# OSA Vision Meeting

September 14-16, 2012
University of Rochester
Rochester, New York

# OVERVIEW

Since 2001, the OSA Fall Vision Meeting has grown as a high-quality, low-cost conference focused on all aspects of the visual system. This year, we return to the University of Rochester and the Center for Visual Science, who are graciously hosting the meeting for the 5th time.

This year's meeting includes invited sessions, two contributed talk sessions, as well as contributed poster presentations. We are also pleased to present the 2012 Tillyer Award to Professor Gerald H. Jacobs from the University of California - Santa Barbara in recognition of his contributions to fundamental understanding of the biological mechanisms underlying color vision, and for pioneering comparative studies which have revealed the nature, variations, and evolution of primate color vision. The Tillyer Award was established in 1953 through an endowment from the American Optical Co. It is presented not more than once every two years to a person who has performed distinguished work in the field of vision, including (but not limited to) the optics, physiology, anatomy or psychology of the visual system. There will be a lecture by Dr. Jacobs followed by a banquet in his honor on September 15.

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# ORGANIZATION

***Division Chair (01/11-12/13)***
- Joseph Carroll, Medical College of Wisconsin

***Clinical Vision Sciences Chair (01/11-12/13)***
- Jason Porter, University of Houston

***Clinical Vision Sciences Vice-chair (01/11-12/13)***
- Rowan Candy, Indiana University

***Applications of Visual Science Chair (01/12-12/14)***
- Laura Walker-Renninger, SKERI

***Applications of Visual Science Vice-chair (01/12-12/14)***
- Brian Vohnsen, University College Dublin

***Vision Chair (01/11-12/13)***
- Alyssa Brewer, UCI

***Vision Vice-chair (01/11-12/13)***
- Jeffrey Mulligan, NASA Ames Research Center

***Color Chair (01/10-12/12)***
- Kathy Mullen, McGill University

***Color Vice-chair (10/10-12/12)***
- David Brainard, UPenn

***Local Organizing Committee***

- Jennifer Hunter
- Krystel Huxlin
- Duje Tadin
- David Williams
- Michele Schultz
- Sara Peterson

# PROGRAM SCHEDULE

All talks are in the Class of '62 Auditorium
All breakfasts, breaks, and lunches are in the Medical Center Atrium

## Thursday (9/13/12) – Welcome Reception

***7:00 pm - 9:00 pm—Reception, Staybridge Suites, 1000 Genesee Street***

## Friday (9/14/12)

***8:00 am - 8:45 am—Breakfast, Registration & Put-up Posters***

***8:45 am - 9:00 am—Welcome***

***9:00 am - 11:00 am—Invited Session 1: Interpreting high-resolution images of the living retina***

The advent of new in-vivo high resolution imaging technologies has led to exciting new observations about the relationship between structure and function in the human retina. This session will cover new understanding and interpretation being acquired in normal and diseased eyes at resolutions beyond those of conventional instrumentation.

**Moderator:** Mina Chung, University of Rochester

**Confirmed Speakers:**
Stephen Burns, Indiana University
Donald Miller, Indiana University
Christine Curcio, University of Alabama, Birmingham

***11:00 am - 11:30 am—Break***

***11:30 am - 1:00 pm—Contributed Color Session (6 @ 15 minutes each)***

***1:00 pm - 2:00 pm—Lunch***

***2:00 pm - 3:30 pm—Poster Session***

***3:30 pm - 5:30 pm—Invited Session 2: Color and the statistical structure of natural images***

It is well accepted that biological visual processing is shaped by the statistical structure of the natural environment. In recent years this broad idea has received increased attention as our understanding of image statistics has improved, and has also led to a more informed approach to computer image analysis. This session will focus on the application of these ideas to the area of color vision, with talks that draw from the study of human vision, the study of image analysis, and the study of color image statistics.

**Moderator:** David Knill, University of Rochester

**Confirmed Speakers:**
David Foster, University of Manchester
William Geisler, University of Texas, Austin
Michael Webster, University of Nevada, Reno
Todd Zickler, Harvard University

***6:30 pm—Dinner, Nixon-Peabody***

## Saturday (9/15/12)

***8:00 am - 8:30 am—Breakfast***

***8:30 am - 10:30 am—Invited Session 3: Dysfunction of the visual system in neurodegenerative conditions***

Several neurodegenerative diseases impact visual function. Targeted assessment of the visual system may therefore reveal alterations that contribute uniquely to earlier detection and better understanding of these conditions. This session will explore how structural and functional observations have improved our knowledge of neurodegenerative disease processes, with a focus on multiple sclerosis and optic neuritis.

**Moderator:** Ari Green, University of California, San Francisco

**Confirmed Speakers:**
Steve Feldon, University of Rochester
Randy Kardon, University of Iowa
Laura Frishman, University of Houston
Netta Levin, Hadassah University Hospital, Israel

***10:30 am - 11:00 am—Business Meeting***

***11:00 am - 12:30 pm—Poster Session & Break***

***12:30 pm - 1:30 pm—Lunch***

***1:30 pm - 3:30 pm—Invited Session 4: 3D displays and perception***

3D technology is being incorporated into movies, televisions and personal electronics. What are the technical issues behind crafting content for a human 3D experience? How does our visual system interpret and respond to images created with 3D technology? Our speakers will explore this topic with an emphasis on the science behind human stereoscopic perception.

**Moderator:** Laurie Wilcox, York University

**Confirmed Speakers:**
Martin Banks, University of California, Berkeley
Jenny Read, Newcastle University
Inna Tsirlin, York University
Ali Kazimi, York University

***3:30 pm - 4:00 pm—Break***

***4:00 pm - 5:00 pm—Presentation of Tillyer Medal: Introduction by Jay Neitz, University of Washington***
***Tillyer Lecture by Dr. Gerald H. Jacobs***

***6:00 pm—Tillyer Banquet, Rochester Museum & Science Center***

## Sunday (9/16/12)

***8:00 am - 8:30 am—Breakfast***

***8:30 am - 10:30 am—Invited Session 5: Signal suppression: mechanisms and functional roles***

Signal suppression via divisive inhibition is ubiquitous in visual processing (and appears to be present in other parts of the brain as well), consistently providing good accounts for a wide range of psychophysical and neurophysiological data. Familiar examples are found in contrast gain control and other adaptation phenomena. This symposium aims to draw together different views and perspectives on these topics from neurophysiology, psychophysics and brain imaging.

**Moderator:** Lynn Olzak, Miami University

**Confirmed Speakers:**
Michael Rudd, University of Washington
John Foley, University of California - Santa Barbara
C.C. Chen, National Taiwan University
Tim Meese, Aston University

***10:30 am - 11:00 am—Break***

***11:00 am - 12:30 pm—Contributed Vision Session (6 @ 15 minutes each)***

***12:30 pm - 1:30 pm—Lunch & Poster Removal***

***1:30 pm - 1:45 pm—Young Investigator Award***

***1:45 pm - 3:45 pm—Invited Session 6: Controlling the Motion of Attention***

Under normal circumstances, the eyes scan the visual environment seemingly automatically, in order to bring the images of objects of interest to the fovea. It has been suggested that the map that determines where the eyes go next is one and the same as the map of attention. But under unnatural laboratory conditions, it is possible to dissociate attention and eye movements. Attention may be directed to the periphery while eye movements are voluntarily inhibited (covert attention); eye movements can be directed to a location other than the most salient location (the anti-saccade task); in multiple object tracking, the nature of the task makes it impossible to fixate all of the locations that must be attended; and results from change blindness demonstrate that where the eyes are pointing can be dissociated from what information is taken in. The speakers in this symposium explore the relations between attention and eye movements, and possible mechanisms for their control.

**Moderator:** Tania Pasternak, University of Rochester

**Confirmed Speakers:**
Mary Hayhoe, University of Texas, Austin
Steve Heinen, The Smith-Kettlewell Eye Research Institute
James Brockmole, University of Notre Dame
Eileen Kowler, Rutgers University

***3:45 pm - 4:00 pm—Final Remarks***

**END OF MEETING**

# SESSION DETAILS

## Friday (09/14/12)

### Interpreting high-resolution images of the living retina

***Moderator: Mina Chung, University of Rochester***

9:00 AM–Stephen Burns, Indiana University
Retinal imaging in the 21st century

The capabilities for retinal imaging have changed remarkably over the last 25 years. Twenty five years ago the primary technology for imaging the retina involved film based cameras using optical approaches from the 19th century. With the advent of the Scanning Laser Ophthalmoscope and modern electro-optics technology imaging has expanded to encompass not only high-resolution imaging, but also functional imaging. The Scanning Laser Ophthalmoscope introduced near infrared imaging and real-time control, OCT has enabled investigation of retinal structures with depth resolutions of a few microns, and with increasing speed. Adaptive Optics has enabled real time imaging with lateral resolutions on the order of 2 microns. This talk will summarize the enabling technologies leading to this increased capability, as well as introduce some of the methods that are currently being investigated to allow precise mapping of retinal structure and function. Examples of our ability to now provide high resolution mapping of photoreceptors, blood flow, vascular networks, and nerve fiber layers will be presented, as well as brief examples of dynamic imaging of visually driven changes to the retina.

9:30 AM–Donald Miller, Indiana University
Interpreting AO-OCT images of cone photoreceptors

In less than a decade, optical coherence tomography (OCT) has gained widespread use for high-resolution imaging of the living retina. Its main attributes are its micron-scale axial resolution, unprecedented sensitivity, and ability to capture both amplitude and phase of the retinal reflection. OCT, however, is not without shortcomings. Principal ones include coherence effects (speckle) and sensitivity to eye motion, both more degrading than in traditional imaging modalities such as flood illumination and scanning laser ophthalmoscope. While these limitations increase the difficulty to interpret the OCT image, fundamental information about structure and function can still be extracted, information traditionally limited to highly invasive approaches such as histology. To illustrate its use, examples are presented for imaging individual cone photoreceptors in three dimensions using OCT in conjunction with adaptive optics (AO).

9:55 AM–Christine Curcio, University of Alabama, Birmingham
SD-OCT's four outer retinal hyper-reflective bands (ORHRB) in health and age-related macular degeneration (AMD)

SDOCT available to clinical ophthalmology reveals four ORHRB formed by the photoreceptors and their support system, the retinal pigment epithelium (RPE), and Bruch's membrane of the choroidal vasculature. The neurosensory retina is an array of molecular machines aligned with sub-micrometer precision in the vertical axis. The retinal pigment epithelium (RPE) is as compartmentalized as the photoreceptors, on a greatly compressed vertical scale (14 µm). An anatomically correct outer retinal model 1 aligns securely with the external limiting membrane (junctional complexes), inner segment ellipsoid (ISel), interdigitation level formed by photoreceptors and RPE (cell-cell contacts), and RPE/Bruch's membrane (BrM, metabolic and vascular support). ISel in turn is packed with high light scattering mitochondria, offering promise of monitoring mitochondrial health in vivo through SD-OCT.

The ORHRB are on the road to base camp for another imaging peak of public health significance: the sub-retinal and sub-RPE pathology of age-related macular degeneration (AMD). How the photoreceptors read-out their deteriorating support system will be learned through better understanding of RPE status and lesion size/ composition during early AMD. Eight layers of pathology, reflecting different chemical compositions, biogenesis, and degrees of pathogenic significance localize to a <50-µm span. Major components of drusen and basal linear deposit molecularly overlap with the lipidic core of coronary artery plaque. SD-OCT and a myriad of intravascular imaging techniques developed for cardiovascular disease may be exploited to quantify the true burden of AMD's lesions.

10:20 AM–Discussion Session

**Contributed Color Session**

11:30 AM–Richard Murray, York University
Human lightness perception is guided by simple assumptions about reflectance and lighting

Two successful approaches to understanding lightness perception that have developed along largely independent paths are anchoring theory and Bayesian theories. Anchoring theory is a set of rules that predict lightness percepts under a wide range of conditions (Gilchrist, 2006). Some of these rules are difficult to motivate, e.g., larger surfaces tend to look lighter than small surfaces. Bayesian theories rely on probabilistic assumptions about lighting and surfaces, and model percepts as rational inferences from these assumptions combined with sensory data. Here I reconcile these two approaches by showing that many rules of anchoring theory follow from simple assumptions about lighting and reflectance. I describe a Bayesian theory that makes the following assumptions. (1) Reflectances follow a broad, asymmetric normal distribution. (2) Lighting consists of multiplicative and additive components (Adelson, 2000). (3) The proportion of additive light tends to be low. These assumptions predict the main rules of anchoring theory, including: (a) The highest luminance in a scene looks white, and (b) other luminances have lightnesses that are proportional to luminance. (c) A reflectance range less than 30:1 is adjusted towards 30:1. (d) When a low-luminance region becomes larger, its lightness increases, and the lightness of all other regions also increases. (e) The luminance threshold for glow increases with patch size. (f) Lightness constancy is better in scenes containing many distinct luminance patches. Thus anchoring theory can be formulated naturally in a Bayesian framework, and seemingly idiosyncratic properties of lightness perception are rational consequences of simple assumptions about lighting and reflectance.

11:45 AM–Rob Lee, University of Oxford
Perceptual separation of changes in lighting and reflectance can be supported by specularity

Colour signals from a given retinal location are not stable over time, since eyes and objects move and lighting conditions are dynamic. It is behaviourally useful to separate a change in illumination from a change in reflectance. For an isolated matte surface, these changes are indistinguishable. However, for a 3D glossy surface, in which light varies across the surface as a mixture of diffuse and specular components, illuminant and reflectance changes are in principle separable. A change in reflectance causes darker (less specular) locations to change in chromaticity more than the lighter (more specular) locations, whereas a change in illuminant shows no such relationship. We presented hyperspectrally raytraced movies showing surfaces undergoing illuminant or reflectance changes and asked observers to classify the change. We ensured that the magnitude of the chromatic change of the diffuse component could not be used as a cue. Performance was at chance for matte surfaces and increased with specularity. Accurate classification was possible even at low specularities (~0.2). With multiple uncorrelated changes (spatial odd-one-out) performance increased more gradually, reaching 100% only with full specularity. Previous work shows the importance of specularity in colour constancy: highly specular reflections provide a direct estimate of the illuminant, improving constancy (Yang & Maloney, 2001) and, with multiple surfaces, chromaticity variation across each surface falls on lines in colour space that intersect at the illuminant chromaticity (D'Zmura & Lennie, 1986; Lee, 1986). We show that observers can extract structured chromaticity relationships that are not available at any given instant.

12:00 PM–Toshifumi Mihashi, Topcon Corp
Hyperspectral two-dimensional visual stimulator

We built a hyperspectral two-dimensional visual stimulator (H2DVS) with two diffractive gratings and a digital micro mirror device (DMD). White light from a Xenon arc lamp was collimated and reached to the first diffraction grating. The light was separated into each spectrum and focused onto the DMD. The spectral components were arbitrarily chosen by controlling the DMD, and went to two off-axis lenses and to the second diffraction grating to form a one-dimensional pixel array. Using a galvanic mirror to scan the array, we eventually obtained a 20-x-28-mm hyperspectral image with 100-x-10 pixels and 64 intensity levels. Measuring the maximum luminance at nine different points in the image, the average and standard deviation was 45.53 ± 1.21 cd/m2. The spectral resolution was about 1 nm. We confirmed that the color space was almost fully covered.

We expect the H2DVS will be a versatile device for color-matching experiments with exact wavelengths. It may also be useful for performing any psychophysical experiments which require precise spectrum. One example is a visual acuity test in particular wavelengths. Another example is an experiment with iridescence that is related to optical interference. As our preliminary study, we simulated an anomaloscope. We obtained the similar results with the H2DVS for the dichromats and anomalous trichromats to those obtained with a conventional anomaloscope. As we can use any virtual multiple light sources with this simulated anomaloscope, it may be possible to investigate not only M and L cones but S cone, rod, and even melanopsin receptor.

12:15 PM–Marina Danilova, I.P. Pavlov Institute of Physiology
Enhanced discrimination at a perceptual category boundary: Subjective and performance measures are concomitantly shifted by chromatic adaptation

When the eye is adapted to Illuminant D65, the perceptual boundary between reddish and greenish hues coincides approximately with the caerulean line – the set of chromaticities formed by mixtures of skylight and sunlight. If chromatic discrimination is measured along lines orthogonal to the subjective boundary, thresholds are minimal near the transition between reddish and greenish categories (Danilova and Mollon, 2012). However, the subjective category boundary can be displaced by chromatic adaptation. Is the region of enhanced discrimination then concomitantly shifted? Using 2-deg bipartite foveal targets and a two-alternative spatial forced choice procedure, we measured discrimination thresholds on steady fields of three different chromaticities: (a) a field metameric to D65; (b) a pale blue field, shifted along the caerulean line from D65; (c) a field shifted orthogonally to the caerulean line in a pinkish direction. The MacLeod-Boynton chromaticity coordinates of the adapting fields were 0.6552, 0.01666, or 0.635, 0.029, or 0.675, 0.029. The luminance of each half of the target field was independently jittered, to ensure that only chromaticity could be used to solve the task. In interleaved experimental runs, we measured the chromaticity at which a uniform 2-deg field appeared neither reddish nor greenish.

In the case of all three adapting fields, there were regions of enhanced discrimination and these approximately corresponded with the subjective category boundary. Thus perceptual and performance measures are concomitantly shifted by chromatic adaptation.

12:30 PM–Yeon Jin Kim, McGill University
Cross-orientation masking in color vision: application of the two-stage model with suppression within and between eyes

Cross-orientation masking occurs when the detection of a test grating is masked by a superimposed grating at an orthogonal orientation, and is widely thought to indicate the presence of "cross-channel" interactions mediating contrast normalization. In achromatic vision, modeling and psychophysical experiments have suggested that there are at least two routes to cross-orientation suppression prior to binocular summation: a within-eye (monocular) pathway that is non-adaptable, and an interocular (dichoptic) adaptable pathway that is cortical and mediates mutual suppression between the eyes (Baker et al., Neuroscience, 146, 2007: Meese & Hess, 2004). Here we develop this two-stage model and test its application to color vision. Test and mask stimuli were red-green isoluminant Gabors presented orthogonally. TvC masking functions were obtained for three spatial frequencies (0.375, 0.75 & 1.5cpd at 2Hz) for monocular, binocular and dichoptic presentations in four subjects. We generalized the two-stage model so that it could be used to fit the monocular, dichoptic and binocular TvC functions. We determined the weight of suppression parameters for the monocular and dichoptic suppression, with the remaining parameters fixed on the basis of known values. We find that the two-stage model is a good fit to the chromatic data, supporting the idea that color and achromatic vision use the same two routes to cross-orientation suppression. The dichoptic pathway shows greater suppression than monocular in color vision. It is also unselective as it can be activated by achromatic or chromatic contrast (Mullen et al., 2012). We find no effect of spatial frequency on either pathway.

12:45 PM–Steven Buck, University of Washington
A new comparison of brown and yellow

There is longstanding controversy about the relationship of the color brown to perceptually unique or elemental hues, in particular to unique yellow. We explored this perceptual relationship with a foveal 2-deg-diameter test stimulus within a dark or bright surround, which rendered the same test stimulus as yellow or brown, respectively.

We show that brown and yellow share two characteristics of unique hues: Observers (1) reliably set a red/green null or balance for both brown and unique yellow and (2) can cancel all chromatic content of both R/G-balanced brown and unique yellow by adding blue. Thus, both brown and yellow are distinct from red and green and opponent to blue.

We also show two differences between properties of balanced brown and unique yellow: They (1) have different red-green balances and (2) show opposite directions of rod hue bias. The chromaticity of balanced brown is shifted toward red compared to that of unique yellow, and rods exert a red bias on balanced brown but a green bias on unique yellow. Thus, the properties of yellow do not explain the properties of brown.

These results stop short of establishing brown as a unique hue, separate from yellow, but do suggest differences in the neural pathways underlying brown and yellow: (1) Brown pathways have stronger M- vs. L-cone weighting compared to yellow pathways, and (2) that rods favor red vs. green for brown, the opposite to yellow, presumably by acting through S-cone pathways, which show a rod red bias.

### Color and the statistical structure of natural images

***Moderator: David Knill, University of Rochester***

3:30 PM–David Foster, University of Manchester
Identifying surfaces by color in natural scenes: gamut distribution not volume counts

Color helps inform us about the contents of the natural world. In principle, the more colors there are in a scene, the more individual surfaces that can be perceptually identified. But an analysis based on the size of the gamut of colors ignores how identification is affected by the distribution of colors within the gamut; for example, surfaces with rare colors are easier to find than surfaces with common colors. To take into account the effects of color distribution on identification, information-theoretic methods were used to estimate the number of perceptually identifiable surface colors, N say, in each of 50 natural scenes. Surface colors were specified numerically in the approximately uniform color space CIECAM02, and a nominal color-discrimination threshold was set to 0.6 units, although the exact value was not critical. When the gamut of each scene was given the uniform distribution, allowing comparison with estimates based on gamut volume, it was found that N ranged from 7.4x10^4 to 1.0x10^6. When, instead, the gamut of each scene was given its true nonuniform distribution, it was found that N was much reduced but more wide-ranging, from 4.0x10^3 to 3.0x10^5. There was little correlation over scenes between the reduction in N and gamut volume. In practice, therefore, it is the gamut distribution, not the gamut volume per se, that sets the bounds on surface-color identification in natural scenes.

3:55 PM–William Geisler, University of Texas, Austin
Estimating gray scale and color in natural images

Evolution and learning guarantee that visual systems will exploit the statistical structure of natural images when performing visual tasks. Thus, understanding which aspects of this statistical structure are incorporated into the human nervous system is a fundamental goal in vision science. We consider the task of estimating missing gray scale or color (R, G or B) values at arbitrary pixel locations in natural images, given the context of available pixel values. First, we measured the relevant statistical information for these tasks in calibrated natural images. We find that the statistical structure is sufficient for surprisingly accurate estimation of missing pixel values. Second, we measured human accuracy for estimating missing gray scale values and compared human accuracy with various simple heuristics (e.g., local average, median, and mode), and with optimal observers that have complete knowledge of the local statistical structure in natural images. We find that human estimates are more accurate than simple heuristics, and they match the performance of an optimal observer that knows the local statistical structure of relative intensities (contrasts). This optimal observer predicts the detailed pattern of human estimation errors and hence places strong constraints on the possible underlying neural mechanisms. However, humans do not reach the performance of an optimal observer that knows statistical structure of absolute intensities, which reflect both local relative intensities and local mean intensity. Also, as predicted from our analyses of natural images, human estimation accuracy is negligibly improved by expanding the context from a local patch to the whole image.

4:20 PM–Michael Webster, University of Nevada, Reno
Color inferences about natural color signals

The visual system coarsely samples the light spectrum with only three classes of cones to represent color with the perceptual attributes of hue, saturation, and lightness. We have examined potential inferences these attributes might embody about the underlying color signal, by asking how spectra that share the same hue but differ in saturation are related. The hues of many wavelengths change when white light is added, an interaction between hue and saturation known as the Abney effect. However, when the spectrum is instead diluted by broadening the bandwidth (e.g. in spectra with Gaussian profiles), hues tend to remain more invariant. This suggests that the visual system may attempt to represent the spectrum in terms of its predicted centroid and bandwidth, and thus is tying constant hues to constant inferred properties of the environment (e.g. the spectral peak), rather than to constant physiological responses (e.g. the relative responses of color-opponent mechanisms). By this account, the conventional Abney effect occurs because the visual system is tricked into making the wrong guess because the spectrum is unnatural. A Gaussian inference provides a good approximation to hue percepts at shorter wavelengths and predicts some differences between hues in the fovea and periphery, but fails to explain color appearance at longer wavelengths, pointing to a potential role of S cones or screening pigments in shaping color inferences. A Gaussian model is also a reasonable inference for a trichromatic visual system to adopt because it approximates natural spectra roughly as well as comparable linear models.

4:45 PM–Todd Zickler, Harvard University
Spatio-spectral image statistics and their use in computer vision

There are many computational models for the spatial statistics of grayscale (luminance) images, and in computer vision we rely heavily on these for denoising, deblurring, distinguishing shading from material boundaries, and so on. There are also models for the statistics of spectral point samples, and these are useful for tasks like computational color constancy. What we know less about is whether there are significant correlations between the spatial and spectral dimensions of natural images and, if there are, whether these correlations are useful for vision. I'll describe some attempts at answering these questions, including our collection and analysis of a database of hyperspectral real-world images, and our development of computer vision techniques that leverage spatio-spectral image models.

5:10 PM–Discussion Session

## Saturday (09/15/12)

### Dysfunction of the visual system in neurodegenerative conditions

***Moderator: Ari Green, University of California, San Francisco***

8:30 AM–Steve Feldon, University of Rochester
The optic neuropathies–sight unseen

The optic nerve differs from almost all other cranial nerves in two important ways. First, the optic nerve is an extension of brain tissue rather than a peripheral nerve. Second, it is the only cranial nerve amenable to direct observation in a clinical setting. Thus, optic nerve disease provides an opportunity to directly study human diseases of the central nervous system at the tissue and cellular levels.

Currently available techniques for visualizing the optic disc, retinal nerve fiber layer, and optic nerve include standard stereo photomicroscopy, ocular coherence tomography, scanning laser ophthalmoscopy, and adaptive optics modifications of these instruments. Magnetic resonance imaging, both structural and functional, is also important. The future may hold even more promise for in vivo studies with development of cellular and subcellular techniques such as two photon confocal imaging, photoacoustic imaging, and functional molecular imaging.

Perhaps the prototypical neurodegenerative amenable for study is demyelination in diseases such as multiple sclerosis and neuromyelitis optica. However, there is the opportunity to study other diseases affecting the brain, as well. These include Alzheimer 's disease, traumatic brain injury, neurotoxicity, genetic mutations, and ischemic damage. With a review of the clinical and pathological changes in the optic nerve, the stage is set for developing and testing new clinical investigative imaging techniques to study neurodegenerative disease manifestation in the living eye.

8:55 AM–Randy Kardon, University of Iowa
Can structural analysis of the retinal layers tell us about the status of the brain in neuro-dengerative disorders?

Purpose: To provide an overview of current approaches for assessing neurodegenerative disorders such as Multiple Sclerosis, Traumatic Brain Injury (TBI), and Parkinson Disease by using structural features of the retina as biological markers for severity and progression of disease.

Methods: Spectral Domain Optical Coherence Tomography (SD-OCT) was used to acquire volume scans of the macula and optic nerve in humans with multiple sclerosis and TBI and in mouse models of TBI (blast injury) and Parkinson Disease. Segmentation of the retinal layers provided a means for assessing the thickness of retinal layers containing the retinal ganglion cell complex and the axons within the retinal nerve fiber layer (RNFL) to correlate this with retinal function. Retinal outcome measures are correlated with measures of structure and function of the brain.

Results: For each neurodegenerative disorder, there is a statistically significant correlation between inner retinal structure and central nervous system outcome measures. With current SD-OCT eye tracking and reference scan capabilities, the repeat measurement variability is less than 1 micron, allowing the ability to detect very small changes over time to monitor progression.

Conclusions: There is evidence that the thickness of the retinal ganglion cell layer and nerve fiber layer may provide surrogate measures for severity of disorders associated with central nervous system degeneration and may also provide a means for monitoring progression. Current studies are under way to correlate retinal structure with quantitative MRI findings in patients with MS every six months to determine the clinical utility of using this approach for making treatment decisions over time.

9:15 AM–Laura Frishman, University of Houston
Non-invasive assessment of visual function in demyelinating and neurodegenerative disorders

Multiple sclerosis (MS) is a chronic autoimmune inflammatory disease of the central nervous system, characterized by demyelination, axonal dysfunction, and neuronal degeneration. The anterior visual pathway is often affected. 30% to 70% of patients diagnosed with MS will have optic neuritis (ON) during the course of the disease (1); visual problems are frequently the earliest symptoms. Asymptomatic or subclinical involvement of optic nerves occurs in MS as well. Common noninvasive tests to evaluate visual pathway abnormalities include a subjective test of visual sensitivity, standard automated perimetry, and structural evaluations of retina and retinal nerve fiber layer integrity, using optical coherence tomography or other imaging approaches. This talk will summarize recent work evaluating the relative utility of two objective electrodiagnostic tests, multifocal visual evoked potential (mfVEP) and photopic electroretinogram (ERG), in assessing visual function in MS/ON eyes and in MS eyes without a history of ON. The mfVEP technique, which records 60 local visual evoked responses simultaneously from a 40 deg field of vision provides amplitude measures reflecting neuronal function, and also, uniquely, information about nerve conduction velocity (latency) which is useful for assessing extent of demyelination. The mfVEP technique has high sensitivity and specificity in detecting visual pathway abnormalities in patients with MS/ON, and is also useful in detecting subclinical lesions. The amplitude of the photopic negative response (PhNR) of the photopic ERG provides information on the function of retinal ganglion cells and their axons, within the eye. The PhNR amplitude reductions in eyes of MS patients both with and without a history of ON indicate the presence, in the retina, of subclinical pathologic changes associated with the disease.

9:35 AM–Netta Levin, Hadassah University Hospital, Israel
Demyelination affects temporal aspects of perception: an optic neuritis study

Demyelination, the pathological hallmark of optic neuritis (ON) is identified by prolonged Visual Evoked Potentials (VEP) latency. Yet, no behavioral correlate to this prolongation was previously described. We hypothesized that dynamic visual processes, such as motion perception, may be more vulnerable to slowed conduction in the optic nerve. To that end, we performed a longitudinal study on patients with unilateral, first-ever ON. Static and dynamic visual functions, VEPs, functional MRI (fMRI) and diffusion tensor imaging (DTI) examinations were repeatedly assessed in patients and age-matched controls over the course of a year. We found a sustained motion perception deficit, via the affected eye, long after the recovery of static visual functions. fMRI studies showed recovery in cortical activation during static object recognition, as opposed to sustained deficit in tasks that require motion perception. Moreover, motion perception deficit was highly correlated with prolonged VEP latencies.

Interestingly, the patients' fellow eyes, which also demonstrated prolonged VEP latencies, exhibit intact dynamic visual functions. We suggested that these delayed latencies evolved due to prolonged cortical processing of the fellow eyes' input. We found that these changes offered a functional advantage; synchronization of inputs resulted in improved dynamic 3-dimentional perception. Thus, while results in the affected eyes, highlight the need for rapid transmission of visual input to perceive motion, the results in the fellow eyes reflect an adaptive process aimed at binocular integration in time, to adjust the damage incurred. Our results emphasize the importance of the temporal domain when assessing demyelinative diseases.

9:55 AM–Discussion Session

## 3D displays and perception

***Moderator: Laurie Wilcox, York University***

1:30 PM–Martin Banks, University of California, Berkeley
Flicker, motion artifacts, and depth distortions in stereo 3D displays

Most stereoscopic displays rely on field-sequential presentation to present different images to the left and right eyes. With sequential presentation, images are delivered to each eye in alternation with dark intervals, and each eye receives its images in counter phase with the other eye. This type of presentation can exacerbate image artifacts including flicker, and the appearance of unsmooth motion. To address the flicker problem, some methods repeat images multiple times before updating to new ones. This greatly reduces flicker visibility, but makes motion appear less smooth. I describe an investigation of how different presentation methods affect the visibility of flicker, motion artifacts, and distortions in perceived depth. It begins with an examination of these methods in the spatio-temporal frequency domain. From this examination, it describes a series of predictions for how presentation rate, object speed, simultaneity of image delivery to the two eyes, and other properties ought to affect flicker, motion artifacts, and depth distortions. I then report a series of experiments that tested these predictions. The results confirmed essentially all of the predictions. I conclude with a summary and series of recommendations for the best approach to minimize these undesirable effects.

1:50 PM–Jenny Read, Newcastle University
The visual cues to depth

Binocular disparity is a very potent cue to depth, but is encoded with poor spatial and temporal resolution compared to luminance information. This fact is important for distributors of 3D content, since it opens up the possibility of saving bandwidth by transmitting a detailed luminance image + coarse depth map. I will discuss the cortical mechanisms believed to be responsible for the relatively poor resolution of stereo 3D. The initial step is the extraction of disparity in primary visual cortex. Here, neurons compute something close to the cross-correlation between image-patches in left and right eyes. Critically, they respond best to patches of uniform disparity. This is quite unlike luminance, where Hubel & Wiesel famously showed that neurons prefer step changes in luminance. This means that the scale with which we encode disparity is set by the size of V1 receptive fields themselves, not by the size of their subregions. Surprisingly, we encode complex contingencies between disparity and motion in transparent stimuli with the essentially same resolution as disparity in solid surfaces, suggesting that these must be important ecologically. Finally, at low frequencies we are more sensitive to horizontally-oriented variation in depth, as occurs in the ground plane, than to vertically-oriented variation, as occurs for example at a door jamb. I shall present new data and a speculation about why this is so.

2:10 PM–Inna Tsirlin, York University
The effect of crosstalk on perceived depth in 3D displays

Crosstalk in stereoscopic displays is defined as the leakage of one eye's image into the image of the other eye. All popular commercial stereoscopic viewing systems, including the ones used in movie theaters, suffer from crosstalk to some extent. It has been shown that crosstalk causes image distortions and reduces image quality. Moreover, it decreases visual comfort and affects one's ability to discriminate object shape and judge the relative depth of two objects. These results have potentially important implications for the quality and the accuracy of depth percepts in 3d display systems. To asses this hypothesis directly, we have explored the effect of crosstalk on the perceived magnitude of depth in a variety of stereoscopic stimuli. We found that with simple synthetic images increasing crosstalk beyond four percent resulted in a significant decrease in the magnitude of perceived depth, especially for larger disparities. This degradation was largely independent of the spatial separation of the ghost image. Further, we found qualitatively and quantitatively similar detrimental effects of crosstalk on perceived depth in complex images of natural scenes. The consistency of the negative impact of crosstalk, regardless of image complexity, suggests that it is not ameliorated by the presence of pictorial depth cues. We have recommended that display manufacturers keep crosstalk levels below the critical value of four percent to achieve optimal depth quality.

2:30 PM–Ali Kazimi, York University
Hazardous Stereography

This is a somewhat eclectic paper, an anecdotal snapshot of the making of the first independent live action short drama, Hazardous, filmed in stereoscopic 3D in Canada. Weaving together explanations, insights, ruminations on stereography and with a first hand account of the logistical, production and creative challenges faced during the making of this film in 2010 – and the technological shifts since that time. The paper also introduces readers to the new key creative position of stereographer and the effect of this position on the grammar and structure of a S3D film.

2:55 PM–Discussion Session

## Sunday (09/16/12)

### Signal suppression: mechanisms and functional roles

***Moderator: Lynn Olzak, Miami University***

8:30 AM–Michael Rudd, University of Washington
The functional role of contrast normalization in an edge-based theory of cortical color computation and filling-in

The subjective colors of visual figures can be strongly influenced by color and luminance contrast at the figural borders or edges. Edges can even generate false color that perceptually fills in the figure (Craik-O'Brien-Cornsweet, Watercolor illusions). Here, I discuss the relationship between such edge (i.e. oriented contrast) based filling-in phenomena and the neural mechanisms supporting color and lightness constancy. I propose a model of color computation within the ventral pathway in which high-level cortical computations seek to differentiate between reflectance-derived and illumination-derived contrast spanning a range of spatial scales in the retinal image. The outputs of these computations feed back to suppress the responses of neurons in early visual cortex to illumination-derived contrast. The responses of non-suppressed (active) neurons undergo contrast normalization prior to being spatially integrated to form a neural representation of surface color (likely in area V4). The model accounts for the results of achromatic color matching experiments performed with perceptually ambiguous displays in which instructions bias the observer to interpret local contrast as being due to either reflectance or illumination variation. It gives a precise quantitative account of the data, explaining instances of lightness contrast and assimilation, lightness constancy and its failures, and their dependence on instructions (attention). Contrast normalization plays a critical role in the theory by reducing response saturation in the neurons comprising the cortical color map; and it does so in a principled manner that takes into account the neural classification of local luminance and wavelength variation in the retinal image.

8:55 AM–John Foley, University of California - Santa Barbara
Divisive suppression in contrast vision

The contrast discrimination threshold decreases (facilitation) and then increases (masking) as pedestal contrast increases. If another pattern (mask) is substituted for the contrast pedestal, both facilitation and masking usually decrease as the patterns become dissimilar. Masking occurs over a wider range than facilitation. When contrast discrimination in measured in the presence of a dissimilar mask of fixed contrast, thresholds are higher at low pedestal contrasts. They decrease as pedestal contrast increases, sometimes crossing the baseline contrast discrimination function and then increase at high pedestal contrasts. These effects are found for masks that vary in spatial frequency, temporal frequency, orientation, and phase. They are also found for lateral masking, forward and backward masking, masking by noise and contrast adaption. Many of these effects are accounted for by a model (Foley, 1994) in which the detecting mechanism receives both excitatory and divisive inhibitory inputs. Their net effect is to produce an S-shaped response function. A fixed context pattern adds an increment to the baseline divisive inhibitory signal that changes the form of the response function. One effect of this change is to shift the steep region of the function to higher contrasts, thus improving contrast discrimination in this range. Elaborations of the model are required to account for some effects. Alternative models in which induced noise is substituted for divisive inhibition, sometimes account for discrimination data as well as the divisive inhibition model. However, experiments in which perceived contrast is matched show that suppression underlies these effects.

9:20 AM–C.C. Chen, National Taiwan University
Lateral modulation of contrast detection and discrimination

The visual performance to a visual target can be changed by the presence of another visual stimulus (Flanker) nearby. Many theories have been proposed to explain the flanker effects. We used a dual-task paradigm, in which an observer is to detect a target superimposed on a pedestal and in the presence of flankers, to investigate the mechanisms underlying such flanker effects. The typical result is that, compared with the no-flanker conditions, the target threshold vs. pedestal contrast (TvC) functions shifted horizontally on log-log coordinates when the flanker appears. This result can be explained by a model in which the effect of the flankers is to modulate both the excitatory and the divisive inhibitory sensitivity of the target mechanism to both the target and the pedestal. The flanker effect depends on spatial configuration of stimuli, such as the relative distance, location, orientation, phase, and depth between the target and the flankers. Such spatial configuration dependence suggests that the flanker effect may serve a function for contour and surface completion.

9:45 AM–Tim Meese, Aston University
Contrast integration and counter suppression: a general scheme for visual hierarchies?

Low contrast stimuli are much easier to detect with two eyes than with one, suggesting a process of signal summation. But in everyday life, when we close one eye, the contrast of the world does not diminish, but remains fairly constant implying that different or additional processes are involved above threshold. We have developed a generic gain control model of contrast summation that involves contrast integration along the dimension of interest and slightly less potent suppression along the same dimension: the model giveth with one hand and taketh away with the other. This counter intuitive behavior allows the model to benefit from pooling at threshold, yet maintain a contrast code that is invariant with the extent of pooling above threshold. It also suggests that it might be possible to reveal the operation of the integration process above threshold with appropriate experimental manipulations. By measuring various forms of 'dipper functions' we have been able to confirm this in the domains of: ocularity, space, orientation and time. The model also predicts paradoxical psychometric functions ('swan' functions) that we find for appropriate arrangements of target and pedestal in each of the same four dimensions. Furthermore, we show that the general arrangement that we propose is a suitable basis for building visual hierarchies and population codes for global measures along various dimensions of interest. This idea receives some direct support from novel experiments in which we reveal aftereffects for global size adaptation.

10:10 AM–Discussion Session

## Contributed Vision Session

11:00 AM–Kuo-Sheng Lee, National Taiwan University
Possible mechanisms for the contextual effect of macaque V1 receptive fields

In the superficial layer of macaque monkey V1, many neurons have stronger responses to light decrements (OFF responses) than light increments (ON responses) [Yeh et al., 2009]. This OFF-over-ON bias is evident when V1 receptive fields are mapped with sparse noise, but is weaker with dense noise (i.e. Hartleys, Ringach et al., 1997). One possible mechanism for the mismatch between sparse- and dense-noise maps is the difference in ON and OFF response gains from the input to the output layers of V1 under the two different mapping conditions. In this study, we focused on how the change in ON and OFF response gains might affect the similarity between the sparse- and dense-noise maps of the same neuron. On average, the response strength of the ON subfield should be increased to approximately two times of its origin (1.93+0.19; mean+S.E.M.) to reach the possibly highest receptive-field similarity (RFS, cross-correlation between the two maps). The sole change in the response gain of ON subfield increased the RFS by 66% (From 0.35 to 0.58), and it could account for approximately 81.4% of the overall differences between the two maps. Overall, these results suggest that either a selectively feedforward model (OFF is stronger than ON) [Xing et al., 2010] or a structural network with a greater ON-subfield overlapping in the input layer (Paik & Ringach, 2011; 2012) might contribute to the dark dominance in the superficial layer of V1.

11:15 AM–Anasuya Das, University of Rochester
Beyond blindsight: perceptual re-learning of visual motion discrimination in cortical blindness improves static orientation discrimination

Cortical blindness is a dense unilateral scotoma that follows primary visual cortex damage. Interestingly CB subjects retain the ability to detect stimuli that have high temporal and low spatial frequency content – termed blindsight, as detection is not always accompanies by awareness. Recent work has shown the effectiveness of repeated perceptual stimulation in shifting the blind field border by using stimuli that are optimized for eliciting blindsight. Previous work from our lab has shown that global direction discrimination can be relearned in the blindfield and this learning generalized to other motion stimuli, which still fell within the spatio-temporal channels of blindsight. The question that still remains is whether visual motion relearning is specific to motion stimuli or whether it transfers to non-motion stimuli that traditionally do not elicit blindsight. CB subjects were trained on a global direction discrimination task in their blindfield and then transfer of learning was tested using static gabors. We measured contrast sensitivity and orientation discrimination at the retrained location pre- and post-training. Contrast sensitivity for static gabors improved post-training especially for spatial frequencies less that 5cpd, however contrast thresholds were not equivalent to intact field thresholds. A subset of our patients then underwent contrast learning, which further improved contrast thresholds to comparable intact field levels. Orientation difference thresholds also improved significantly for low spatial frequency static gabors. These results suggest that perceptual learning in cortically blind fields generalizes to a broader range of stimuli than predicted by blindsight alone.

11:30 AM–Hyung-Goo Kim, University of Rochester
Dynamic perspective as a proxy for smooth pursuit in coding depth sign from Motion parallax in area MT

When an observer moves through the world, stationary objects in a scene have retinal image motion that depends on distance. Theoretical work[1] has shown that the depth of an object in a scene can be computed monocularly from the ratio of retinal image motion and the rate of change of eye orientation relative to the scene. The latter quantity can come from efference copy signals about the smooth pursuit velocity of the eye, and we have previously shown that neurons in area MT can combine ambiguous retinal image motion with smooth pursuit signals to represent depth.

However, it is also possible that changes in eye orientation relative to the scene can be signaled through purely visual mechanisms. As the eye changes orientation relative to a scene (e.g., during pursuit), dynamic changes in perspective introduce a component of "rocking" motion in the optic flow field (hereafter 'dynamic perspective'). We hypothesized that neurons in area MT combine dynamic perspective information with ambiguous retinal image motion to represent depth in the absence of pursuit or binocular cues. Fixating animals viewed a depth-sign ambiguous motion parallax display with or without a background that contained dynamic perspective.

More than half of MT neurons show significant depth-sign selectivity driven by dynamic perspective cues. Moreover, the depth-sign preference is well correlated with that obtained when animals actively pursue a visual target without background motion. These results suggest that the visual system can use dynamic perspective cues as a proxy for efference copy regarding eye velocity.

11:45 AM–Andrew Haun, Schepens Eye Research Institute
Perceived contrast of complex images

We present evidence that the perceived contrast of complex, real-world images is biased towards their high spatial frequency components, and that neither the contrast sensitivity function nor contrast constancy are useful descriptions of broadband contrast perception. We adapted the classification image paradigm to measure decision weighting functions for luminance contrast as a function of spatial frequency in systematically modified broadband natural images. The experiment yields bandpass weighting functions which can be explained by combining an existing model of perceived contrast (Cannon & Fullenkamp 1991) with suppression disproportionately exerted on low spatial frequency responses. We were also able to recover local luminance classification functions showing that negative-polarity ('dark') contrasts are most important to human judgments of overall image contrast, consistent with recent evidence that dark image regions are encoded preferentially during early contrast encoding (e.g. Komban, Alonso, & Zaidi 2011). Our implementation of suppression is simplified but consistent with broader aspects of contrast psychophysics – we predict that studies of contrast masking or adaptation using broadband images should show that suppression is progressively stronger towards low spatial frequencies, keeping perceptual responses just above mechanism thresholds and ensuring that higher-frequency components are perceptually emphasized.

12:00 PM–Laura Young, University of Oxford
Going beyond the wavefront: Improved predictions of performance obtained by accounting for the spatial frequency requirements of the task

Ocular aberrations cause distortions of the image falling on the retina, as characterised by the optical transfer function of the eye. Recent work has shown that good predictions of visual acuity can be made from the wavefront measurement, particularly when the neural contrast sensitivity function is taken into account, as in the visual Strehl ratio for example (Cheng et al., 2004; Marsack et al., 2004; Thibos et al., 2004). We have recently shown that the effect of an aberration on visual performance depends on its type (Young et al., 2011) and is task-specific even for related tasks such as letter recognition and reading (Young et al., 2012). How then might we better understand the wavefront measurement in terms of real-life visual performance? We have tested the correlation between different metrics for predicting visual performance from the wavefront aberration and our experimental data. Letters are typically identified via a narrow spatial frequency band (Solomon & Pelli, 1994), however the centre frequency can change depending on the size of the letter and if it is spatially filtered (Majaj et al., 2002), switching when it is useful to do so (Oruc & Landy, 2009). We show that by additionally accounting for the spatial frequencies mediating letter identification we can better predict changes in performance from the wavefront measurement. Using bandpass noise we masked the spurious resolution that is introduced by an aberration. The pattern of performance improvements suggest that "off-frequency looking" is important when identifying aberrated letters.

12:15 PM–Athanasios Panorgias, UC Davis
Senescent changes in retinal recovery after light stimulation using the mfERG

The multi-focal electroretinogram (mfERG) acquires spatially resolved retinal signals that can facilitate diagnosis and treatment of visual disorders. However, much information contained in the recorded signals remains unexploited. Here, we use the mfERG to detect age-related changes in retinal recovery from a photopic double-flash response.

mfERGs were recorded from 33 normal subjects with no ocular pathology (mean age: 39.4 years, range: 18.2 - 57.8 years) using the VerisPro software (EDI) that allows extraction of retinal responses at different inter-stimulus intervals (ISIs) and different flash combinations. 103 hexagons and 2.66cd sec/m^2 stimulus luminance were used. The responses were grouped into macular and peripheral retinal areas. In the macular region, the stimulus subtended a ~10 degrees radial area centered on the fovea with the central 1 degree excluded. The peripheral stimulus formed a ring with inner and outer radii ~10 and 20 degrees, respectively.

Single-flash responses preceded by a double flash were extracted from the signal. Age-related changes in retinal recovery were found for the macular, but not peripheral retina at the minimum ISI (13.3ms). A t-test comparing the 10 youngest and the 10 oldest observers revealed a statistically significant difference ($p<0.05$, $\alpha=0.05$). For longer ISIs no difference was found.

The results suggest that fast adaptation in the macular area is more vulnerable to aging than the peripheral area and that, for the age range covered here, the older retina has the capacity to fully recover between 13.3 and 26.6ms and respond like a young retina. These regional differences cannot be explained by pre-retinal factors.

**Controlling the Motion of Attention**

***Moderator: Tania Pasternak, University of Rochester***

1:45 PM–Mary Hayhoe, University of Texas, Austin
Understanding attentional control in the context of behavior

It will be difficult to properly understand attention without understanding how it functions in the context of natural behavior. What principles control the selection of visual information from the environment? From the results of several studies that monitor eye movements in both real and virtual environments, several principles emerge. First, both selection and storage of visual information in natural tasks depend on momentary task relevance. Thus to understand attentional control we will need to have a theory that takes into account the priority structure of natural tasks.

Second, observers deal with attentional limitations by using memory representations, and do not re-attend to information that is typically stable. Thus an important determinant of attentional control may be what observers have previously learnt about the dynamic properties of the world. Third, observers are sensitive to the statistical properties of the visual scene and rapidly modify overt attentional allocation when changes occur. These principles provide a basis for understanding the generation of complex gaze sequences involved in natural visually guided behavior.

2:10 PM–Steve Heinen, The Smith-Kettlewell Eye Research Institute
Motion integration for pursuit does not hinder attentive motion segregation

The smooth pursuit system integrates the motion of stimuli with inconsistent local velocity components to obtain a global velocity vector (Heinen & Watamaniuk, 1998). Since pursuit of a single spot is attentive, it might be expected that the integration process required to pursue global motion would place additional attentional demands on the pursuit system. If so, either pursuit of global motion or simultaneous performance on an attention-demanding task should be compromised. We had observers attentively follow the local elements of a small, multiple object tracking (MOT) stimulus (Pylyshyn & Storm, 1988) that translated across the screen, and simultaneously pursue the global stimulus motion with their eyes. The stimulus was a cloud of 4, 8, or 10 dots that moved randomly within a virtual 10 deg containment region. Observers attentively tracked 0, 2, 4 or 5 target dots respectively from the cloud. The MOT task was performed on the cloud as it translated from left to right at a global speed of 7 deg/sec, or remained at the center of the screen without translational motion. We found that performance on the MOT task was the same with and without pursuit, and decreased as the number of MOT targets increased. Furthermore, pursuit gain was no different when pursuing the cloud with or without the MOT task imposed, and improved as the number of dots increased. With the maximum number of dots, the gain was the same with or without an embedded pursuit target, indicating the elements were integrated with no interference from the attention task. The results suggest that motion integration during pursuit is a relatively inattentive process.

2:35 PM–James Brockmole, University of Notre Dame
Reference frames, implied motion, animacy, and the movement of attention

A variety of perceptual and conceptual aspects of a scene can influence one's eye movements and, hence, the manner in which they move their attention from place to place. In the present study, we examined how one's interpretation of various spatio-temporal properties of individual objects affects gaze. When we assess the location of an object, we assign a spatial reference frame defining the object's front, left, top, etc. We may additionally assess an object's ability to move and, if it were to do so, the likely cause and direction of motion. Such determinations enter into a variety of cognitive processes ranging from the allocation of covert spatial attention to the production of language. The present study examined how one's interpretation of an object's orientation and potential for motion affect the overt allocation of attention and gaze-control decisions. Observers viewed stationary objects including furniture (immobile), vehicles (potential for inanimate motion), and animals (potential for animate motion). Eye movements directed away from a fixated object were biased in the direction it faced. This effect was increased if an object implied a particular direction of motion. Animate motion did not increase this bias over inanimate motion. Thus, determining an object's spatial orientation and potential for movement affects shifts of overt attention. An influence of animacy, however, may be confined to covert or reflexive aspects of attention. This research indicates that the movement of attention can be, in part, controlled by the assessment of the spatio-temporal characteristics of individual objects within a scene.

3:00 PM–Eileen Kowler, Rutgers University
Exploring the environment with eye movements and attention

Visual scenes contain far too much information to be apprehended in a single glance. Limitations come from several factors, including the decline in visual resolution with distance from the fovea, the interference produced by crowding, and the inability to identify or encode multiple visual objects or features within the same brief glance. These limitations mean that effective vision depends on both saccadic eye movements and perceptual attention to select the objects, features or regions with the greatest momentary need for limited processing resources. Some approaches to saccades and attention have emphasized the strong links between the two processes in space and time, while others have emphasized their independence. This talk will present recent results from experiments that measure perceptual performance during saccadic sequences while varying memory load, perceptual load, target contrast, external noise and the cues available to guide saccades. The results show strong links between spatial attention and saccades that affect the quality of the perceptual representations, the accuracy of saccades and the contents of visual short-term memory. By contrast, feature-based attention operates largely independently of saccadic planning. The net result is that spatial attention can ensure accurate saccades and facilitate seamless transitions between glances, while attention based on features can contribute to longer-range selection of useful places to look.

3:25 PM–Discussion Session