written by second language writers. For both first and second language writers, essay quality is best predicted by indices related to language sophistication such as high lexical diversity, the use of less familiar (frequent) words, and syntactic complexity. While corpus results indicate that cohesion plays a minimal role in the quality of essays, our experimental results indicate that essays for which the cohesion is increased through manipulation receive higher scores than their original versions. These latter findings are aligned with intuitive notions that better essays are more coherent. We will discuss these discrepant results and alternative NLP approaches to measuring coherence in essays.

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Jeff Mulligan  
NASA Ames Research Center

Empirical Measurement of Visual Conspicuity

Traditional measurement of target visibility in the periphery typically involves a fixating subject intently waiting for the appearance of the stimulus. In real-world environments such as aircraft cockpits and automobiles, however, the operator is typically engaged in a variety of nonmonitoring tasks when visual alerting signals appear. We use the term conspicuity to distinguish the attention-getting power of a visual stimulus from simple visibility.

We have developed an experimental paradigm to study visual conspicuity: subjects are engaged in a central task in which they must use a computer mouse to keep a wandering target spot in the central portion of the screen while simultaneously monitoring a set of peripheral numeric displays for color change events. When such an event occurs, the subject must make a judgment concerning the displayed numeric value, indicating the response with a mouse click on one of two buttons located above and below the item. Both frequency of occurrence and importance or value are varied between the various possible alert locations. The results are modeled using the N-SEEV model (Steelman-Allen et al., HFES 2009).

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Tatiana Pasternak  
University of Rochester

Memory-Related Signals in the Prefrontal Cortex Depend on Cell Type Only in the Absence of Sensory Stimulation

Neurons in the prefrontal cortex (PFC) show direction-selective responses to behaviorally relevant visual motion (Zaksas & Pasternak, 2006, Hussar & Pasternak, 2009). In this study we examined memory-related signals in the PFC during a task where monkeys compared two directions of motion, sample and test, separated by a brief delay. For the analysis of neuronal activity recorded during the sample, the delay, and during the comparison test, we used spike waveform durations to classify the recorded neurons into narrow-spiking (NS) putative inhibitory interneurons and broad-spiking (BS) putative pyramidal neurons. We found that while responses of both classes of neurons to visual motion used in the task were equally likely to be direction-selective, during the memory delay the pattern of activity for the two cell classes was different. BS neurons were significantly more active than NS cells and were more likely to show anticipatory changes in firing rates. Furthermore, BS neurons were also significantly more likely to carry signals reflecting the direction of the preceding sample. These signals were largely transient and appeared in different neurons at different times in the delay, suggesting that the information about the remembered direction is likely to be distributed among PFC neurons. The difference between the two classes of neurons became particularly apparent at the end of the delay when memory-related signals were represented exclusively by BS neurons.

In contrast, during the comparison phase of the task, responses to the test of NS and BS cells were similar and, on trials when test direction matched that of the preceding sample, both cell types showed lower activity. This match suppression, likely to represent the process of sensory comparison, reflected the difference in the direction between sample and test, decreasing with smaller difference between the two stimuli and disappearing when the monkey was not required to perform direction discrimination. Furthermore, responses during the test of both cell classes reflected the upcoming decision, showing significant choice probability towards the end of the response.

These results reveal important differences in the contribution of the putative inhibitory interneurons and of the pyramidal cells to delayed discrimination tasks. Stimulus-driven activity, likely to represent bottom-up signals arriving from sensory cortex, was similar in both classes of cells, suggesting that both cell types participate in the sensory components of the task. However, in the absence of sensory stimulation, delay activity was dominated by putative pyramidal neurons. Since these neurons are a likely source of top-down projections from the PFC to visual and parietal cortical neurons, they may be a source of anticipatory and stimulus-related delay activity frequently observed in these neurons.

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Misha Pavel  
Oregon Health and Science University

Early Perceptual Stimulus Processing and Triage  
Authors: M. Pavel, C. Huang, K. Hild, & S. Mathan

The efficient allocation of attention and information processing resources is a fundamental cognitive function and a determinant of performance in most sensory-motor tasks. An efficient way to allocate processing resources would require the triaging of stimuli, prioritizing stimuli that are novel (incongruent) and important. We report preliminary results of a perceptual experiment based on a rapid serial visual presentation in which we manipulated independently task and target difficulty. In addition to recording manual responses used by the participants to indicate the detection of complex targets, we recorded EEG single trial evoked potentials. As expected, the target detection events were generally associated with features such as P300. There was, however, a reliable feature approximately 100 msec after stimulus onset that was correlated with the target difficulty, but not with performance or task difficulty. These results suggest that the perceptual system first detects the incongruence of the stimulus and then allocates the needed processing resources.

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Nicholas Port  
Indiana University

Ocular-Motor Performance of Indiana University Varsity Athletes  
Authors: N. L. Port, K. R. Monroe, & S. A. Hitzeman

**PURPOSE:** The long-term goal of the research project is to test whether ocular-motor performance correlates with athletic performance. In our first pilot project, we aim to discover how the visual and ocular-motor systems of collegiate varsity athletes differ from those of controls.

**METHODS:** Sixty-three freshman varsity Indiana University (IU) athletes across eighteen sports performed two experiments (fixation and saccade) as part of the standard IU School of Optometry visual screening battery performed on all incoming freshman athletes. Twenty-six IU School of Optometry students were used as a control group. In addition, we studied ninety Junior Olympic athletes in August of 2009 in an identical sports vision screening (data not yet included in analyses). In the two experiments, subjects were seated on an adjustable stool with their chin on a chin-rest and viewed stimuli presented on a 21" computer monitor. We tracked eye movements with a remote video-based noninvasive SR Eyelink eye tracker at 1000Hz. In our fixation experiment, subjects fixated a white dot on a black background for 30 seconds in either the presence or absence of a distracter stimulus. The distracter stimulus was a large field of drifting dots that randomly changed directions after random periods of time ranging from 0.2 to 2 seconds. In the saccade experiment, the computer screen showed two static targets 11 deg. apart; subjects made as many accurate saccades as possible during a 30-second viewing interval, alternating between the targets. Both experiments were repeated twice for each subject.

**RESULTS:** In the fixation experiment, there was more root mean squared (RMS) error and greater eye velocity variability (SD) in the distracter condition than in the nondistracter condition. In the distracter condition, RMS error varied significantly across sport and the control group (ANOVA,  $df = 18$ ,  $F = 2.14$ ,  $p = 0.0082$ ); in the nondistracter condition, RMS error did not vary significantly across sport and the control group (ANOVA,  $df = 18$ ,  $F = 0.6446$ ,  $p = 0.8571$ ). Eye velocity variability also varied significantly across sport for both distracter (F-test  $p < .0001$ ) and nondistracter conditions (F-test,  $p < .00001$ ). A multiple-comparison test (with Bonferroni corrections  $p < 0.05/18$ ) indicated several sports and the control group differed from each other. Finally, a difference was found between male and female athletes in fixation ability.

In the saccade experiment, the number of saccades made in 30 seconds varied significantly across sport and the control group (ANOVA,  $df = 18$ ,  $F = 4.52$ ,  $p < 0.00001$ ). In addition, male athletes made more saccades than female athletes (median = 102 vs 93); gender distributions are significantly different from each other ( $p = 0.003$  two-sample Kolmogorov-Smirnov goodness-of-fit hypothesis test;  $p < .00001$  two-sample T-test).

**CONCLUSIONS:** Collegiate level varsity athletes have better ocular-motor performance than controls, and performances vary systematically across sport and gender.

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Nicholas J. Priebe  
The University of Texas at Austin

#### Variability, Spike Threshold and Stimulus Selectivity in Primary Visual Cortex

The question of how precise response selectivity emerges in the visual cortex has been marked by considerable controversy, ever since Hubel and Wiesel first described orientation selectivity. Today, there are essentially two opposing views of how selectivity arises. Feed-forward models, derived from Hubel and Wiesel's original proposals, rely entirely on the properties and organization of thalamic, or feed-forward, inputs to cortical cells. Feed-back models require some form of lateral inhibition to refine response selectivity relative to the rather weak bias provided by thalamic inputs.

This debate has in large part been driven by the paradox presented by two divergent lines of evidence. On the one hand, many cortical response properties, such as cross-orientation suppression, orientation, direction and temporal frequency selectivities, appear to require lateral inhibition. On the other hand, while lateral inhibition could potentially provide considerable computational power to neuronal circuits, several lines of evidence suggest that it may not sharpen selectivity in the cerebral cortex. In intracellular recordings from primary sensory cortical areas *in vivo*, synaptic activity often lacks the necessary properties to support lateral inhibition. Specifically, inhibitory inputs are most often tuned to the same stimuli as the excitatory inputs, and inhibition evoked by non-preferred stimuli is generally weak. Additionally, inactivation of the cortical circuit, including both excitatory and inhibitory components, does not degrade the selectivity of the remaining feed-synaptic inputs.

I will present intracellular *in vivo* recordings that suggest a model for cortical computation that does not rely on lateral inhibition. Instead, we can explain complex aspects of cortical responses parsimoniously from simple, well-characterized, nonlinear features of the feed-forward excitatory pathways, such as spike threshold, contrast saturation, and spike rectification, along with stimulus-induced changes in background membrane potential fluctuations. These changes in the amplitude and frequency of membrane potential fluctuations alter the relationship between the average membrane potential and firing rate, and act as a gain control element that shapes cortical selectivity.

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Roger Ratcliff  
Ohio State University

Sleep Deprivation, the Psychomotor Vigilance Task and Driving (and Simple RT)  
Authors: R. Ratcliff & H. Van Dongen

I will present a model for the psychomotor vigilance test. This task has become a standard in assessing the behavioral effects of sleep deprivation. In the task, a millisecond timer remains off for between 2 and 10 seconds and then is turned on. The subject has to hit a button as soon as he/she detects that the counter is running. A critical finding is that when subjects are sleep deprived, they show lapses in performance, that is, produce long reaction times (RTs). The decision process used is a one-boundary diffusion process (inverse Gaussian or Wald distribution of finishing times). This is preceded by a random Gaussian process that represents vigilance; it produces a delay prior to a signal to turn on the decision process. The model fits lapses (proportion of responses > 500 ms say), the RT distributions, and hazard functions. It fits these for sleep deprived and non-deprived sessions. The model parameters track alertness measures and parameters correlated with data collected at the same levels of deprivation from a two-choice numerosity discrimination task.

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John Reynolds  
The Salk Institute

Spatial Attention Decorrelates Intrinsic Activity Fluctuations in Macaque Area V4

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Paul Sajda  
Columbia University

Sparse Decoding of Neural Dynamics by a Large-Scale Model of V1  
Authors: P. Sajda, J. Shi, J. Wielaard, & R. T. Smith

Sparse coding has been posited as an efficient information processing strategy employed by sensory systems, particularly visual cortex. Substantial theoretical and experimental work has focused on the issue of encoding, namely how the early visual system maps the scene into a sparse representation. In this work we investigate the complementary issue of a sparse decoding of the neural activity, given a realistic mapping of the visual scene to neuronal spike trains. Specifically we consider sparse decoding within the context of a large-scale spiking neuron model of primary visual cortex (V1). The model was not optimized to generate a sparse encoding, rather its architecture and parameters were set to reproduce a range of classical and extraclassical physiological responses, at both the single-cell and population level, which are consistent with experimental data. Given the stimulus-dependent spike trains generated by a large population of cells in the model (>4000), we use a linear decoder which imposes sparsity via an L1 norm. The decoder can be viewed as a decoding neuron (linear summation followed by a sigmoidal nonlinearity) in which there are relatively few non-zero synaptic weights. We find: (1) the best decoding performance is for a representation that is sparse in both space and time, (2) decoding of a temporal code results in better performance than a rate code and is also a better fit to the psychophysical data, (3) the number of neurons required for decoding increases monotonically as signal-to-noise in the stimulus decreases, with as little as 1% of the neurons required for decoding at the highest signal-to-noise levels, and (4) sparse decoding results in a more accurate decoding of the stimulus and is a better fit to psychophysical performance than a distributed decoding, for example one imposed by an L2 norm. We conclude that sparse coding is well-justified from a decoding perspective in that it results in a minimum number of neurons and maximum accuracy when sparse representations can be decoded from the neural dynamics.

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Matthias Scheutz  
Indiana University

## Gendered Voice and Robot Entities: Do Males and Females View Robots Differently?

Authors: M Scheutz & P. Schermerhorn

Social-psychological processes in humans play an important role in long-term human-robot interactions. In this talk, we report results from several studies showing interesting differences in the way male and female subjects view and are affected by robots during human-robot interactions. For example, we find that males tend to think of robots as more human-like, show evidence of "social inhibition" on an arithmetic task performed in the presence of a robot, and respond in a more socially desirable way on a survey administered by a robot. In contrast, females tend to view robots as more machine-like, do not seem to be affected by a robot's social presence while engaged in the arithmetic tasks, and exhibit less socially desirable behaviors responding to a robotic survey taker. We formulate several hypotheses based on proposals in the literature -- including the "voice-as-agent hypothesis" and the "gender-alignment hypothesis" -- in an effort to explain the observed effects and demonstrate based on recent results from extensive HRI experiments that neither can fully explain our findings.

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Shihab Shamma

University of Maryland

## Coherence as the Basis of Complex Scene Analysis

Authors: S. Shamma, L. Ma, & M. Elhilali

In the analysis of auditory scenes, it is common to postulate a complex set of grouping rules that are inspired by Gestalt principles found originally particularly useful in the segmentation and perception of images. However, these approaches become rather complicated when they have to take temporal factors into account, and often leave out the important questions of what role attention and feature binding play in the formation of perceptual objects and sources. The talk will address these issues and propose an alternate simpler point of view that integrates these factors through the temporal coherence of the stimulus attributes, and proposes a role for attention in the binding of the attributes of emergent objects.

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Steven K. Shevell

University of Chicago

## What Neural Representation Mediates Perceptual Memory for Rivalrous Images?

Authors: S. K. Shevell & P. Kang

Continuous viewing of rivalrous images with luminance contrast, such as a vertical grating to one eye and a horizontal grating to the other eye, gives a percept that alternates over time between the two images. This perceptual alternation can be slowed, or even stopped, if the same images are presented intermittently (Leopold et al., 2002). A basic question is whether the stabilized percept, which reveals perceptual memory between intermittent presentations, reflects a persisting dominant response from one eye (Chen & He, 2004; Pearson & Clifford, 2005) or persistence of what is consciously seen (the percept). This was tested with rivalrous images that give multistable percepts, not just the two percepts of complete left-eye or complete right-eye dominance. The experiments reveal perceptual memory at the level of the percept, not the level of a retinotopic representation from a dominant eye.

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Richard Shiffrin

Indiana University

## Explaining Noisy Data: Normative and Generative Models of Function Estimation

Authors: D. Little & R. Shiffrin

Whether analyzing one's own data or judging models fit to others' data, a scientist almost always views a 2-D plot of two data variables and forms a 'mental model' of the 'best' account. How do scientists form such mental models? Do such

models balance fit and complexity in the way suggested by the best modern statistical methods such as Bayesian Model Selection (BMS) which incorporates the "Bayesian Occam's Razor?" We show observers many different 2-D plots of noisy data. For each we collect a best estimate of the most likely causal function that could produce y as a function of x. A first analysis assumed observers select functions from a set of polynomials from degree zero to seven. The observers' responses did not match the BMS normative account in several ways. For one thing they did not seem to distinguish degree zero from one: linear functions of any slope seemed equivalent. For another, they did not seem to choose high degree polynomials but rather often generated functions that tracked the data smoothly. We then used Gaussian Processes (incorporating BMS) to fit a model assuming observers choose from five function classes: polynomials of degree one to four, and a Gaussian process that predicts a given y value by interpolating a value based on exponentiated squared distance from nearby observed data points. This model showed considerable observer differences in the use of simple functions versus data tracking functions. A second study explored the observers' models of the sources of noise in the data by examining the responses to 'aberrant' data points.

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Barbara Shinn-Cunningham  
Boston University

#### Dynamics of Focusing and Switching Auditory Attention

Information in acoustic signals is conveyed by changes in sound over time. As a result, listeners must sustain attention on a desired sound source over time in order to extract meaning. To understand the processes by which listeners deploy attention in a complex acoustic scene, we have been exploring the dynamics involved in focusing, sustaining, and switching auditory attention. In this talk, I will review recent results from our lab that show how selective auditory attention evolves through time. For instance, our behavioral results from studies show that when listening for a sequence of speech syllables, similarity of the syllables over time enhances the ability to selectively hear out and recall the sequence in an automatic, bottom-up way. These results show that perceptual organization of the acoustic scene interacts with the dynamics of attention. Recent imaging results reveal that the attentional network engaged in spatial selective attention is similar for auditory and visual tasks, a finding that suggests that similar dynamics may influence sustained visual attention.

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George Sperling  
University of California, Irvine

#### Modeling the Time Course of the First Few Seconds of Binocular Rivalry

Bartels and Logothetis did a binocular interruption experiment to determine the sources of binocular rivalry. They presented different, incompatible flower images to the left and right eyes. Usually, only one of the two images was perceived (binocular rivalry). After either 0.3 or 3.0 sec, there was an interruption and subsequently either the same stimuli were presented again or the stimuli were exchanged between eyes. I present a model for their experiment that shows precisely how the strengths of images in a lower-level eye competition and in a higher-level image competition decay over time. The input to the model is the sequence of stimuli. The output is the probability of perceiving a particular image after the interruption. The model assumes that: (1) the instantaneous ocular strength of the eye that is receiving the dominant image is represented by a positive number, and the strength of the suppressed eye by its negative; a second number represents the strength of the dominant image, its negative represents the suppressed image; (2) ocular- and image-component strengths add linearly; (3) the summed strengths are perturbed by additive, Gaussian internal noise; and (4) the highest-strength eye+image combination is perceived after the interruption.

The transformation of the raw probability-of-perception data into strengths removes all complex interactions present in the raw probability data. For these images, ocular strength was greater than image strength. For all subjects individually, and for all conditions investigated, the strengths of ocular and image components decline over time at same rate, completely in parallel. Conclusion: The data and model show how a process (binocular rivalry) that used to be considered as unitary can now not only be dissected, it can be precisely measured at each of two different processing levels.

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