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ABSTRACTS
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Ben Backus
SUNY College of Optometry

A Model for the Treatment of Two Disorders of Binocular Vision

Amblyopia and strabismus are two disorders of binocular vision that resist treatment in adults. Both have a high prevalence, with an incidence of 4% each, and with 50% of people who have strabismus also having amblyopia. Recent computer-based visual training approaches have had some success (e.g. Hess, Mansouri, & Thompson, 2010, Optom & Vis Sci 87: 697–704; Levi & Li, 2009, Vis Res 49: 2535-49; Polat et al, 2004, PNAS 101, 6692–7; Zhou et al, 2006, Vis Res 46: 739-50), but no solid models exist for understanding how they work in terms of underlying neurophysiology. Normally, most binocular neurons have similar tuning for each eye (e.g. Freeman & Ohzawa, 1990, Vis Res 30: 1661–76). We propose that aberrant RF subunit structure for the amblyopic eye must lead to dysfunctional binocular vision. Accordingly, the receptive fields of individual neurons must be repaired for treatment to be successful. We created a model for simulating treatment, the Single Neuron Doctrine for treatment of Binocular Vision (SND-BV 1). In this model binocular neurons are represented by receptive field structures that consist of linearly weighted LGN inputs. In simulations, the model binocular neuron starts with a gabor-shaped receptive field structure for the good eye. The good eye's subunit causes activation of the neuron some of the time during binocular viewing of training stimuli. Hebbian learning then increases the weights on the correct (simultaneously active) LGN inputs from the weak eye. The weak eye's RF structure comes to resemble the good eye's RF structure, while both eyes' structures deviate from the original gabor over time in a manner that depends on the training stimuli. Interestingly, if any of the model's LGN neurons have an unbalanced receptive field, training with dark or light stimuli leads to corruption of the binocular RF structure, which may help explain why physiological measurements of LGN RFs show them to be balanced. The model does not include inhibitory interactions between differently tuned neurons in cortex, nor dynamic (i.e. rivalrous or clinical) interocular suppression, nor communication between V1 and other cortical areas. These features will need to be included for the model to be useful in designing therapies for patients. Nevertheless, SND-BV 1 provides a foundation for visualizing change over time in RF structures that may be necessary for treatment, and shows how a physiologically plausible system would operate without the additional constraints provided by inhibitory interactions, which is essential for understanding what those constraints normally contribute.

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Marty Banks
University of California, Berkeley

Is Stereo Vision Optimized for Natural Environments?
Authors: M. S. Banks, E. A. Cooper, & W. Sprague

We asked if regularities in the visual environment provide a basis for some unexplained phenomena in stereovision. Specifically, we asked whether the positions of corresponding retinal points—positions in the two eyes that when stimulated yield the same perceived direction—are adapted to regularities in the binocular disparities encountered in the everyday environment. The positions of objects in the world that stimulate corresponding points define the horopter. Stereopsis is most precise near the horopter, which is pitched top back above fixation and is curved somewhat convexly to the left and right of fixation. Does the horopter align with regularities in the 3D visual environment? To answer this, we built a mobile device that simultaneously measures binocular fixations and the 3D scene layout. Subjects performed everyday activities, like preparing a meal or walking through an environment, while we measured where they were looking (including how far away) and the 3D scene in front of them. From these data we reconstructed the images projected to the

eyes, particularly the binocular disparities, as subjects performed these tasks. The data revealed a number of things. 1) Disparities encountered during everyday tasks have clear regularities, which vary across tasks. 2) The encountered disparities tend to be uncrossed above fixation and crossed below in agreement with the pitch of the vertical horopter. 3) The encountered disparities during some, but not all, tasks tend to be uncrossed to the left and right of fixation in agreement with the convexity of the horizontal horopter. Thus, despite varying patterns from one task to another, the disparity distributions we measured generally align with the positions of corresponding points, supporting the hypothesis that the regions of best stereovision are well adapted to the complex patterns of visual input experienced in everyday activities.

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Johannes Burge
University of Texas at Austin

Using Natural Images to Determine Optimal Processing for Speed Estimation
Authors: J. Burge & W. Geisler

The neural computations underlying selective perceptual invariance with natural stimuli are enormously complex. Many studies of neural encoding-decoding assume neurons with invariant tuning functions. Except for neural noise, these neurons give identical responses to all stimuli having the same value of the relevant dimension. This cannot occur under natural viewing conditions. Variation in the natural signals along irrelevant dimensions inevitably causes the responses to vary. Here, we use a Bayesian task-specific encoding-decoding framework that specifies how to encode task-relevant information and process it to construct neurons that are largely invariant to irrelevant natural image variation. We use the framework to estimate retinal image speed from photoreceptor responses to natural movies. The space-time receptive fields (RFs) that optimally encode information relevant for estimating speed are direction selective but, interestingly, they are not speed-tuned. The RF responses to natural images specify how to wire up these direction-selective units to create speed-selective units. That is, appropriate non-linear combination of the RF responses yields a new population of neurons that are speed-tuned and are (largely) invariant to irrelevant stimulus properties. These speed-tuned neurons represent the log-likelihood (LL) of speed and have tuning curves that are approximately log-Gaussian in shape. MAP decoding yields unbiased speed estimates over a wide range (-8 to 8 deg/sec). The optimal space-time RFs and speed-tuned LL neurons share many properties with neurons in cortex. Most motion sensitive neurons in V1 and MT are direction- but not speed-selective whereas ~25% of V1 and MT neurons are speed-tuned. Also, speed-tuned neurons have tuning curves that are log-Gaussian in shape. Critically, the optimal space-time RFs and the optimal speed tuning curves in our analysis were not arbitrarily chosen to match the properties of neurophysiological RFs. Rather, they emerge from a task-specific analysis of natural signals. Thus an ideal-observer analysis, with appropriate biological constraints and zero free parameters, predicts many of the dominant neurophysiological features of speed processing. Similar analyses provide insight into how to construct selective invariant tuning for other behaviorally relevant stimulus dimensions (e.g. defocus, disparity, motion in depth) not trivially available in the retinal images.

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David Burr
University of Florence

Cross-Sensory Integration and Calibration During Development

Much evidence suggests that humans integrate information between senses in a statistically optimal manner, maximizing the precision of performance. We have recently shown that reliability-based integration of vision and touch develops only after about 8 years of age. For younger children one sense dominates over the other: for size discrimination, touch dominates over vision; but for orientation, discrimination vision dominates. We suggest that the dominance of one or other sense reflects cross-modal calibration of developing systems, where one sense calibrates the other rather than fusing with it. But unlike sensory fusion, it is the more robust and accurate sense that dominates the calibration, even if it is the less precise. Several lines of evidence support this idea: congenitally blind children show a selective deficit in haptic orientation-discrimination, and dyskinetic children (with highly impaired movement control) show a selective deficit in visual size judgments. Both these impairments could result from a lack of cross-sensory calibration in early development.

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Tom Busey
Indiana University

An Instrumentation Package for Performance Monitoring of Snowboarding
Authors: T. Busey, O. Busey, & S. Ketels

We have adapted hardware and software originally designed to control small UAVs to enable performance monitoring of students while they learn to snowboard. The hardware package measures position via GPS, altitude via a barometer, orientation via a magnetometer, tilt via accelerometers, motion via gyros, and foot pressure via pressure sensors in the boots. Data is recorded to an onboard memory and current development focuses on bluetooth connections for visualizations on a mobile device in Google Earth. We will discuss derived measures that find the centroid of each turn and compute measures such as speed and direction. This will help students discover where they are losing speed during the turn. Other measures such as comparison of the GPS direction vs. the magnetometer help determine the proportion of "skidded" versus "carved" turns, an important indicator of skill, and likely an important predictor of catching edges. Applications of the technology to the learning environment will be discussed, including warning signals that indicate an imminent front edge catch. More advanced boarders might also benefit from an analysis of the development of their skills with this device and app.

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Baptiste Caziot
SUNY College of Optometry

Fast Perception of Binocular Disparity
Authors: B. Caziot, M. Valsecchi, K. R. Gegenfurtner, & B. T. Backus

Is depth perception from binocular disparities slow or fast? Surprisingly, the answer is not yet clear. Common experience with stereograms suggests that stereopsis is slow compared to other visual processes, as does the prior literature. Yet other facts suggest no reason why stereopsis could not be fast: neurons in primary visual cortex respond to disparity at the same time as other stimulus properties and vergence eye posture can respond to disparity in 80 ms. We used a two-alternative forced-choice task to measure accuracy and response times for detecting a brief (17-67 ms) stereo pop-out target. The target was detected quickly, with choice responses deviating from chance performance at about 200 ms, comparable to responses for luminance-defined stimuli. Masks that disrupted only monocular processing, or that contained depth structure different from the target, were not effective to disrupt performance. Thus depth processing does not take longer than luminance processing *per se*.

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Patricia Cheng
University of California, Los Angeles

Nature's Wisdom: Why Causal Discovery in Preschool Children Can Inform Scientific Causal Inference.

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Charles E. Connor
Johns Hopkins University

A Sparse Object Coding Scheme in Area V4

Humans have a remarkable ability, unmatched by the best computer vision systems, to perceive, understand, and interact

with shapes in the natural world. Our perception of shape depends on stage-wise transformation of image information in the ventral visual pathway of the brain. We use electrode recording from old world monkeys (an extremely close model for human vision) to reverse engineer transformation and representation of shape in the brain. We find that neural populations represent shapes as 3D spatial configurations of medial axis and surface fragments. Neurons act as filters tuned for the relative 3D position, 3D orientation, and 3D curvature of these shape fragments. This explicit representation of geometric information underlies our ability to understand, describe, and manipulate 3D structure.

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Lawrence Cormack
University of Texas at Austin

Assaying Visuomotor Behavior Using the Response Movement Correlogram

Last year at this meeting, Jeff Mulligan introduced the concept of the eye movement correlogram (EMC). The EMC quickly determines the latency and precision of oculomotor responses to moving stimuli; we have used it to dissociate different types of eye moment responses to second order stimuli, and also showed an interesting oculomotor consequence of divided attention (Mulligan, Stevenson, and Cormack, 2013). Here, we extend the notion of the EMC to manual responses, yielding the response movement correlogram (RMC). This is obtained by cross-correlating the horizontal and vertical velocity time series of the stimulus with those of the response. Like the EMC, the RMC can quickly reveal differences in the processing of different types of information. For example, when trying to keep a cursor centered on a Gabor doing a 2D random walk, latencies are relatively lower and more precise for the response component parallel to the contrast energy (i.e. perpendicular to the stripes) than for the orthogonal component (peak latencies of ~350 vs. ~390 msec and full-width-at-half-height values of ~160 vs. ~220 msec). As this occurs for both horizontal and vertical Gabors, it presumably does not reflect a directional asymmetry for moving a finger, hand, or arm, but rather the use of phase information from the Gabor carrier when available. This basic result can be cleanly demonstrated with under 2 minutes of actual data collection. In conclusion, the RMC produces robust results using large amounts of data gathered in a short amount of time, and is a potentially interesting paradigm complementary to traditional psychophysics.

Reference: Mulligan, Stevenson, and Cormack (2013) Proc. SPIE 8651, Human Vision and Electronic Imaging XVIII, 86510Z; doi:10.1117/12.2010333

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Thaddeus Czuba
Albert Einstein College of Medicine

More Than Meets the Eye: Binocular 3D Motion Processing in Area MT
Authors: T. B. Czuba, A. C. Huk, L. K. Cormack, & A. Kohn

Primate area MT has long been recognized as a hub for visual motion processing. MT neurons encode information about visual motion through selectivity for the direction, speed, retinal position, and position-in-depth (via binocular disparity) of motion within the visual field (Born & Bradley, 2008). Though sensitivity to retinal position and disparity set up a strong premise for a representation of motion within three-dimensional space, whether or not MT neurons explicitly encode 3D directions of motion — opposed to separable tuning for frontoparallel motion and static disparity — remains to be seen (Zeki, 1974; but see Maunsell & Van Essen, 1983b). Over the last decade, we've seen mounting psychophysical evidence for distinct binocular 3D motion mechanisms (e.g. Fernandez & Farell, 2005; Shioiri et al., 2009; Rokers et al., 2011; Czuba et al., 2011) and a recent neuroimaging study implicated the human MT/MST complex in binocular 3D motion processing (Rokers et al., 2009).

We therefore sought to reexamine single-unit responses in primate area MT for evidence of distinct 3D motion tuning using a comprehensive set of dichoptic binocular & monocular motion stimuli. We recorded from area MT in two anesthetized-paralyzed macaques using a novel approach for functional binocular alignment that allowed for precise dichoptic stimulus presentation under conditions of unknown fixation & vergence. The overwhelming majority of MT units (~70%) exhibited a significant differential response to motion toward versus away from the observer, which could be used by downstream areas to decode 3D direction. We found that nearly 20% of recorded MT units had binocular motion

preferences consistent with 3D motion toward or away from the observer; conditions that correspond to opposite directions of motion in the two eyes, spanning a small — but ecologically significant — range of real world trajectories. Comparisons of binocular tuning with predictions based on linear combinations of constituent monocular responses revealed evidence of both facilitative and suppressive nonlinearities in the combination of motion signals from the two eyes. 3D-tuned units showed significantly greater deviations from simple linear predictions than those tuned for more frontoparallel directions. Static disparity tuning, however, was poorly correlated with 3D motion sensitivity and could not account for deviations from linear predictions. Widespread sensitivity for 3D motion in area MT suggests a much more comprehensive representation of motion than previously thought, and motivates a reworking of our conceptions of how real-world motions are represented in extrastriate cortex.

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Peter Dixon
University of Alberta

Speed, Accuracy and Mind-Wandering

Mind-wandering has been investigated using a probe technique in which subjects are periodically interrupted and asked whether they are on task. Research using this paradigm demonstrates that mind-wandering impairs performance on a range of simple and complex tasks. However, it is not always easy to characterize the nature of these effects of mind-wandering. For example, some aspects of performance, such as eye movements while reading or the coordination of dual-task performance, remain relatively intact. Further, speeded responses while mind-wandering can be either faster or slower and accuracy may or may not suffer. Here, I argue that what unifies these effects is that performance typically requires an interpretation of a stimulus in its context, and mind-wandering impairs that interpretation. Inadequate interpretation in turn can affect the shape of the speed-accuracy tradeoff function.

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Barbara Dosher
University of California, Irvine

Perceptual Learning, Feedback, and Generalization.

Perceptual learning improves how we see visual stimuli and is the basis of visual expertise. Often, these improvements reflect the development of improved templates or filters or enhancement of stimulus inputs. In perceptual learning, both mechanisms may reflect sophisticated reweighting of information from sensory representations as they determine perception and decision. This talk considers whether and how the Augmented Hebbian Reweighting Model and its extension the Integrated Reweighting Theory account for broad phenomena such as the roles of feedback in learning, training conditions that permit learning, and the basis of generalization.

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James Elder
York University

A Generative Theory of Shape
Authors: J. H. Elder, A. Yakubovich, & G. Goren

Theories of shape representation abound, but few models are truly generative, able to explain the natural shapes we observe through a small number of causal hidden variables. This generative property is important for the human object pathway, as it would allow higher-order shape areas (e.g., V4/TEO) to feed back global constraints to earlier visual areas (e.g., V1/V2) to resolve local grouping ambiguities.

Here we report progress on a promising new theory of shape representation based upon a family of local image deformations called formlets. This theory has the critical property that shape topology remains invariant under all formlet actions, guaranteeing the validity of hypothesized shapes, and performs favourably on the problem of contour completion

relative to models that do not preserve topology.

How can we assess whether this theory explains human shape perception? One possibility is that the image deformations on which the theory is based might leave traces in the human perceptual record. To explore this idea, we test for distortions in spatial judgments made near visible shapes, and relate these distortions to the deformations predicted by formlet theory.

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Justin Halberda
Johns Hopkins University

Approximate Number and Average Size are Representations With No Individuals
Authors: J. Halberda & H. Y. Im

A debate in visual perception and cognition has focused on the extent to which the approximate number of items in a visual collection is extracted directly from the visual environment (e.g., number as a basic visual feature) versus being merely represented via a proxy such as visual density or texture. This debate recapitulates a debate concerning the representation of average size (i.e., is average size of the items in a collection represented versus only object-based attention to a subset of the items in a collection). In each of these cases, a paradox is quite palpable – representing the average size of items or approximate number of items would seem to require that there first be individual items represented, with sizes, in order to be counted or averaged. I believe that average size is a representation that is extracted with no individual sizes ever being represented; and I believe that approximate number is extracted without there ever being individual items that are represented and counted. In this talk, I present evidence from psychophysical studies of average size and approximate number identification under conditions of limited viewing that supports these claims – number and size appear to be represented in an all-or-none fashion without gradual accumulation of evidence across discretely sampled items.

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Xiaoping Hu
Emory University

Probing More Into the Dynamic Nature of Resting State Brain

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Shaw Ketels
University of Colorado at Boulder

Snowboarding as an Empirical Domain
Authors: S. L. Ketels, T. Busey, & O. Busey

In the early stages of skill acquisition, learning how to snowboard can be quite debilitating, especially for adults. Each painful experience contributes to strong negative associations, both explicitly and implicitly. These experiences impede the establishment and successful coordination of complex motor skills that are, ironically, necessary to avoid these experiences in the future. Thus avoiding falls, especially the most painful varieties of falls, is crucial in learning how to snowboard. "Catching edges" is widely understood to lead to the most painful falls. This refers to "catching" the downhill edge of the snowboard on the hill, quickly and unexpectedly tossing riders downhill with the combined force of whatever momentum they have established in conjunction with gravity. Snowboarding is a complex motor skill that involves building complex novel motor representations. Novel fundamental balance processes are a prerequisite for all other snowboarding movements. It is thus a good candidate domain for the investigation of the acquisition of motor skills, and may have implications in other domains, such as stroke rehabilitation. The popularity of snowboarding and the potential for great pain in the initial stages of learning offer more immediate applications as well.

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Michel Landy

New York University

Coordinate Systems for Movement Planning
Authors: M. S. Landy & T. E. Hudson

In what coordinate system are visually guided reaches planned? The vast majority of papers in the motor literature suggest (or assume) a vector-based, polar coordinate frame: movement direction and extent. For eye movements, this is consistent with the map in superior colliculus. But neural coding of reaches is considerably more complex. Over several studies, we have evidence that two movement-planning codes are used: the direction/extent code as well as a code centered on the movement goal, possibly in a Cartesian coordinate system. Our first evidence comes from a study of reach learning. Subjects made point-to-point reaches on a tabletop as instructed by a computer display. A fixed set of start/target pairs were practiced repeatedly over a 45-minute session. In half of the session, reaches were grouped in mini practice blocks, grouped by the reach vector (e.g., all the forward-and-rightward reaches were practiced repeatedly, followed by a block of various leftward reaches, etc.). In the other half, the same set of reaches was reordered into mini-blocks grouped by movement endpoint (e.g., all reaches to the far-left target were practiced repeatedly, then those to the near-middle target, etc.). The pattern of movement errors was completely different for the two learning conditions. Grouped-by-vector reaches were noisier with covariance enlarged along the reach direction; grouped-by-target errors were smaller and isotropic. In a second study, we measured adaptation to movement perturbation (in our case, false feedback of movement endpoint on the display). We introduced a novel, sensitive method for measuring the adaptive response to reach feedback perturbation: the amount of shift of movement feedback was a sine wave over trials. When two movement coordinates were perturbed (e.g., reach extent and direction), a different temporal frequency of perturbation was used for each coordinate. Subjects were able to independently adapt to reach extent and direction. In another session, subjects were able to independently adapt to perturbations in the x- and y-directions. Adaptation generalizes to reaches in directions at which no feedback was ever provided. The sine wave method allows us to use very small perturbations (less than a finger width) so that subjects are unaware of the existence or type of perturbation, so that adaptive responses are unlikely to be the result of cognitive strategy. We conclude that multiple coordinate systems are used for the planning of reaches, and that the motor system likely integrates these multiple movement plans in a manner favoring the more accurate plan, much as sensory cues are optimally integrated.

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Zhong-Lin Lu
Ohio State University

The Quick Methods: Bayesian Adaptive Estimation of Psychological Functions

Adaptive procedures are developed to reduce the burden of data collection in psychophysics by creating more efficient experimental test designs and methods of estimating either statistics or parameters. In some cases, these adaptive procedures may reduce the amount of testing by as much as 80% to 90%. For example, adaptive methods for estimating properties of psychometric functions improve test efficiency by targeting stimuli to prespecified regions of the empirical psychometric functions (e.g. threshold region) based on subject responses. Our goal is to develop adaptive methods for the estimation of psychophysically measured functions and surfaces. In this talk, I will describe the Bayesian adaptive framework for optimizing psychophysical tests and its application to the development of various quick methods for measuring TvC functions, d' psychometric functions, contrast sensitivity functions, and forgetting functions. I will provide animations, simulations and psychophysical validations of these methods, and discuss challenges and future directions.

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Cory Miller
University of California, San Diego

Vocal-Motor Activity in Primate Frontal Cortex During Natural Communication

Frontal cortex has long been argued to play little to no role in primate vocal production. This argument, however, has been based largely on circumstantial evidence, namely limited vocal control in nonhuman primates and the responses of

subcortical motor nuclei during vocal production. In contrast, two recent studies measured cFos expression following bouts of vocal production in marmosets and found significant increases in the expression of this IEG. Here we recorded the activity of single neurons in marmoset frontal cortex in three adult animals while subjects engaged in a natural vocal behavior known as antiphonal calling. Analyses indicated several significant trends. First, neurons throughout premotor cortex showed significant increases or decreases in firing rate during vocal production. Second, neurons in ventral premotor cortex were more likely to be excited or suppressed during the duration of vocal production, while the responses of neurons in dorsal premotor occurred only at the onset or offset of an individual vocalization pulse. Third, in addition to vocal production-related responses, neurons in ventral premotor cortex were also responsive to presentations of vocalizations as acoustic stimuli. In contrast, neurons in dorsal premotor were only responsive during vocal-motor activity. These data suggest that frontal cortex likely plays a functional role in primate vocal production and has important implications for our understanding of the evolution of speech and language.

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Concetta Morrone
University of Pisa

Adaptability and Plasticity in Adult Human Primary Cortex

Vision is a flexible system whose neuronal properties adapt continuously to the statistical content of the retinal images and to past experience. For example, perceived size is strongly affected by the previously presented scene: brief prior presentation of larger or smaller adapting stimuli changes the perceived size of a test stimulus, with larger adapting stimuli causing the test to appear smaller than veridical, and vice versa. By measuring the BOLD responses of the primary visual cortex (V1), we showed that local activation closely matched the perceptual rather than the retinal stimulus size and the effect may be the consequence of a long-lasting local inhibition or decrease of excitability after the strong response evoked by the adapter (Pooresmaeili et al, Journal Neuroscience 2013).

Recent studies also point to a similar but stronger homeostatic response after prolonged manipulation of the visual input, short-term monocular deprivation. We showed strong residual plasticity in the adult human visual cortex, particularly for processes involving competition between ocular inputs (Lunghi et al Current Biology 2011, JoV 2013). One of the most sensitive measures of the effects of deprivation is binocular rivalry, a form of visual bistability that engages strong competition between monocular signals. Surprisingly, short-term monocular deprivation results in the deprived eye dominating rivalrous perception, lasting up to 3h after patch removal. Several of our results suggest that monocular deprivation may act to up-regulate contrast gain, resulting in stronger signals from the deprived eye (contrary to what is thought to occur with patching therapy). We also report preliminary data of an ongoing study from our group measuring change in neuro-mediators by MR spectroscopy that indicate a release of GABAergic inhibition after short deprivation in occipital cortex.

In summary, the adult human visual cortex retains a high degree of adaptability and experience-driven plasticity, which comes into play in response after short-term visual deprivation, and is particularly evident in neural competition and a release of cortical inhibition. The first homeostatic reaction of the adult visual system to deprivation or to a strong visual activation seems to be an increase (for deprivation) or a decrease (for adaptation) of the responsiveness of neurons whose input had been strongly modulated, to compensate for the signal attenuation and optimally convey the remaining visual information.

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Jeff Mulligan
NASA Ames Research Center

Smooth Pursuit of Flicker-Defined Motion
Authors: J, B. Mulligan & S. B. Stevenson

We examined the pursuit response to stimuli defined by space-variant flicker of a dense random dot carrier pattern. On each frame, every element of the pattern could change polarity, with a probability given by a two-dimensional Gaussian distribution. A standard distribution produces a circular region of twinkle, or the signal can be inverted, resulting in a spot of static texture in a twinkling surround. In this latter case, the carrier texture could be stationary, or could move with the twinkle modulator, thereby producing first-order motion in the region of the spot. While the twinkle-defined spot produces

a strong sensation of motion, the complementary stimulus defined by the absence of twinkle does not; when viewed peripherally, it appears to move in steps even when the generating distribution moves smoothly. We examined pursuit responses to these stimuli using two techniques: 1) the eye movement correlogram, obtained by cross-correlating eye velocity with the velocity of a randomly-moving stimulus; and 2) delayed visual feedback, where transient stabilization of a target can produce spontaneous oscillations of the eye, with a period empirically observed to vary linearly with the applied delay. Both techniques provide an estimate of the internal processing time, which can be as short as 100 milliseconds for a first-order target. Assessed by the correlogram method, the response to flicker-defined motion is delayed by more than 100 milliseconds, and significantly weaker (especially in the vertical dimension). When initially presented in the delayed feedback condition, purely saccadic oscillation is observed. One subject eventually developed smooth oscillations (albeit with significant saccadic intrusions), showing a period-versus-delay slope similar to that observed for first-order targets. This result is somewhat surprising, given that we interpret the slope of the period-versus-delay function as reflecting the balance between position- and velocity-sensitive inputs to pursuit.

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Richard Murray
York University

A Classification-Image-Like Method Reveals Strategies in 2AFC Tasks
Authors: R. F. Murray & L. M. Pritchett

There is still uncertainty about how observers perform even the simplest tasks, such as making 2AFC decisions. We demonstrate a novel method of using classification images to calculate "proxy decision variables" that estimate an observer's decision variables on individual trials. This provides a new way of investigating observers' decision strategies. In one such experiment, we tested three models of the mapping from decision variables to 2AFC responses. Nine observers viewed two disks in Gaussian noise, to the left and right of fixation, and judged which had a contrast increment. On each trial we calculated the cross-correlation of the classification image with the two disks, providing proxy decision variables. After several thousand trials we mapped the observer's decision space: we plotted the probability of choosing the right-hand disk as a function of the two decision variables. We tested the hypotheses that observers base their 2AFC decisions on (a) the difference between the two decision variables, (b) independent yes-no decisions on the two decision variables, or (c) just one of the decision variables. We found that all observers' decision space maps had a triangular guessing region, which is not predicted by any of the above models. However, this finding is consistent with model (a) plus intrinsic uncertainty. We conclude that the difference model favoured by detection theory is a valid model of 2AFC decisions. We discuss how proxy decision variables can be used to test a wide range of additional signal detection models, in domains such as cue combination and visual search.

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Misha Pavel
Northeastern University

Can Big Data Compensate for Small Ideas?
Authors: M. Pavel & H. Jimison

Recent availability of large data sets where analysis yielded a number of interesting results triggered an avalanche of exciting conjectures that Big Data "will transform the way we think about data, data analysis and for that matter scientific inquiry." These include the notions that there is no need for statistical analysis of errors and, for that matter, statisticians. In particular, some of these statements include propositions that we no longer need hypotheses – new ideas will emerge from data-mining of large data sets using "sophisticated algorithms" from the area of machine learning. Moreover, we no longer need sampling since the Big Data yield N = ALL.

In this presentation we will describe examples of potential consequences of these "deep transformative" ideas. We will also examine the process that underlies the development of algorithms used to data-mine big data. We will then describe several approaches that have traditionally been used to mitigate the biased implications of such results. These will include a description of a hierarchy of mathematical modeling approaches that may need to be evoked in order to render Big Data useful in advancing our theoretical understanding as well as optimize practical decision making. We propose that the recent

interest in Big Data could stimulate – and renew – a more general interest in the utility of measurement theory and mathematical modeling.

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Zygmunt Pizlo
Purdue University

Solving Large Problems With Small Working Memory

We describe an important elaboration of our multiscale/multiresolution model for solving the Traveling Salesman Problem (TSP). Our previous model emulated the non-uniform distribution of receptors on the human retina and the shifts of visual attention. The model produced near-optimal solutions of TSP in linear time by performing hierarchical clustering followed by a sequence of coarse-to-fine approximations of the tour. Linear time complexity was related to minimal amount of search performed by the model, which posed minimal requirements on the size of working memory. The new model implements the small working memory requirement. The model stores information only about as few as 2-5 clusters at any one time in the solution process. This requirement matches known capacity of human working memory. We conclude by speculating that this model provides a possible explanation of how the human mind can effectively deal with very large search spaces.

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Nicholas Port
Indiana University

Visual Motion Perception & Ocular-Following Eye Movements in People of All Ages
Authors: N. Port, T. Waeltz, S. A. Hitzeman, & S. Beckerman

Beginning with Fred Miles & colleagues (1986), there have been dozens of papers arguing that studying the ocular motor reflex "Ocular Following" provides a behavioral window into the function of the low-level visual motion cortical structures of the brain (e.g MT extrastriate cortex). However, only a small number of papers have examined the visual motion perceptual judgements of subjects while simultaneously measuring their ocular-following response and none have examined how this might change with age.

We investigated the perceptual motion judgments of 273 subjects (during free public eye exams), aged 7 to 77, while simultaneously recording eye movements with a portable table-top 1000 Hz SR-Research eye tracker. The motion task used was the classic Movshon noise stimulus (Newsome et. al. 1989) with motion coherence levels ranging from easy (25%) to impossible (0% - no signal). In the classic Movshon noise stimulus, the size of the field of moving dots is relatively small (e.g. 5 deg diameter); in our experiment, however, we used a full field pattern of dots in order to drive strong ocular-following responses.

As expected from the literature, we found that the response time of ocular-following movements is a function of motion signal strength, with stronger motion signals producing faster response times. Choice-probabilities (ROC curves) were calculated from the ocular-following responses, allowing for the creation of psychometric functions from the ocular-following responses. Ocular-following choice probabilities do a very good job of predicting subject choice, often even hundreds of milliseconds before the subject chooses his response. Indeed, even during the impossible trial when there was no motion stimulus, ocular-following still predicted the subject choice for some subjects. One interpretation is that a subject's bias in perceiving a stimulus may be present in low-level cortical cells (e.g MT), which in turn drive the ocular-following response on impossible trials. With regard to age, we found no effect; more children than adults, however, were rejected during data collection because they did not understand the task instructions. Thus visual motion processing and MT visual cortex might be mature by age 7, the youngest subjects we tested in this field study experiment. This study may imply that one can use ocular following as a surrogate for perceptual motion judgements in individuals who cannot indicate their choice in classic psychophysics experiments.

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Roger Ratcliff & Gail McKoon

Ohio State University

Single Trial Analysis of EEG in Memory

The diffusion model for simple decision making can decompose response times and accuracy into components of processing that reflect the quality of evidence used in a decision, the amount of evidence required to make a decision, and the duration of stimulus encoding and response production, along with the variability in these components across trials. Research using single and multiunit recordings in primates and neuroimaging studies in humans have recently begun attempts to identify where and how the relevant neural computations are carried out. We present a study of EEG and memory and show that a single-trial analysis (Sajda & Philiastides) of EEG indexed the quality of the evidence used in the decision process even within a class of nominally identical stimuli. The analyses show strong relationships between the evidence accumulation rate in the decision process and a single-trial ERP measure at about 600 ms. Along with this, variability in the regressor matched variability in evidence accumulation rate across trials. Finally, we compared the single trial regressor values to values derived from signal detection theory and from the diffusion model and find that the regressor values match diffusion model values best.

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Matthias Scheutz
Tufts University

An Embodied Real-Time Model of Language-Guided Visual Search

There is mounting evidence in the visual search literature that incremental presentation of natural language cues can improve visual search (e.g., by Michael Spivey and colleagues). In this talk, we present an embodied real-time model of language-guided visual processing that can be used to determine the processes underlying human visual processing. Specifically, the model allows for four configurations (parallel vs serial processing, with and without interaction among processes processing different cues) that can be compared to the human data. Moreover, the model makes novel predictions about search processes and their interactions in yet untested settings.

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Steve Shevell
University of Chicago

What Perceptual Filling-In Reveals About Working Memory

Working memory (WM) capacity is related to maintaining relevant visual representations while simultaneously inhibiting irrelevant ones. A controversial question is whether human variation in WM capacity is due to individual differences in inhibitory processes. The perceptual phenomenon of color filling-in over chromatic, binocularly rivalrous stimuli was used to address this question. Experimental results show a clear link between individual differences in WM capacity and inhibitory processes. They also demonstrate a novel relation between WM and visual perception by highlighting the connection between human working memory and lower-level processes mediating perceptual coherence.

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Richard Shiffrin
Indiana University

On Dynamic Models for Memory Retrieval
Authors: G. Cox & R. Shiffrin

Memory retrieval of a recent event unfolds in a series of (overlapping) stages: context features are present at the outset before the test item is presented; features of the test item (say a word) are extracted over time, added to the context features to form a continuously richer memory probe; the probe is used to access knowledge (e.g. the traces for letters, the lexical trace for the word--this occurs quickly) and also to access traces of recent events (this occurs more slowly); features are

retrieved from knowledge (e.g. semantics of the word) and added to the growing probe. At epochs defined by the addition of new features to the probe, event traces are activated in parallel to a degree determined by similarity of probe to trace (similarity is characterized in a sophisticated formula as a likelihood ratio); recognition is based on "familiarity" defined as the average likelihood ratio across the activated traces (shown by Shiffrin and Steyvers to produce an "optimal" decision). We present some new much faster methods for generating predictions of RT distributions and accuracy. Time permitting we will present 1) different decision models for the way to utilize the changing familiarity, and 2) applications to data.

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Sverker Sikstrom
Lund University

Accounting for Retrieval-induced forgetting with Spike-Time-Dependent Plasticity
Authors: S. Sikstrom, M. Johansson, G. Waldhauser

Retrieval-induced forgetting (RIF) is the empirical phenomenon that the repeated retrieval of desired memory representations can impair the recall of related, but irrelevant items. We present a theory suggesting that Spike-Time-Dependent Plasticity (STDP) plays an essential role for this phenomenon. According to this STDP-RIF theory, practiced items receive a stronger and faster input to the neural representation which, according to STDP, leads to Long-Term Potentiation (LTP). Non-practiced and related items receive a relatively weaker input leading to (slower input to the neural representation and) Long-Term Depression (LTD). Finally, unrelated items do not provide sufficient input for spike synchronization leading to no changes in plasticity. The theory accounts for why retrieval practice provides stronger forgetting than repetition practice, as well as other phenomena related to RIF. In addition it provides a framework of how neural/spike synchronization relates to memory.

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Steven Silverstein
Rutgers University

Perceptual Organization Impairment in Schizophrenia: Mechanisms and Consequences

Over 50 studies have demonstrated perceptual organization impairment in schizophrenia. Recent work has begun to clarify those brain mechanisms and clinical factors involved in abnormal performance. This talk will present data from 2 paradigms (contour integration and the Ebbinghaus illusion) to achieve the following 3 goals: 1) describe the nature of perceptual organization impairment in schizophrenia and the stimulus conditions under which it does and does not occur; 2) clarify the neurobiological basis of this, using data from fMRI and ERP studies; and 3) characterize clinical features related to reduced perceptual organization, both cross-sectionally and longitudinally. The data reveal that perceptual organization impairments in schizophrenia are most pronounced when prior experience or other top-down mechanisms are required to group fragmented stimuli, that both occipital lobe regions involved in grouping (e.g., V2-V4, LOC) as well as frontal lobe regions show reduced activation during perceptual organization tasks in people with schizophrenia, and that impairments are most pronounced during periods of disorganization and psychosis. The latter set of findings suggests that reduced perceptual organization is part of a broader impairment in context-based coordination of cognitive activity, and therefore that laboratory tasks can serve as biomarkers of the processes contributing to "disconnection" symptoms such as fragmented thinking and inappropriate affect.

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George Sperling
University of California, Irvine

The Moving-Barber-Pole Illusion
Authors: P. Sun, C. Chubb, & G. Sperling

In the Barber-Pole-Illusion (BPI), a diagonally moving grating is perceived as moving vertically because of the shape of the vertically oriented window through which it is viewed --- a strong shape-motion interaction. We introduce a novel

stimulus --- the moving-barber-pole in which a diagonal, drifting sinusoidal carrier is windowed by a raised, vertical, drifting sinusoidal modulator that moves independently of the carrier. In foveal vision, the moving-barber-pole stimulus can be perceived as several active barber-poles drifting horizontally but also as other complex dynamic patterns. In peripheral vision, however, pure vertical motion (the moving-barber-pole illusion, MBPI) is perceived for a wide range of conditions. In foveal vision, the MBPI can be observed, but only when the higher-order modulator motion is masked. (1) High-temporal-frequencies and (2) viewing stimuli peripherally greatly reduce the effectiveness of higher-order motion mechanisms and, ideally, can isolate a single mechanism responsible for the MBPI. For example, unlike the fovea, in peripheral vision, masking higher-order motion has no effect whatsoever on the perceived motion direction in moving-barber-pole stimuli. Presumably this is because higher-order motion is already so weak that further reduction is irrelevant.

Different theories to explain the BPI make indiscriminable predictions in standard barber-pole displays. But, in moving-barber-pole stimuli, the motion directions of features (e.g., end stops), of the first-order carrier, and of the higher-order modulator are all different from the MBPI. A three-stage spatio-temporal-integration mechanism that (1) computes local motion energies, (2) integrates them for a limited time period along various spatial paths, and (3) selects the path with the greatest motion energy, quantitatively accounts for these high-frequency peripheral data. The STI model also accounts for the perceived motion-direction in peripherally viewed moving-barber-pole stimuli that do and do not exhibit MBPI even at low frequencies, i.e., over the entire range of modulator (0-10Hz) and carrier (2.5-10Hz) temporal frequencies tested.

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Bosco Tjan
University of Southern California

Quantifying the Relationship Between the fMRI BOLD Signal and Neuronal Activity
Authors: P. Bao & B. Tjan

Quantifying the relationship between neuronal activity and the fMRI blood oxygenation level dependent (BOLD) signal is hard because "neuronal activity" is a multivariate quantity, and precisely measuring neuronal activity requires invasive techniques. Attempts to infer this relationship from stimulus-evoked BOLD response have been frustrated by the complex nonlinearity between stimulus and neuronal activity. Here we describe a unique in-vivo model for non-invasively determining the relationship between neuronal and BOLD activities. We demonstrated in the low-level visual cortex of a human subject who was born without the optic chiasm that there are two nearly identical populations of non-interacting but co-locating neurons, with non-overlapping receptive fields. By presenting identical stimuli to both of these receptive fields instead of just one, we can double the local neuronal activity, regardless of the definition of "neuronal activity." Using this in-vivo model, we found that BOLD response amplitude is proportional to approximately the square root of the sum-total of the local neuronal activity.

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Rudiger von der Heydt
Johns Hopkins University

Spike Synchrony Reveals Grouping Circuits for Proto-Object Coding in Visual Cortex
Authors: A. B. Martin, & R. von der Heydt

We see a world filled with objects, but neurons in visual cortex signal elemental features, such as pieces of contour. How these features are grouped to objects isn't known. Our study of firing synchrony in macaque visual cortex indicates that "proto-objects" form as the result of specific network connectivity. We find that the emergence of synchrony depends on an intrinsic property of the neurons: their preference for side of border ownership. Only neurons whose side preferences are consistent with a common object fire synchronously. We show that this synchrony has the characteristics of pre-attentive feedback grouping circuits. It is these native grouping circuits that enable the system to treat distributed feature signals as a whole. Our findings suggest a novel coding mechanism for object perception.

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Laurie Wilcox

York University

On the Effects of Perceptual Grouping on Depth Percepts From Stereopsis

Stereosis is an extremely precise cue to relative depth; under ideal conditions practiced observers achieve thresholds as low as 8 arc sec. However, stereoacuity is highly susceptible to changes in configuration. McKee (1983) provided a classic demonstration of such configural effects when she measured stereoacuity for a pair of vertical lines in isolation, and then again when they were connected to form a rectangular figure. In the closed figure condition, thresholds increased dramatically even though the same disparity information was present and unambiguous (see also Westheimer, 1979; Mitchison and Westheimer, 1984). In this presentation I will describe a series of experiments in which we build on this work to show that the disruptive effects of figural grouping are not limited to threshold discrimination tasks, but also influence the perceived magnitude of the offset in depth between two elements. Importantly, the reduction in perceived depth is closely tied to Gestalt grouping cues such as proximity, connectedness and similarity. From these studies we propose that the phenomenon is a by-product of the visual system's efforts to maintain cohesiveness within objects, and to segment them from their surroundings.

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Steven Zucker
Yale University

The Differential Geometry of Shape From Shading. Biology Reveals Curvature Structure: Organizing Isophotes.
Authors: D. Holtmann-Rice, E. Alexander, R. Fleming, & S. W. Zucker

Our visual systems must decouple those shading variations due to geometric and lighting changes from surface material variations to infer surfaces. In general, e.g. when viewing an apple, there are pigmentation changes and shading variations, but they develop by different physical processes. Hence they are, technically, independent. We show that when shading and color are made to flow dependently across an image, apparent depth disappears even for stimuli eliciting otherwise powerful shape percepts. This leads to the introduction of iso-hue flows and a formal theory of what independence means. We further describe how iso-hue flows could be represented in visual cortex, and how they interact with shading flows and surface inference.

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<u>Submitted, Not Presented</u>

Bota Dzhaksylykova Baitukbaeva
Abai Kazakh National Pedagogical University

Academic Approaches to Determining Person's Emotions

Human emotions are multi-facet and subtle responses of individuals to the physical and social environment. The emotions typically develop and become more complex as the environment affects a person or as a result of intentional self-influence of a person or his/her influence on other people and the outer world.

The classic fundamental psychological studies focused on emotions are rather controversial. For this reason, the single definition of emotions has not been given yet. Furthermore, their boundaries, role, and content in one's psychics remain unrefined. As a result, the belief that emotions have a disorganizing effect and cannot regulate intense activity remains very common. It is impossible to methodologically ascertain the effect of emotions on activity and the mechanism of emotional control without giving a precise definition of human emotions. The unambiguity of the used categories is extremely important in the sphere of psychic processes, which cannot be subjected to an absolutely objective analysis.

When studying the problem of emergence and evolution of emotions, scholar E.P. Ilyin has drawn a conclusion that "even the protozoa have activity regulation mechanisms in form of pre-receptor hedonic feelings." Hence, the "receptor orientation should be defined as a significantly more advanced level" [1, p. 56].

The history of evolution of the psychology of emotions has witnessed a number of attempts at relating physiological transformations in the organism to certain states and at finding various complexes of organic traits accompanying different emotional processes.

Thus, according to the James–Lange theory, the physiological changes are the primary reasons for human emotions. They make the brain respond via the feedback system and arouse emotional feelings with corresponding modalities. The Danish psychologist K. G. Lange and the American physician W. James have noticed that all the emotions affect regulation of the nervous system. This fact has underlain the theory of emotions, which is based on the function of the vasomotoric system (sometimes referred to as the "peripheral" theory of emotions).

In accordance with this theory, the cause-and-effect relations of this phenomenon are as follows: "I am afraid because I am trembling", "I feel sad because I cry", and "I am angry because I was struck" [2, p. 65]. In other words, the emergence of emotional experience is caused by various changes in the human organism: expansion or narrowing of blood vessels; dyscoordination, action inhibition or motive arousal; decreased or increased heart rate, etc.

Translated into English by
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Due to the lack of grant support, we will not be able to visit Teton Village.