OSA Fall Vision Meeting

October 21-23, 2016
# PROGRAM SCHEDULE

**October 21-23, 2016**

* All talks & discussion sessions are at the Large Conference Room, Hilton Garden Inn

## THURSDAY, OCTOBER 20

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<tbody>
<tr>
<td>7:00 pm – 9:00 pm</td>
<td>Registration and Welcome Reception, FEI Atrium</td>
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## FRIDAY, OCTOBER 21

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<tr>
<td>8:00 am</td>
<td>Registration &amp; Poster Setup</td>
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<tr>
<td>8:45 am</td>
<td>Welcome &amp; Introduction, David Williams</td>
</tr>
<tr>
<td>9:00 am – 9:30 am</td>
<td><strong>David Brainard</strong>, University of Pennsylvania  &lt;br&gt;Past, present and future of Vision and Color in OSA</td>
</tr>
<tr>
<td>9:30 am – 10:00 am</td>
<td>Break</td>
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**The Developing Visual System**  <br>Chair: William Bobier, University of Waterloo

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<tr>
<td>10:00 am – 10:25 am</td>
<td><strong>Christine Wildsoet</strong>, University of California, Berkeley  &lt;br&gt;Ocular growth regulation and the evolution of myopia</td>
</tr>
<tr>
<td>10:25 am – 10:50 am</td>
<td><strong>Anne Fulton</strong>, Boston Children’s Hospital  &lt;br&gt;The developing retina: typical and in retinopathy of prematurity (ROP)</td>
</tr>
<tr>
<td>10:50 am – 11:15 am</td>
<td><strong>Daphne Maurer</strong>, McMaster University  &lt;br&gt;The influence of visual experience during Infancy: lessons from infants treated for dense cataracts</td>
</tr>
<tr>
<td>11:15 am – 11:40 am</td>
<td><strong>Scott Johnson</strong>, UCLA  &lt;br&gt;Mechanisms of statistical learning in infancy</td>
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### Contributed Session: Retinal Imaging
**Chair:** Jessica Morgan, University of Pennsylvania

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<tr>
<td>1:30 pm – 1:45 pm</td>
<td>Robert Cooper, University of Pennsylvania</td>
<td>Irradiance and duration dependence of the cone photoreceptor intrinsic reflectance response</td>
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<tr>
<td>1:45 pm – 2:00 pm</td>
<td>Salihah Qaysi, University College Dublin</td>
<td>Analysis of photoreceptor pointing using quadrant pupil detection</td>
</tr>
<tr>
<td>2:00 pm – 2:15 pm</td>
<td>Laura Young, University of Oxford</td>
<td>Recording fixational eye movements with a new AOSLO: simulation, measurement and evaluation</td>
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<tr>
<td>2:15 pm – 2:30 pm</td>
<td>Yuhua Zhang, University of Alabama at Birmingham</td>
<td>High speed adaptive optics parallel confocal ophthalmoscopy</td>
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<tr>
<td>2:30 pm – 2:45 pm</td>
<td>Soon Cheong, University of Rochester</td>
<td>Long-term function of channelrhodopsin restored visual responses recorded in the living eye</td>
</tr>
<tr>
<td>2:45 pm – 3:00 pm</td>
<td>Jesse Schallek, University of Rochester</td>
<td>Imaging invisible cells: new advances in adaptive optics reveal structure of the translucent retinal cells of the inner retina</td>
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<td>3:00 pm – 3:30 pm</td>
<td>Break</td>
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### Visual Human Factors in Driving
**Chair:** Jeff Mulligan, NASA

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<tr>
<td>3:30 pm – 3:55 pm</td>
<td>Mary Hayhoe, University of Texas Austin</td>
<td>Understanding how tasks control gaze</td>
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<td>3:55 pm – 4:20 pm</td>
<td>Rick Tyrrell, Clemson University</td>
<td>Perceiving pedestrians at night: a critical visual task</td>
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<td>4:20 pm – 4:45 pm</td>
<td>John Wann, Royal Holloway College, University of London</td>
<td>Errors in the detection and discrimination of vehicles: a simple optical model to explain driver and pedestrian misjudgements</td>
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<tr>
<td>8:30 am – 9:00 am</td>
<td>Registration</td>
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</table>
| 9:00 am – 9:25 am | **Ziad Hafed**, Werner Reichardt Centre for Integrative Neuroscience  
A neural locus for perceptually-relevant microsaccadic suppression in the primate superior colliculus |
| 9:25 am – 9:50 am | **Susana Martinez-Conde**, SUNY Downstate Medical Center  
Towards an integrative view of microsaccadic function                                |
| 9:50 am – 10:15 am | **Martin Rolfs**, Humboldt University Berlin  
Microsaccadic inhibition is tightly coupled with explicit visual detection               |
| 10:15 am – 10:40 am | **Michele Rucci**, Boston University  
Microsaccades and high-acuity vision                                                    |
| 10:40 am – 11:00 am | Discussion                                                                              |
| 11:00 am – 12:00 pm | Break & Posters                                                                          |
| 12:00 pm – 1:30 pm | Lunch                                                                                   |
### Contributed Session: Clinical
**Chair:** Richard Aslin, University of Rochester

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<tr>
<td>1:30 pm – 1:45 pm</td>
<td><strong>Shanna Coop</strong>, University of Rochester</td>
<td>Psychophysical measurement of marmoset acuity and myopia</td>
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<td>1:45 pm – 2:00 pm</td>
<td><strong>Nancy Coletta</strong>, New England College of Optometry</td>
<td>Fixational eye movements in a visual acuity task</td>
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<td>2:00 pm – 2:15 pm</td>
<td><strong>Rajkumar Nallour Raveendran</strong>, University of Waterloo</td>
<td>Impaired fixation stability in amblyopia cannot be explained by the visual acuity impairment</td>
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<tr>
<td>2:15 pm – 2:30 pm</td>
<td><strong>Elizabeth Saionz</strong>, University of Rochester</td>
<td>Can training in the subacute post-stroke period generate greater visual recovery after V1 damage?</td>
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<tr>
<td>2:30 pm – 2:45 pm</td>
<td><strong>Michael Melnick</strong>, University of Rochester</td>
<td>Training-induced recovery of fMRI-based motion adaptation signals in V1 damaged humans</td>
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<tr>
<td>2:45 pm – 3:00 pm</td>
<td><strong>Michael Crognale</strong>, University of Nevada, Reno</td>
<td>Functional mapping of visual cortex in hydrocephaly</td>
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<tr>
<td>3:00 pm – 3:30 pm</td>
<td><strong>Break</strong></td>
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<tr>
<td>3:30 pm – 5:00 pm</td>
<td><strong>Tillyer Award &amp; Lecture</strong></td>
<td><strong>Dennis M. Levi</strong>, University of California, Berkeley</td>
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<tr>
<td>6:00 pm – 9:00 pm</td>
<td><strong>Banquet (Ballroom 384 at the City Grill)</strong></td>
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### Contributed Session: Vision
**Chair:** Geoff Aguirre, University of Pennsylvania

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<td>9:00 am – 9:15 am</td>
<td><strong>Alexandra Boehm</strong>, University of California, Berkeley</td>
<td>Mapping the spatial extent of perceptive fields for flicker adaptation using retinally stabilized stimuli</td>
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| 9:15 am – 9:30 am | Jihyun Kim, Universitat Pompeu Fabra  
Retinal lateral inhibition revisited |
| 9:30 am – 9:45 am | Manuel Spitschan, University of Pennsylvania  
Human visual cortex responds to isolated melanopsin-directed stimulation |
| 9:45 am – 10:00 am | Marina Danilova, Russian Academy of Sciences  
The comparison of spatially separated stimuli: judgments of speed |
| 10:00 am – 10:15 am | Jacob Yates, University of Rochester  
Decoding from populations of MT neurons during motion-discrimination |
| 10:15 am – 10:30 am | Mario Dalmaso, University of Padova  
Working memory load is reflected in the frequency of microsaccades |
| 10:30 am – 11:00 am | Break |
| 11:00 am – 11:10 am | Tribute & Introduction |
| 11:10 am – 11:35 am | Austin Roorda, University of California, Berkeley  
Color percepts elicited by stimulation of individual targeted cones |
| 11:35 am – 12:00 pm | Sophie Wuerger, University of Liverpool  
Colour vision across the life span: effect of age, ambient illumination and individual differences |
| 12:00 pm – 12:25 pm | Karl Gegenfurtner, Giessen University  
The paradox of color constancy |
<p>| 12:25 pm – 12:30 pm | Wrap-up |
| 12:30 pm – 2:00 pm | Lunch &amp; Poster Removal |
| 2:00 pm – 2:30 pm | Business meeting &amp; YIA presentation |</p>
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<td>David Williams, University of Rochester</td>
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<td>Optical recording of the light response from</td>
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<td>ganglion cells in the living mammalian eye</td>
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<td>3:05 pm – 3:30 pm</td>
<td>Qasim Zaidi, State University of New York</td>
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<td>Genesis of pattern and contour selectivity</td>
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<td>by intra-cortical circuits: functional</td>
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<td>implications</td>
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<td>3:30 pm – 3:55 pm</td>
<td>Laurence T Maloney, New York University</td>
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<td>Measuring color appearance and the</td>
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<td>structure of color space</td>
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<tr>
<td>3:55 pm – 4:00 pm</td>
<td>Wrap-up</td>
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Dennis Levi, O.D., Ph.D. is Professor of Optometry and Vision Science at UC Berkeley. He served as Dean of the School of Optometry from 2001 – 2014. His research on amblyopia and spatial vision has been continuously funded by the National Eye Institute (NEI) since 1976, and he has published over 275 scientific papers and two books.

Levi served as Chair of the Vis B. study section, and was a member of the Strabismus, Amblyopia & Visual Processing Panel of the National Eye Institute. He also served on the National Research Council (NAS) Committee on Disability Determination for Visual Impairments. He currently serves on the National Advisory Eye Council.

Levi served as Editor-In-Chief and Chairman of the Board of Vision Research from 2004-2012, and was elected as Editor-In-Chief of Journal of Vision from 2013-2018. He also serves on a number of other Editorial Boards, including, Ophthalmic and Physiological Optics, Scientific Reports and Annual Reviews of Vision Science. Levi was elected Fellow of the Optical Society of America for his research contributions in the areas of amblyopia and spatial vision, and has received numerous awards including the Glenn Fry Award, the Garland Clay Award and the Prentice Medal from the American Academy of Optometry.
The Developing Visual System
Ocular growth regulation and the evolution of myopia

Christine F. Wildsoet, University of California, Berkeley

Refractive errors tend to be the norm in young infants but generally resolve during early development through emmetropization. Once thought to be largely a passive process, animal studies have provided definitive proof of a defocus-driven active process of local ocular growth regulation, which is sensitive to the sign of defocus and relies on input from not only the central retina, but the peripheral retina as well. In myopia, this process appears to derail, and eyes continue to elongate beyond that required to achieve emmetropia. This presentation will provide an update, based on results from relevant animal and human studies, on current thinking around ocular growth regulation and the origin of the current epidemic of myopia, which is predicted to affect 50% of the world’s population by 2050.
The developing retina: typical and in retinopathy of prematurity (ROP)

Anne B. Fulton, Ronald M. Hansen, James D. Akula, Anne Moskowitz

We have tracked the structural and functional development of normal retina and used these normative data to facilitate interpretation of the retinal dysfunction and dysmorphia associated with retinopathy of prematurity (ROP). ROP, a potentially blinding disease, is active when the neurosensory retina is quite immature. Interpretation of non-invasive psychophysical and electrophysiological data in infants and children and in rat models of ROP are backed up by our biophysical, molecular biological, and histological data in the rats. A key result is that the onset of active ROP coincides with development of the rod photoreceptor outer segments and the phototransduction cascade. Dysfunction of the rods persists for years after the active disease has healed in early infancy. Taken all together, our results lead us to propose light as a non-invasive, non-pharmacological intervention designed to minimize and ultimately prevent ROP and its consequences.
The influence of visual experience during infancy: lessons from infants treated for dense cataracts

Daphne Maurer, McMaster University

Our research takes advantage of a natural experiment: children with a period of visual deprivation caused by dense, central cataracts. Longitudinal studies of their visual recovery reveal that even short periods of deprivation near birth cause lasting deficits not only in acuity but also in higher-level perceptual skills such as motion perception. The deficits are often sleeper effects that appear much later in development. They imply that the infant’s early visual experience tunes the visual neural system to allow later specialization. When the experience is missing, deficits emerge later. Nevertheless, some potential for recovery remains even in adulthood—as revealed by video game therapy.
Mechanisms of statistical learning in infancy

Scott Johnson, UCLA

Statistical learning is the process of identifying patterns of probabilistic co-occurrence among stimulus features, essential to our ability to perceive the world as predictable and stable. Research on auditory statistical learning has revealed that infants use statistical properties of linguistic input to discover structure--including sound patterns, words, and the beginnings of grammar--that may facilitate language acquisition. Research on visual statistical learning has revealed abilities to discriminate, learn, and generalize probabilities in visual patterns, but the mechanisms (including developmental mechanisms) underlying infant performance remain unclear. This talk will present new work that examines competing models of statistical learning and how learning might be constrained by limits in infants’ attention, perception, and memory. Broader implications for theories of cognitive development will be discussed.
Contributed Session: Retinal Imaging
Irradiance and duration dependence of the cone photoreceptor intrinsic reflectance response

Robert F. Cooper, William S. Tuten, David H. Brainard, Jessica I. W. Morgan

Adaptive optics (AO) imaging of the human cone mosaic has shown that a visible stimulus can induce intrinsic changes in cone infrared reflectivity. We studied this intrinsic response as a function of stimulus irradiance and duration. Five subjects were imaged using a previously described AO scanning light ophthalmoscope. Following 2 minutes of dark adaptation, image sequences were obtained 0.65° from the fovea using a 790 nm imaging light. Four seconds after the start of each sequence, a 680 nm stimulus of variable irradiance (0.037 to 18.9 µW/deg^2) and duration (0.2 to 2 secs) was delivered to one half of the imaging field. Reflectance signals were extracted from each cone and standardized to their pre-stimulus values. The difference in the standard deviation of the reflectance of stimulated and control (unstimulated) cones was determined at each time point. The peak was extracted from the resultant time-varying response. Peak response increased with both stimulus irradiance and duration, qualitatively consistent with a dependence of the response on photoreceptor function.

Supported by Alfredo Dubra, Grace Han, NIH Grant U01EY025477, Research to Prevent Blindness Stein Innovation Award, Foundation Fighting Blindness, the F.M. Kirby Foundation, the Paul and Evanina Mackall Foundation Trust.
Analysis of photoreceptor pointing using quadrant pupil detection

Salihah Qaysi, Denise Valente, Brian Vohnsen

Photoreceptors are endowed with directional properties that are expressed by their angular sensitivity to incident light as well as directionality in retinal images commonly referred to as the Stiles-Crawford effect of the first kind and the optical Stiles-Crawford effect, respectively. Individual photoreceptor tilt can be analyzed by moving the incident light across the pupil when capturing retinal images [1, 2]. The aim of this study is to examine the viability of a quadrant pupil detection scheme in which light enters near the SCE peak and backscattered light is captured through four equal-sized sectors in the pupil from which individual photoreceptor tilt can be derived.

The method employs a pyramidal prism to capture simultaneously 4 high-resolution retinal images. A numerical analysis using Matlab is performed to quantify the angular tuning in scattered light from each cone in the captured retinal images. The experimental results for parafoveal retinal imaging in healthy subjects are compared with modeled cone mosaic images. Retinal photoreceptors are modeled by single-layered scattering by mitochondria in the ellipsoid [3]. Retinal images are calculated through four equal-sized sectors in the pupil lane in a 4f system. The Modeled photoreceptors are placed in the retinal plane with different angular tilts.

The initial result of our sectored quadrant pupil imaging system allows not only determination of total intensity images, but also direct determination of photoreceptor inclinations in the backscattered light intensity. It is found that the method is highly suited to determine photoreceptor inclinations without requiring displacement of the incident light in the pupil plane, whereby the determination of photoreceptor tilt becomes simplified. The experimental results compared well with the theoretical expectations thereby confirming the potential of the technique. It offers the possibility to analysis cone photoreceptor tilt in 2-D and is expected to probe valuable when analyzing retinal disease.


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This research has been funded by King Abdullah Scholarship Program (KASP) – Saudi Arabia and by Science Foundation Ireland grant 08/IN.1/B2053.
Recording fixational eye movements with a new AOSLO: simulation, measurement and evaluation

Laura K. Young [1,2], Anna K. Hauperich [1], Timothy J. Morris [2], Christopher D. Saunter [2], Hannah E. Smithson [1]

[2] Department of Physics, Durham University, Durham, UK.

Adaptive optics scanning laser ophthalmoscopy (AOSLO) produces high-resolution images of the retinal mosaic. These images contain distortions due to eye motion, which can be used for high speed and resolution eye tracking that is referenced to the photoreceptor mosaic. Patch-based registration methods employ either a) cross-correlation or b) a map-seeking circuit. Both techniques compare images to a reference frame, which may itself contain motion and so provides only a relative measure. We have developed a method for generating motion-free reference frames and use it to compare techniques a) and b) to a modified method using feature (cone) tracking. We present a comparison of these algorithms under variations in image quality, retinal structure and types of eye movement. We discuss the implications for psychophysical experiments, which require accurate measurement of eye movements and cone density/arrangement, as well as for clinical experiments, in which sub-optimal image quality can affect such measures.
High speed adaptive optics parallel confocal ophthalmoscopy

Yuhua Zhang, Jing Lu, Boyu Gu, and Xiaolin Wang

Department of Ophthalmology, University of Alabama at Birmingham

To improve the image acquisition efficiency of high resolution adaptive optics (AO) confocal ophthalmoscopy and counter the image distortion induced by continuous and rapid eye movement, we have developed a high speed AO parallel confocal ophthalmoscope (AOPCO). This instrument employs a digital micromirror device to modulate the imaging light into a line of point sources, illuminating the retina simultaneously. By using a high speed line camera to acquire the image and AO to compensate ocular wave aberration, the AOPCO can image the living human eye with cellular level resolution at the frame rate of 200 Hz with a digitization of 768×512 pixels/frame over a field of view of 1.93 x 1.28 degrees. We demonstrate the ability for reducing even eliminating the spatial distortion of retinal imaging caused by involuntary fixational eye movements and the potential for investigating fast moving features like erythrocytes through the retinal vasculature in the living human eye.


Supported by National Institutes of Health (NIH) (EY021903, EY024378, P30 EY003039). National Science Foundation (NSF) (IIA-1539034); Institutional support from Research to Prevent Blindness and EyeSight Foundation of Alabama.
Long-term function of channelrhodopsin restored visual responses recorded in the living eye

Soon K. Cheong, Jennifer M. Strazzeri, David R. Williams, William H. Merigan

University of Rochester

Purpose: A critical part in developing optogenetic and electrical vision restoration therapies is the ability to assess the restored function over long periods of time. Here we describe the application of an in vivo method to record and track the response of retinal neurons in a study of optogenetic vision restoration in a mouse model of photoreceptor degeneration (rd10).

Methods: We expressed the calcium indicator GCaMP6s and/or a red-shifted channelrhodopsin (ChrimsonR-tdTomato) in inner retina neurons using adeno-associated viral vectors. In vivo functional imaging of GCaMP6s was performed using a custom built adaptive optics scanning light ophthalmoscope to measure cell responses to light stimulation. Uniform field 0.2 Hz square wave stimuli were presented in Maxwellian view using two LEDs: 365 nm to drive S-opsin, and 620 nm to drive ChrimsonR. Responses were also recorded in wild-type (C57BL/6J) mice transfected with only GCaMP6s.

Results: Robust co-expression of GCaMP6s and ChrimsonR-tdTomato was observed in many neurons and persisted in mice as old as 210 days, 145 days after injection. In rd10 mice with ChrimsonR, cells showed robust responses to 620 nm stimulation at all ages tested: 70, 84 and 112 days old. In rd10 mice without ChrimsonR, no cells showed light evoked activity to 620 nm or 365 nm stimulation. In wild-type mice without ChrimsonR, many cells showed light evoked activity to 365 nm but none responded to 620 nm stimulation.

Conclusion: Expression and function of the channelrhodopsin ChrimsonR persists for extended periods of time, demonstrating excellent potential as a viable therapy for vision restoration in humans. In vivo imaging of calcium responses can be used to monitor responses of retinal neurons over time and may be a useful method for evaluating vision restoration methods.
Imaging invisible cells: new advances in adaptive optics reveal structure of the translucent retinal cells of the inner retina

Jesse Schallek, Aby Joseph, Vigneshwar Subramanian, Andres Guevara-Torres

University of Rochester

While the advent of adaptive optics ophthalmoscopy has provided microscopic resolution in the living eye, the majority of neurons in the mammalian retina have evaded detection. This is because most retinal cells are highly translucent, allowing photons to travel through the neural retina with minimal scatter and absorption before reaching the photoreceptors. While retinal translucency is beneficial for vision, it poses a challenge for imaging because cells provide weak optical contrast.

Recent advances in non-confocal ophthalmoscopy now reveal cells that were once hidden by their translucency. By comparing directional cell scatter, we provide detailed images of: ganglion cells, horizontal cells, multi-laminar photoreceptor somata, red blood cells, platelets, white blood cells and putative sub-cellular organelles in the living eye without contrast agents.

We optimized the non-confocal contrast by integrating “split-detection” capabilities (Scoles et al. 2014) into an adaptive optics scanning light ophthalmoscope (AOSLO) custom built for the mouse eye (Guevara-Torres et al. 2015). The split-detection approach compares directional light scatter in the retina. The imaged point spread function of the AOSLO was bisected by a knife-edge prism and relayed into two, phase-locked photomultiplier tubes. The left and right half of the imaged retinal point spread function was digitally subtracted to remove the mutual light information common in the two channels. C57BL/6J mice were anesthetized and imaged with and without contrast agents applied to validate cell type.

Imaged ganglion cells were confirmed by imaging tagged Thy-1 fluorescent cells. Leukocytes were confirmed with fluorescent labeling of nuclei with acridine orange. Red blood cells, platelets, photoreceptor somata and horizontal cells matched the known morphology, density and/or topography in the mouse retina. This new catalog of cells has greatly expanded the number of cell types that may be studied in the living mammalian retina in health and disease.


Supported by the Research to Prevent Blindness (RPB) Career Development Award, an Unrestricted Grant to the Flaum Eye Institute from RPB, New York, NIH Kirschstein NRSA Postdoctoral Fellowship F32EY023496 and the RPB Stein Innovation Award.
Imaging invisible cells: new advances in adaptive optics reveal structure of the translucent retinal cells of the inner retina

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Visual Human Factors in Driving
Understanding how tasks control gaze

Mary Hayhoe, University of Texas Austin

While it is universally acknowledged that both bottom up and top down factors contribute to allocation of gaze, we currently have limited understanding of how top down factors determine gaze choices in the context of ongoing natural behavior such as driving or locomotion. Modeling top-down gaze control has been very difficult because it depends on characterizing the underlying task structure. One purely top-down model by Sprague et al (2007) suggests that natural behaviors can be understood in terms of simple component behaviors, or modules, that are executed according to their expected reward value, with gaze targets chosen in order to reduce uncertainty about the particular world state needed to execute those behaviors. I will discuss the plausibility of the central claims of this approach in the context of driving and locomotion tasks. The modular approach of independent component behaviors is consistent with many aspects of performance, and can generate sequences of fixations similar to those observed in human driving and walking behavior. Thus the model forms a useful, although incomplete, starting point for understanding top-down factors in active behavior.
Perceiving pedestrians at night: a critical visual task

Richard A. Tyrrell, Ph.D., Clemson University
Joanne M. Wood, Ph.D., Queensland University of Technology
D. Alfred Owens, Ph.D., Franklin & Marshall College
Stephanie Whetsel Borzendowski, Ph.D., Applied Building Sciences, Inc.
Ashley Stafford Sewall, Ph.D., Cvent, Inc.

Limitations in drivers’ visual abilities are a leading contributor to nighttime crashes into pedestrians. Too often, pedestrians at night are poorly illuminated, low contrast, and unexpected. This creates a critical visual challenge even for visually healthy and attentive drivers. To maximize their safety at night, pedestrians must be conspicuous, not merely potentially detectable as an ambiguous object. A conspicuous pedestrian will attract a driver’s attention and be readily perceivable as a pedestrian. This talk will summarize research on the conspicuity of pedestrians at night. A key discovery from basic visual science – our perceptual sensitivity to biological motion – has been harnessed to make pedestrians more conspicuous. Most road users, drivers and pedestrians alike, are not aware of the natural limitations of night vision. Consequently, at night drivers “overdrive” their headlights, and pedestrians overestimate their own conspicuity and avoid using conspicuity-enhancing markings. Collectively, these findings demonstrate the need for interventions to educate road users about night vision.
Errors in the detection and discrimination of vehicles: a simple optical model to explain driver and pedestrian misjudgements

John Wann, Dept of Psychology, Royal Holloway College, University of London

Failure to detect an oncoming vehicle, or misjudgement of the speed of that vehicle, are among the most common errors listed in road accident statistics. These errors are elevated for drivers in the 70+ age group, are more prevalent in accidents involving children and are also disproportionately high for collisions involving motorcycles. This talk will outline some principles of optical looming that result in some counter-intuitive effects, it will also briefly present empirical findings from simulator studies that support this model as an alternative to simple "distraction" explanations of "looked but failed to see" errors. The findings lead to proposals regarding inner city speed regulation, motorcycle headlight design, driver education and possibly the design of screening tests for older drivers.

This work was supported by the UK Economic & Social Research Council.
Visual field requirements for driving

Alex Bowers, Schepens Eye Research Institute

Visual field requirements for driving vary widely and are largely without scientific basis. While some states specify a minimum horizontal binocular field extent (e.g., 120° in MA), others have no field requirements (e.g., NH), and some have monocular field requirements. Other countries, such as the UK and Australia, have requirements addressing both the integrity of the central visual field and the peripheral extent. This talk will review the results of studies which have started to address some of the existing knowledge gaps about the impact of field loss on driving performance. An essential consideration is whether a person with field loss is able to detect hazards in a timely manner, in particular, those hazards which first appear in non-seeing areas of the field. This is difficult to evaluate in an open-road driving situation where there is no control over if, where, or when hazards might appear. However, a series of driving studies in the safe, controlled, repeatable environment of a driving simulator has provided important insights into the effects of field loss on hazard detection. (1) Compensatory eye/head scanning is often inadequate resulting in missed detections or delayed responses, even when participants are highly primed to the hazard appearance. (2) The extent of compensatory eye/head scanning varies widely despite similar amounts of remaining visual field, suggesting that we need to evaluate more than just horizontal field extent. (3) The presence of central field loss should be taken into account when developing vision requirements for driving because central scotomas delay responses to hazards.
Fixational Eye Movements
A neural locus for perceptually-relevant microsaccadic suppression in the primate superior colliculus

Ziad M. Hafed, Werner Reichardt Centre for Integrative Neuroscience

Microsaccades cause rapid retinal-image shifts that go perceptually unnoticed. The mechanisms for perceptual microsaccadic suppression are not well known; moreover, those for large saccades have been highly controversial, in part due to sparse understanding of neural substrates. Here we uncovered an unexpectedly specific neural locus for microsaccadic suppression in the superior colliculus (SC). We first developed a sensitive behavioral measure of perceptual suppression in two monkeys, demonstrating selectivity of microsaccadic suppression to low spatial frequencies. We then investigated visual responses in either purely visual SC neurons or anatomically-deeper visual-motor neurons, which are also involved in saccade generation commands. Surprisingly, visual-motor neurons showed the strongest visual suppression, and the suppression was dependent on spatial frequency like in perception. Most importantly, visual-motor neuron suppression selectivity was highly predictive of behavioral suppression effects in each individual animal, with our recorded population explaining up to ~74% of behavioral variance even on completely different experimental sessions. In contrast, purely visual neurons only had mild and unselective suppression. Because microsaccades are mechanistically similar to large saccades, our results illuminate the broader topic of saccadic suppression in general. Specifically, our results run directly contrary to a hypothesized SC mechanism for saccadic suppression, in which a motor command in the visual-motor and motor neurons is relayed to the more superficial purely visual neurons to suppress them, and to then potentially be fed back to cortex. Instead, our results indicate that an extra-retinal modulatory signal mediating perceptual suppression is already established in visual-motor neurons.
Towards an integrative view of microsaccadic function

Susana Martinez-Conde, State University of New York, Downstate Medical Center

Human eyes never stop moving, despite our subjective experience to the contrary. Even when we attempt to anchor our eyes to an object or feature of interest, we still produce so called ‘fixational’ eye movements, namely microsaccades, drift and tremor. In recent years, microsaccade research has become a mainstay of oculomotor and visual neuroscience, with important implications for basic research, the understanding of various clinical conditions, and for the replication of studies conducted in circumstances in which microsaccades occur. In this talk I will discuss some of the consequences of making (and not making) microsaccades in a variety of visual tasks and environments, as well as some of the pathologies that affect microsaccades, with the aim of developing an integrative framework of microsaccadic function.
Microsaccadic inhibition is tightly coupled with explicit visual detection

Martin Rolfs¹ and Alex L. White¹,²
¹Bernstein Center for Computational Neuroscience and Department of Psychology, Humboldt University Berlin; ²Department of Psychology, University of Washington

The rate of microsaccades, small eye movements that occur spontaneously during visual fixation, rapidly drops following the onset of transient stimuli. Here, we demonstrate that this involuntary reflex is yoked to fluctuations in explicit visual perception. Human observers reported the presence or absence of a brief visual stimulus while we recorded microsaccades, small spontaneous eye movements. Microsaccades were reflexively inhibited if and only if the observer reported seeing the stimulus, even when none was present. Moreover, perceptual sensitivity and the oculomotor reflex were both susceptible to orientation-specific adaptation, a signature of cortical processing. The oculomotor reflex therefore tracked perceptual visibility even when the stimulus was physically unchanged. By applying a novel Bayesian classification technique to patterns of microsaccades on individual trials, we were able to decode the state of perception more accurately than the state of the stimulus. We conclude that unified detection mechanisms link perception and oculomotor control: an elemental ‘subjective’ internal event—becoming aware of a change in the environment—is immediately and inadvertently revealed by motor inhibition. By demonstrating an objective measure of conscious detection that does not require explicit reports, this finding opens doors to clinical applications and further investigations of perceptual awareness.
Microsaccades and high-acuity vision

Michele Rucci, J. Intoy, and Martina Poletti
Boston University

Microsaccades are miniature replicas of the saccadic gaze shifts normally used to look at different objects in the scene. Unlike their larger counterparts, microsaccades maintain the stimulus within the foveola, the retinal region with highest visual acuity, raising the question of why observers make them. One of the long-standing proposals on the visual functions of microsaccades is that they enable exploration of small regions in the scene in the same way saccades are normally used to scan larger regions. Recent results based on improved methods for localizing the center of gaze have provided strong support to this proposal. They have shown that when humans are not requested to maintain prolonged fixation on a point—a common, yet unnatural, condition in vision research experiments—they use microsaccades to precisely center gaze on nearby details of interest. These small gaze shifts are critical in high-acuity tasks and occur because of an eccentricity-dependent decline in visual functions even within the foveola itself. Here we will review this body of results and quantify the different costs of making and not making microsaccades.
Contributed Session: Clinical
Psychophysical measurement of marmoset acuity and myopia

Shanna Coop, Samuel U. Nummela, Shaun Cloherty, Chantal Boisvert, Mathias Leblanc, Jude F. Mitchell

The common marmoset has attracted increasing interest as a model for visual neuroscience. A measurement of fundamental importance to ensure the validity of visual studies is spatial acuity. The marmoset has excellent acuity that has been reported at the fovea to be nearly half that of the human (Ordy and Samorajski, 1968), a value that is consistent with them having similar photoreceptor densities combined with their smaller eye size (Troilo et al, 1993). Of interest, the marmoset exhibits a higher proportion of cones than rods in peripheral vision than human or macaque, which in principle could endow them with better peripheral acuity depending on how those signals are pooled in subsequent processing. Here we introduce a simple behavioral paradigm to measure acuity and then test how acuity in the marmoset scales with eccentricity. We trained subjects to fixate a central point and detect a peripheral Gabor by making a saccade to its location. First, we found that accurate assessment of acuity required correction for myopia in all subjects. This is an important point because marmosets raised in laboratory conditions often have mild to severe myopia (Graham and Judge, 1999), a finding that we confirm, and that would limit their utility for studies of vision if uncorrected. With corrected vision, we found that their acuity scales with eccentricity similar to that of humans and macaques, having roughly half the value of the human and with no clear departure for higher acuity in the periphery.


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Fixational eye movements in a visual acuity task

Nancy J. Coletta, Lenna E. Walker, Fuensanta A. Vera-Diaz
New England College of Optometry

Introduction: Corrected myopes exhibit larger visual acuity loss at low luminance (1, 2) and less precise fixational eye movements (3) than emmetropes. We examined the relationship between fixation stability and acuity at two light levels.

Methods: Subjects (31 young adults; dominant eye refraction +2.25 to -10.88 D) were corrected with contact lenses if needed. Mesopic (0.276 cd/m2) and photopic (325 cd/m2) acuity was measured while eye movements were recorded (EyeLink 1000). Fixations were analyzed for letter sizes corresponding to mesopic and photopic acuity limits. Fixation stability is reported as the bivariate contour ellipse area (BCEA), defined as the area of fixation for 68% of the time (4), during acuity reading.

Results: Mesopic acuity was worse for higher myopia (p=0.03) and BCEA were larger for myopes at both light levels (mesopic, p<0.01; photopic, p<0.01). Subjects with smaller photopic BCEA had higher mesopic acuity (p=0.01) and smaller loss of acuity in dim light (p=0.02) relative to their photopic acuity.

Conclusions: Fixation instability in myopia may be associated with difficulty in visual tasks under challenging conditions, such as low luminance.


This work was supported by NEI T35 training grant EY007149.
Impaired fixation stability in amblyopia cannot be explained by the visual acuity impairment

Rajkumar Nallour Raveendran, William R Bobier OD PhD, Benjamin Thompson PhD

Amblyopia is associated with reduced fixation stability of the amblyopic eye and poorer visual acuity (VA) which is correlated with poorer fixation stability. We investigated whether impaired VA can cause reduced fixation stability. Fixational eye movements were measured in 5 controls and 8 patients with amblyopia (2 strabismics & 6 anisometropes) while fixating a suprathreshold cross (1.2° visual angle at 40cm, 10 x 15 sec blocks per condition). Monocular VA of controls was varied from 20/20 to 20/100 using plus lenses. The amblyopia group completed three monocular conditions: a) amblyopic eye fixating, b) fellow eye fixating and c) fellow eye fixating with VA matched to the amblyopic eye using plus lenses. Fixation stability (quantified using bivariate contour ellipse area) was unaffected by reduced VA in the control group. Amblyopic eyes had significantly poorer fixation stability than fellow eyes as noted in previous studies (1,2). However, such differences did not vary even when VA was matched between the two eyes. Therefore, impaired fixation stability in amblyopic eyes is not simply a result of poor visual acuity.


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Can training in the subacute post-stroke period generate greater visual recovery after V1 damage?

Elizabeth L. Saionz, Bogachan Sahin, Zoe Williams, Krystel R. Huxlin

Stroke damage to V1 in adult humans causes cortical blindness (CB). Visual training in chronic (>6 months) stroke patients decreases the deficit but recovered vision is subnormal (1,2). In motor stroke, earlier rehabilitation leads to greater recovery (3). Here, we asked if visual training initiated soon after stroke leads to better improvement in CB. Subacute (<3 months) stroke patients were trained to discriminate global direction of random dot stimuli. Initially, blind field performance was at chance. After daily home training for 3 months, CBs attained intact-level motion integration thresholds at all trained blind field locations. Unlike chronic CBs, subacute CBs exhibited transfer of recovery to untrained locations up to 10 deg deeper into the blind field. CBs who began training <2 months post-stroke also demonstrated improved performance on an untrained fine direction discrimination task. Thus, training initiated in subacute CB generates faster, more generalized visual improvements than in chronic CB.


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Training-induced recovery of fMRI-based motion adaptation signals in V1 damaged humans

M. Melnick, E. Merriam, D. Heeger and K.R. Huxlin

Visual perceptual training recovers coarse global motion discrimination in the blind field of cortically blind (CB) subjects (1,2), though brain areas and mechanisms supporting this recovery remain unclear. In 9 stroke patients with >3 months of visual training, we measured global-motion-evoked fMRI BOLD signals at: 1) trained blind field, 2) untrained blind field, and 3) intact field locations. During MRI, subjects were adapted to global motion and tested in the adapted direction and 180° opposite. Stimuli presented in the intact field elicited strong adaptation in low level visual areas and hMT+. Stimuli presented at untrained blind field locations elicited no significant signal in any visual areas. Stimuli presented at trained blind field locations generated responses in lower level visual cortex and hMT+, with clear but weak adaptation in hMT+. Our data show training to restore direction selectivity in CB subjects, suggesting plasticity of neural circuits that generate adaptation in V1-damaged systems.


Functional mapping of visual cortex in hydrocephaly

Michael A. Crognale, Shuiting Cheng & Lars Strother

Individual variation in cortical morphology is one hurdle for creating functional cortical maps across different populations. This is particularly challenging in populations with gross structural abnormalities as seen in cases of early hydrocephaly. In a testament to brain plasticity, many hydrocephalic patients with timely shunt placements develop normal or near normal function despite large loss and displacement of cortical tissue. We report here functional mapping in visual cortex in a case of hydrocephaly. This case offers particular insight because the gross abnormalities and tissue loss in the early visual areas is largely limited to one hemisphere, allowing a within subject comparison of structure and function. Preliminary results indicate strongly anomalous retinotopic mapping in the affected hemisphere yet little evidence of loss of visual function, suggesting neural compensation for abnormal cortical morphology. More extensive testing of localized visual function is ongoing.

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Contributed Session: Vision
Mapping the spatial extent of perceptive fields for flicker adaptation using retinally stabilized stimuli

Alexandra E. Boehm, Dennis M. Levi, Claudio M. Privitera, Austin Roorda

When an image is stabilized on the retina, it fades from perception due to local adaptation of neurons with receptive fields that are fixed in retinal space. We were interested in mapping the perceptive fields (PF) - the psychophysical equivalent of receptive fields - which delimit the spatial area where fading of flickered stimuli occurs. To do so, we used a tracking scanning laser ophthalmoscope to deliver stabilized stimuli to the retina. Subjects adapted to a small spot stimulus with a Gaussian intensity profile ($\sigma = 0.56$ arcminutes) that flickered at 5 Hz for 2 secs at 10 deg eccentricity. The stimulus faded after approximately 1 sec. The last onset of the stimulus was a probe flash that was spatially offset by 0-6 arcminutes in one of four cardinal directions. Subjects indicated whether the probe was visible using a 0-3 confidence rating scale. The PFs were approximately 10 arcminutes in diameter, asymmetric relative to the adapting point and vertically anisotropic. Outside of the PFs detectability increased rapidly, indicating that there are sharp borders between the PFs of stabilized flickering stimuli.


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Retinal lateral inhibition revisited

Jihyun Kim and Marcelo Bertalmío

Retinal lateral inhibition has long been known as the ‘contrast encoder’ and the relationship among retinal processing, lateral inhibition, and contrast perception has been discussed in the conventional scheme of difference-of-Gaussian (DoG). However, many studies argued that the classic DoG RF failed to explain contrast perception phenomena involving large spatial scale surface interaction (~1 deg). On the other hand, we recently showed that one of the neglected retinal features, wide-RF of retinal interneurons, explains how the visual system performs long-range interaction (Kim & Bertalmio, 2015). The long-range effect was previously explained by the multiscale DoG model (Blakeslee & McCourt, 1997) that proposes a varying spatial-frequency-bandwidth-channel processing. Here we show that the the retinal hierarchical center-surround processing architecture combined with interneurons of narrow and wide RFs accomplishes multi-channel-like results. We propose an update to the conventional view on lateral inhibition.

Kim, J. & Bertalmío, M. (2015, May). Brightness assimilation predicted already at retinal level due to the effect of wide receptive-fields of inhibitory feedback cells. The Fall Meeting of the Optical Society of America Vision, San Jose, CA, USA.


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Human visual cortex responds to isolated melanopsin-directed stimulation

Manuel Spitschan, Andrew S. Bock, Giulia Frazzetta, David H. Brainard, Geoffrey K. Aguirre

Melanopsin is expressed in a subset of retinal ganglion cells and mediates non-image-forming responses to light. It is unknown whether melanopsin contributes to conscious vision. We obtained fMRI data from four subjects who viewed spectral pulses that selectively targeted either melanopsin or the cones (3 sec, cosine windowed, 5 contrasts between 25% to 400%; separate backgrounds used for melanopsin and cone-directed stimuli to maximize available contrast; melanopsin background: 110 cd/m2, 3.39 log10 scotopic Trolands). The melanopsin and cone-directed stimuli evoke distinct pupil light responses. Melanopsin-directed stimulation produces fMRI responses in the visual cortex larger than can be easily explained by imperfections in cone silencing. Both melanopsin and cone-directed stimuli produce monotonic contrast-response functions. We find evidence that melanopsin-directed stimulation produces a more temporally extended fMRI response, consistent with known properties of the melanopsin-containing RGCs.
The comparison of spatially separated stimuli: judgments of speed

Marina Danilova, J.D. Mollon

We consider a theoretically interesting problem: How are stimuli compared when they fall at different, widely separated, positions in the visual field? Previously we have shown that thresholds for discriminating spatial frequency are similar whether targets are juxtaposed or are separated by up to 10 deg (eccentricity being held constant) - and even if the targets fall in opposite hemifields [1,2].

In the present experiments, we measured thresholds for comparing speed in two patches of moving dots. The patches lay on an imaginary circle of 5 deg radius centered on fixation, and presentations were too brief to allow eye movements. The separation between the centers of the patches varied from 2 to 10 deg.

At slow speeds, observers had lowest thresholds when the moving arrays were juxtaposed; but at medium speeds (6-8 deg/s) there was rather little variation in threshold with separation. It is implausible that the comparison depends on dedicated 'comparator neurons', i.e. higher-order cells that would draw inputs from pairs of lower-order cells that signal speed in local retinal regions; and we postulate instead a 'cerebral bus' that carries abstract representations of separated stimuli [1,2].


Decoding from populations of MT neurons during motion-discrimination

Jacob L. Yates, Jonathan W. Pillow, Alexander C. Huk

Motion discrimination is a classic model system for probing computations and circuits underlying perceptual decisions. Despite a long history of studying the sensitivity of single neurons, little is known about how direction can be read out from the activity of neural populations. We recorded from ensembles of MT neurons while monkeys performed a motion-discrimination task. We compared the performance of a simple, neurally plausible, decoder to the psychophysical performance and to the sensitivity of single neurons. We found that the population was more accurate than the best single neurons and performed at least as well as the monkey at our task. We also found that the joint response patterns of neurons was not needed to compute the optimal weight pattern. MT populations were most sensitive to the stimulus immediately following motion onset, which corresponded to psychophysical weights of the monkeys. These results provide empirical groundwork for extending single neuron studies of perception to the population level.
Working memory load is reflected in the frequency of microsaccades

Mario Dalmaso, Luigi Castelli, Pietro Scatturin, Giovanni Galfano

Microsaccades are tiny eye movements that individuals perform unconsciously during fixation. Despite the nature and the purpose of microsaccades are still lively debated, recent evidence showed an association between these micro eye movements and higher-order cognitive processes. In two experiments, here we specifically focused on working memory and addressed whether differential memory load could be reflected in a modulation of microsaccade dynamics. In Experiment 1, participants memorized a numerical sequence composed of either two (low-load condition) or five digits (high-load condition), appearing at fixation. The results showed a reduction in the microsaccadic rate in the high-load compared to the low-load condition. In Experiment 2, the numerical sequence was composed of five digits colored all in red or in green. Participants either memorized the five digits (high load) or the color (low load) of the numerical sequence. Hence, visual stimuli were exactly the same in both conditions. Consistent with Experiment 1, microsaccadic rate was lower in the high-load than in the low-load condition. Overall, these findings reveal the presence of a link between working memory and microsaccades.
John Krauskopf Session I
Color percepts elicited by stimulation of individual targeted cones

Austin Roorda, Ramkumar Sabesan, Brian P. Schmidt, Lawrence C. Sincich, William S. Tuten

To study the circuits underlying color vision near the fovea, we developed a system with adaptive optics and high-speed eye tracking that enables tracking, targeting and stimulation of cones in living eyes. In two subjects with classified mosaics, cones stimulated with 543 nm light against a white background yield expected and unexpected percepts. Stimulated M cones yield either green or achromatic percepts, and the individual responses are pure - largely falling into color or achromatic reporting classes. L cones respond similarly, except the fraction of color-reporting cones yield red percepts. Similar results are found against a blue background, but the M cones convey distinctly blue percepts rather than green. What is unexpected is that the arrangement of the color and achromatic reporting cones are distributed in a way that is inconsistent with simple chromatically-opponent, center-surround midget ganglion cells. To understand how lateral interactions influence these percepts, we’re measuring cone sensitivity thresholds against different adapting background conditions. Collectively, these studies shed light on how foveal cone signals are transformed by retinal circuitry.

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Colour vision across the life span: effect of age, ambient illumination and individual differences

Sophie Wuerger, Kaida Xiao, Tushar Chauhan

Colour vision starts in the retina where light is absorbed in three different cone classes, sensitive to long-, medium-, and short-wavelength light. The cone signals then feed into three different post-receptoral channels, a luminance channel and two cone-opponent chromatic -channels (Derrington, Krauskopf & Lennie, 1984). These two cone-opponent chromatic channels do not correspond to perceptually salient colour mechanisms (unipolar red, green, yellow, blue), suggesting that the two sub-cortical chromatic channels are recombined in visual cortex into orderly hue maps consistent with our fMRI experiments.

Our behavioural results show that hue mechanisms are almost invariant with age and ambient illumination. Variability in unique hue settings across observers is only twice as large as within observer variability.

All these results taken together suggest that the human visual system is able to compensate for retinal (peripheral) signal changes by adjusting the relative cone weightings of the cortical colour mechanisms. The mechanism underlying this hue compensation is still poorly understood, but it is likely that it utilises invariant sources in our visual environment.

The paradox of color constancy

Karl R. Gegenfurtner, David Weiss, Marina Bloj

Color constancy denotes the ability of human and animals to assign a particular color percept to an object. The light reaching the eye confounds illumination and spectral reflectance of the object, making the recovery of constant object color an ill-posed problem. How good the visual system is at solving this task is still a matter of debate. Depending on the laboratory task and the specific cues available to observers, color constancy was found to reach levels between 20% and 80%. If color constancy were indeed that poor, we would experience frequent color changes of objects in everyday life. This does not seem to be the case. Instead, we take it for granted that objects "have" a color, and we do use color terms to describe objects, e.g. a green scarf.

We propose that the reason for this paradoxical situation is the use of laboratory tasks that systematically underestimate the degree of color constancy. We show that constancy is near perfect when using real objects in a natural task and illumination conditions. Our laboratory task was chosen to replicate the role of color constancy in everyday life. Participants were asked to bring a personal object that had for them a well-defined color that they were confident they could identify. Without the object being present, participants selected the Munsell chip that best represented the color of "their" object. They performed the task first in a room under neutral daylight illumination and in four other rooms that had non-daylight illuminations provided by windows covered with colored filters. In all situations they mostly selected the same colored chip as their match to the absent object, even though the light reaching the eye in each case differed considerably. Our results demonstrate that color constancy under real world conditions is exceptionally good and that previously measured insufficiencies can mainly be attributed to reduced laboratory settings and tasks.
John Krauskopf Session II
Optical recording of the light response from ganglion cells in the living mammalian eye

David R. Williams, Lu Yin, Juliette E. McGregor, Soon K. Cheong, Jie Zhang, Qiang Yang, and William H. Merigan, Center for Visual Science, University of Rochester

Our understanding of retinal physiology has come mainly from microelectrode recordings of retinal cells in a dish. However, even the most densely packed microelectrode arrays have limited spatial resolution and require the tissue to be maintained in an artificial environment. High-resolution in vivo optical recording can overcome both these limitations. By imaging many cells simultaneously, sparse cell types that are rarely encountered with a microelectrode can be studied. Moreover, an optical approach deployed in the living animal can track retinal changes over extended time periods, an advantage for studying the progression and treatment of retinal disease. We have developed a fluorescence adaptive optics scanning light ophthalmoscope to record visually driven neuronal activity in mouse and monkey retinal neurons that express a genetically encoded calcium indicator. In the primate, GCaMP6 expression in the foveal ring enables us to record from ganglion cells driven by the most central foveal cones; a region previously challenging to characterize using conventional electrophysiological methods. We are now able to present fine grained stimuli with a precision approaching the width of a foveal cone. This has allowed us to map on-center and off-center receptive fields of up to 150 ganglion cells simultaneously as well as to repeat imaging sessions in the same animal for as long as 12 months. Optical recording of single cells in intact animals has the potential to provide new information about the function of specialized retinal circuits and accelerate the development of methods to restore vision in retinal degeneration.
Genesis of pattern and contour selectivity by intra-cortical circuits: functional implications of the pinwheel mosaic

Qasim Zaidi, Erin Koch, Jianzhing Jin, Jose-Manuel Alonso

We distinguish shapes by contours, and surfaces by patterns and textures of multiple orientations and scales, despite retinal response compression leading to cross-orientation suppression. In striate cortex of primates and carnivores, orientation preference is arranged as iso-orientation domains that radiate circularly from pinwheel centers. Using tangential penetrations with multi-electrode arrays, we found that orientation tuning is narrower, and contrast saturation and cross-orientation suppression stronger, within iso-orientation domains than at pinwheel centers. These differences develop due to excitation (not normalization) from neighboring oriented neurons. As a result of these local intra-cortical computations, narrower tuning, greater cross-orientation suppression and higher contrast gain of iso-orientation cells, lead to extraction of object contours from images; whereas broader tuning, greater linearity and less suppression of pinwheel cells, generate selectivity for surface patterns and textures.

Supported by NIH grants EY05253, EY07556, EY13312.
Measuring color appearance and the structure of color space

Laurence T Maloney, New York University

Researchers studying visual perception have developed numerous experimental methods for probing the perceptual system. The range of techniques available to study performance near visual threshold is impressive and rapidly growing and we have a good understanding of what physical differences in visual stimuli are perceptually discriminable. A key remaining challenge for visual science is to develop models and psychophysical methods that allow us to evaluate how the visual system estimates visual appearance.

In this presentation, I'll describe methods for modeling judgments of visual appearance that go beyond simple rating methods and describe how to model them and evaluate the resulting models experimentally. In particular, I will present joint work with Sophie Wuerger and John Krauskopf developing and using a method to measure angles in color space given judgments of color proximity.

**Posters**

**P1: Antoine Barbot**  
Neural compensation mechanisms following long-term adaptation to severe optical defects

**P2: Vincent Billock**  
Softwired cortical color opponency via winner-take-all competition among spiking neurons

**P3: Kamran Binaee**  
The contribution of visual pursuit to prediction in a naturalistic interception task

**P4: Matthew Cavanaugh**  
Attentional cues potentiate full recovery of fine motion discrimination in cortical blindness

**P5: Dennis Dacey**  
Confirmation of an S-OFF midget ganglion cell pathway using serial block-face scanning electron microscopy

**P6: Abhishek De**  
Detection thresholds for lime-magenta and orange-cyan differ in eccentricity- and spatial frequency- dependence

**P7: Tanner DeLawyer**  
A model for explaining variations in red/green balance

**P8: Robert Dowd**  
Binocular function is altered by long-term exposure To interocular optical disparities in normally developed visual systems

**P9: Sergio Etchebehere**  
Psychophysical study of visual saliency of different hues

**P10: Gustavo Gandara-Montano**  
Femtosecond-laser written gradient-index Fresnel lenses for vision correction

**P11: Kunihiro Hatakeyama**  
Effects of nonlinearity of color matching functions in short wavelength region on metamerism
P12: Andrew Herbert
Augmented reality HUDS: warning signs and driver situation awareness

P13: Ichiro Kuriki
Unified histogram for the population of hue-selective voxels in human visual cortex

P14: Serge Meimon
Wide field 200Hz videos of human retinas with PARIS's AO-FIO

P15: Jeff Mulligan
Identification of fixations in noisy eye movement data via recursive subdivision

P16: Shahram Peyvandi
Does spatially homogeneous color stimulation produce a single response point within the physiological cone excitation space?

P17: Michael Rudd
Individual differences in lightness judgments explained by variable spatial extents of contextual influence

P18: Roberto Francisco Sanchez
In vivo transmission assessment of the human eye

P19: Colleen Schneider
Do areas of retinal ganglion cell degeneration coincide with areas of decreased representation in V1 following stroke?

P20: Christina Schwarz
Selective photoreceptor changes after ultrashort pulse laser exposure in the infrared

P21: Kazutoshi Takahashi
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Neural compensation mechanisms following long-term adaptation to severe optical defects

Antoine Barbot[1,2], Krystel R Huxlin[1,2,3], Duje Tadin[1,2,3] and Geunyoung Yoon[1,2]

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[3] Brain and Cognitive Sciences, University of Rochester

Prolonged exposure to poor optical quality gradually alters neural processing, limiting the visual benefits of advanced optical corrections. Here, we studied the underlying mechanisms of long-term neural adaptation to poor optics in keratoconus (KC), a progressive and severe corneal disease affecting normally-developed adults. We characterized contrast processing in both KC (N=5) and normal (N=5) subjects while bypassing optical factors using an adaptive optics (AO) system. Under AO correction, KC subjects showed abnormal contrast sensitivity, with impaired sensitivity at high spatial frequencies (SF) and enhanced sensitivity at low SFs. Using the Perceptual Template Model and an external noise task, we found that impaired sensitivity to high-SF was associated with reduced weighting of high-SF channels, while improved sensitivity to low-SF information was due to reduced internal noise. The more severe the optical defects, the more pronounced these effects. Our results uncover important plasticity mechanisms underlying long-term neural adaptation to severe optical defects and further our understanding of how optical and neural factors shape our visual experience.

Supported by NIH EY014999.
Softwired cortical color opponency via winner-take-all competition among spiking neurons

Vincent A. Billock, College of Optometry, Ohio State University, Columbus, OH

Motivated by perception of reddish green and bluish yellow in retinally stabilized equiluminant images, Billock et al. (2001) created a softwired disruptable winner-take-all (WTA) model of cortical color opponency. This toy model was grounded in population dynamics and had variables representing neural response strength. A more realistic neural model is desirable. Wilson’s model of spiking cortical neurons was employed and the simulated cortical neurons were coupled using inhibitory synapses and were driven by wavelength-selective geniculate cell spike rates from DeValois et al. Two candidate spiking WTA networks had different dynamic characteristics - each has potential applications to neural modeling. The WTA networks produce r-g and y-b opponent spike rates, which are converted into perceptual responses using Naka-Rushton-like functions derived from DeValois et al. and behavioral data. The resultant sensitivity-based opponent responses resemble Werner & Wooten’s opponent average observer data.

Billock, Gleason & Tsou (2001) JOSA A 18, 2389-2403.

Supported by NSF #1456650.
The contribution of visual pursuit to prediction in a naturalistic interception task

Kamran Binaee and Gabriel J. Diaz

Emerging evidence suggests that pursuit of a target moving in 2D facilitates judgments related to its future trajectory [1], and improves performance when pointing to intercept [2]. However, it is unclear if pursuit aids prediction when the target also moves in depth, as in the real world. To investigate, we recorded the gaze and motor behavior of subjects tasked with catching virtual balls seen through a head mounted display. The virtual ball was "blanked" for 500 ms of its flight. Between-trial manipulation of the pre-blank duration was intended to test the contribution of early visual information to prediction across the blank (600, 800, or 1000 ms). Between trial manipulation of the post-blank duration was used to indirectly affect the angular velocity of the ball at reappearance; at shorter post-blank durations, the ball will appear closer to the subject, moving more quickly through angular space (300, 400, or 500ms). Initial analysis yields some evidence of benefits from pursuit to catching error.


Attentional cues potentiate full recovery of fine motion discrimination in cortical blindness

Matthew Cavanaugh, Antoine Barbot, Marisa Carrasco and Krystel R. Huxlin

Visual perceptual training in cortically blind (CB) fields recovers performance on the trained tasks. However, regardless of training type, contrast sensitivity and fine discrimination thresholds remain abnormal in CB fields. Here, we asked whether training on fine direction discrimination (FDD) with endogenous, feature-based attention (FBA) cues can recover normal FDD thresholds in CB fields. Seven CB subjects previously trained on coarse direction discrimination were newly trained on FDD with valid FBA cues. Following such training, FDD thresholds reached 5±3 deg, not significantly different from thresholds in the intact field of vision (3±1 deg). With neutral cues, FDD thresholds at trained blind field locations averaged 10±0.4 deg, significantly worse than in the intact field of vision (5±1 deg). In sum, we now show that training with FBA cues can recover normal, fine direction discrimination performance in chronic CB subjects. Current work is assessing robustness and generalizability of this phenomenon.
Confirmation of an S-OFF midget ganglion cell pathway using serial block-face scanning electron microscopy

Dennis M. Dacey¹, Lauren Wool², Orin Packer¹ and Rachel Wong¹
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In the primate retina, 'blue cone' bipolar cells make invaginating synaptic contacts exclusively with short (S) wavelength sensitive cones¹. This pathway is the origin of excitatory S-ON input to the blue-yellow opponent small bistratified ganglion cell type². An S-OFF pathway has been characterized in the lateral geniculate nucleus (LGN)³ but its retinal origin has remained contentious⁴,⁵. The question was apparently answered when serial EM reconstruction in macaque retina found that S cones made basal contacts with OFF-midget bipolars, establishing an S-OFF midget pathway⁶. However, a later study failed to confirm this connection in marmoset⁷, and recent LGN recordings suggested that S-OFF signals do not originate from midget pathway cells⁸.

Here we use serial block-face scanning electron microscopy to reconstruct S-cone connectivity in a patch of macaque foveal retina. We identified 17 S cones in a patch of 169 cone pedicles. S cones were identified by a lack of telodendritic contacts with neighboring cones and confirmed by showing that all ON bipolar contacts arise from distinct 'blue-cone' bipolar cells. All S cone pedicles were also densely contacted by OFF bipolar cells. The great majority of these OFF contacts arose from midget bipolar cells. We found each S cone presynaptic to a single OFF-midget bipolar, which in turn was presynaptic to an OFF midget ganglion cell, unequivocally establishing an OFF-midget circuit for each S cone.

We conclude that the S-OFF midget pathway is the origin of S-OFF signals observed at higher synaptic levels⁹ and utilized in the detection of S cone decrements¹⁰.


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References:
Detection thresholds for lime-magenta and orange-cyan differ in eccentricity- and spatial frequency- dependence

Abhishek De and Gregory D. Horwitz

Isoluminant, in-phase modulation of S- and M- cone signals appear orange-cyan whereas isoluminant, in-phase modulation of S- and L- cone signals appear lime-magenta. The neural pathways that detect these modulations are not understood. To investigate the spatial selectivity of these pathways, we used a two-interval 2-AFC detection task. The stimulus was a static Gabor pattern that modulated either along the lime-magenta axis or along the orange-cyan axis at 0.5 cycles/deg or 3.0 cycles/deg. Thresholds at the fovea were lowest for the low spatial frequency lime-magenta stimulus. Thresholds at 5 deg were lowest for the high spatial frequency orange-cyan stimulus. This dependence of behavioral sensitivity on eccentricity and spatial frequency indicates that orange-cyan modulations are detected by neurons with smaller receptive fields than lime-magenta modulations. These results reconcile seemingly contradictory findings regarding the relative magnitude of BOLD responses to these modulations in the visual cortex.

Funded by NIH EY018849.
A model for explaining variations in red/green balance

Tanner DeLawyer, Joris Vincent, Steven L. Buck

Psychophysical data from our lab has shown that an individual’s Red/Green balance (R/Gbal) for long-wavelength targets varies with light level and achromatic surround configuration. New data suggest these balances are relatively unaffected by achromatic surround complexity, but are greatly influenced by total surround flux and reveal changes in postreceptoral weighting of M and L cone signals. A model, R/Gbal = a*(SFlux/TLum)+e, can account for these variations; an individual’s R/Gbal for a chromatic target is predicted by the total flux of the surround (SFlux) divided by the luminance of the target (TLum) multiplied by a weighting function (a) with the addition of an error constant (e). This formula predicts that increasing SFlux will shift an individual’s R/Gbal in a direction consistent with an increased post-receptoral weighting of M cone signals relative to L cone signals. Conversely increasing TLum will shift an individual’s R/Gbal in the opposite direction.
Binocular function is altered by long-term exposure to interocular optical disparities in normally developed visual systems

Robert Dowd, Antoine Barbot, Krystel Huxlin, Duje Tadin, Geunyoung Yoon

Interocular disparities in optical quality create abnormal ocular states that impair binocular vision. Keratoconus (KC)-a progressive corneal disease that arises after normal visual development-results in severe differences in interocular optical quality. Here, we evaluated the ensuing changes in binocular function associated with long-term neural adaptation to such abnormal optical conditions. An adaptive optics (AO) system was used to correct ocular aberrations while measuring neural contrast sensitivity in 5 control and 5 KC subjects. AO correction enables direct assessment of neural function. KC subjects exhibited a large impairment in neural binocular summation, and subjects with severe interocular optical disparity showed binocular inhibition at mid to high spatial frequencies. Our results provide valuable information about the impact of long-term exposure to abnormal optics and interocular disparities on visual processing. This is crucial for improving the way ocular abnormalities like KC are treated.
Psychophysical study of visual saliency of different hues

Sergio Etchebehere and Elena Fedorovskaya

Visual attention refers to the cognitive mechanism that allows us to select and process only the relevant information arriving at our eyes. Visual saliency models, trying to simulate visual attention and corresponding gaze patterns, have been continuously developed over the last years. (Borji & Itti, 2013). Color information was shown to play an important role in visual attention, and is used in visual saliency computations. Vazquez, et al. (2010) have demonstrated that color features can have a higher contribution to visual attention than intensity features by using gray stimuli composed of random distribution of pixels, where the central region of a stimulus had the same mean, but a different standard deviation varied along several directions in CIELAB. These findings point toward re-assessing the role of color in visual attention, and, consequently, a modified way of using color information in visual saliency models. In our experiment observers were asked to view stimuli on a calibrated monitor and report a number of detected color patches presented at random locations on a masking gray background of the same lightness. The patches were produced as random distribution of pixels with target means and standard deviations for hue angles, lightness and chroma. The hue angles were constant within each stimulus. Observers’ eye movements were recorded via an SMI remote eye tracker and used for the analysis in conjunction with the reported data. The red patches (hue angles 10° and 30°) had significantly lower reported chroma values compared to green patches (130° and 150°), while being significantly less frequently fixated than the green patches. A similar discrepancy existed for blue (250° - 270°) and yellow hues (90°): the threshold reported chroma values were lower for blue than for yellow hues, while significantly more fixations occurred on yellow patches. The results can be interpreted in support of a dissociation between attention and consciousness as proposed by Koch and Tsuchiya (2007).


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Femtosecond-laser written gradient-index Fresnel lenses for vision correction

Gustavo A. Gandara-Montano, Len Zheleznyak, Geunyoung Yoon, and Wayne H. Knox

Our group reported the creation of gradient-index (GRIN) microlenses (150 um diameter) in hydrogels through the use of femtosecond laser induced refractive index change (LIRIC) (1). In this study, we report the optical quality of large area stitched Fresnel lenses (6mm diameter, 543nm design wavelength). Five spherical lenses (Range: -3.0 to +1.5 D) and one cylindrical lens (-1.5 D) were created. Each lens was produced in a single layer within a plano hydrogel using a 400nm frequency doubled Ti:sapphire laser and a galvo-scanning system (field of view: 245x88 um). The resulting change in wavefront aberrations was assessed with a Shack-Hartmann wavefront sensor (5.8mm pupil, 543nm wavelength). The measured writing error was 0.11 ± 0.07 D of the desired target (defocus or astigmatism). Induced HORMS was 0.14 ± 0.03 um. Future work includes visual performance testing. This work shows the potential of femtosecond writing for the creation of accurate phase structures exhibiting high visual quality with LIRIC.


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Effects of nonlinearity of color matching functions in short wavelength region on metamerism

Kunihiro Hatakeyama, Tsubasa Kamei, Yuki Kawashima, Takehiro Nagai and Yasuki Yamauchi

Colorimetric match between different color reproduction medias does not ensure visual match. One of the reasons that mediate this discrepancy is the variation in color matching functions (CMFs). We have measured CMFs of observers in color matching experiments. Previously, we conducted metameric matching experiment to evaluate the CMFs (Hatakeyama et al., 2016). In the results, the validity of the CMFs for the colors of the long and meddle wavelength region was confirmed, while some residual color differences were observed for the colors of the short wavelength region. Although nonlinearity in the region has been reported to depend on the saturation conditions when measuring the CMFs, it has not yet confirmed whether it affects on metamerism. We repeated the color matching experiment with less saturated stimuli, and examined the effects of saturation. The results showed that the residual color differences were also observed, suggesting that the nonlinearity of CMFs does not simply depend only on saturation.

Augmented reality HUDS: warning signs and driver situation awareness

Andrew M. Herbert
Joseph Baschnagel
Martin E. Gordon
Zachary McDonald

Subjects were eye-tracked while watching videos of real driving scenes with or without a HUD. In Condition 1 subjects reported what elements in the video attracted their attention in real time (Charlton, 2006). This was followed by a sign recognition test. In Condition 2 subjects engaged in casual conversation while watching another driving video. Warning signs were more conspicuous in low and high clutter driving environments with a HUD. The HUD did not lead to increased fixation duration or frequency for warning signs except when two driving relevant targets were in view (a sign and oncoming car). While the HUD highlighted a warning sign there were fewer fixations on the car compared to the non-HUD situation. Condition 1 showed augmented reality (AR) HUDs can make warning signs more salient to drivers. When there were multiple driving relevant stimuli in high clutter environments, AR HUDs may induce attentional tunneling.


Supported by the Department of Psychology, RIT and the College of Liberal Arts, RIT
Unified histogram for the population of hue-selective voxels in human visual cortex

Ichiro Kuriki, Pei Sun, Kenichi Ueno, Kang Cheng

We have reported the population histograms of the hue selective voxels in human visual cortex, measured using functional magnetic resonance imaging (fMRI) [1]. Each histogram was obtained by investigating blood-oxygenation level dependent (BOLD) signal time course during continuous changes in stimulus hue under isoluminance, and the most selective hue of each voxel was estimated [1]. Unexpectedly, red-green selective voxels scarcely appear together with blue-yellow selective voxels in a histogram when various radius ratios (RR) between the two opponent color axes for the elliptic hue locus were tested. In an attempt of unifying the histograms, differences in hue sampling density was compensated before averaging across all RR conditions. The combined histogram exhibited relatively uniform distributions, and it lends support to our hypothesis that the population of hue-selective neurons is likely more isotropic and anisotropy [1] may be a small fluctuation atop a uniform distribution.


This study was supported by JSPS KAKENHI Grant numbers JP20300114 and JP25242079 to KC and JP24330205 and JP15H03460 to IK.
Wide field 200Hz videos of human retinas with PARIS's AO-FIO


PARIS (Paris Adaptive-optics Retinal Imaging & Surgery) group gathers physicians and physicists around an experimental adaptive optics (AO) platform, located inside Quinze-Vingt Ophtalmology hospital, with a direct access to patients. The AO platform consists in a custom made AO flood illumination ophthalmoscope, featuring a fast AO loop (faster than 60Hz), an 97 actuator deformable mirror (ALPAO) and a high speed SCMOS camera (Hammamatsu Orca Flash4-V2). It provides retinal video stacks acquired up to 200Hz on 2° field of view with an 860nm SLD source (OMICRON).

We present videos of healthy subjects without dilation or cycloplegia revealing capillary blood flow at the surface of the lamina cribrosa. This high performance AO-platform will soon host innovative imaging instruments and is open to collaborative projects.


Identification of fixations in noisy eye movement data via recursive subdivision

Jeffrey B. Mulligan, Donald J. Kalar

Human eye movements typically consist of a series of fixations (during which the eye is relatively still), linked by saccades, which rapidly reorient the direction of gaze to a new location. The locations fixated usually indicate the allocation of attention, and are useful when making inferences concerning state awareness in complex information environments, such as an aircraft cockpit. Identification of fixation events is straightforward when measurement noise is low (on the order of the physiological noise, typically a few arc minutes), but becomes increasingly challenging as noise increases to the levels encountered in current video-based remote tracking systems, which are suitable for installation in flight simulators. Here we present a novel method for identification of fixations in noisy eye position records. The method attempts to fit the signal with a piece-wise constant function, using an iterative method which recursively splits the data into two sub-intervals to produce the least RMS error in the fit. Proposed splits are accepted or rejected on the basis of a statistical t-test, with the level of significance providing a single parameter controlling the sensitivity. We compare the method to other position-based techniques, such as the classic “dispersion” method (which grows fixations rather than splitting as in our method), and a novel “breakout” method developed for the analysis of server log statistics.

Supported by the Technologies for Airplane State Awareness (TASA) project of NASA’s Airspace Operations and Safety Program (AOSP).
Does spatially homogeneous color stimulation produce a single response point within the physiological cone excitation space?

Shahram Peyvandi, Alan Gilchrist
Department of Psychology, Rutgers, The State University of New Jersey

The Poisson fluctuation in absorbed photons occurring when a photoreceptor is exposed to monochromatic light (Geisler, 1989) does not give us, for an array of identical receptors exposed to uniform multi-wavelength light, the proportion of receptors at each specific level of absorbed energy. Here we derived it. The resulting distribution of responses within the CIE 1931 chromaticity space resembles MacAdam’s (1942) magnified scatterings for the variability of color matches. As our approach applies to any array of photosensitive elements, living or non-living, we found that it predicts well the spatial variation of pixel values when a sub-array of a CMOS sensor is exposed to a uniformly illuminated color patch. This implies that variations in reflectivity of individual cones observed in microscopic images of human retina (Roorda & Williams, 1999; Pallikaris, Williams, & Hofer, 2003) used to infer cone absorptance may partly be due to the nature of light as it interacts with identical interleaved receptors.


We greatly acknowledge James Tornes and Manjunath Somayaji from ON Semiconductor for providing us with the imaging module. We acknowledge NSF funding (BCS-1230793).
Individual differences in lightness judgments explained by variable spatial extents of contextual influence

Michael E. Rudd

In simple disk-annulus lightness displays, assimilation can influence the disk lightness over one range of annulus luminances, while contrast influences it over another range of annulus luminances (Rudd, 2010). To account for this pattern, I proposed a computational lightness model involving three neural processing stages: i) encoding of local oriented edge contrast; ii) contrast gain control between neurons responding to nearby edges; and iii) spatial integration of oriented contrast to compute lightness (Rudd, 2014, 2016). Previous experiments demonstrated that a luminance edge can be voluntarily included in this computation—or not—depending on the observer’s interpretation of the edge as a reflectance edge or an illumination edge (Rudd, 2010). Here I present evidence for a second, distinct, type of top-down influence that controls the size of the spatial window over which spatial context influences the disk lightness. To explain quantitative lightness matching data with my model, the first type of top-down influence (edge classification) must occur early (i.e. pre-contrast gain control), while the second type (window size) must occur late (i.e. post-contrast gain control).


In vivo transmission assessment of the human eye

Roberto Sanchez, Anibal de Paul, Luis Issolio

Using the double-pass (DP) technique we estimate the "in vivo" transmission of the human eye. DP images were recorded on an artificial eye for different powers of a laser beam of 780 nm. The intensities of a peripheral area (25 to 35 arc min) were averaged for each image and a linear relationship between the amount of scattered energy around the central area and the laser power was found. Interposing neutral and diffusion filters before the artificial eye we found that the slopes of the lines (PNR) are ordered according to the transmittance of the filters. We obtained similar results changing the reflectance of the artificial retina. From these findings it was possible to obtain a calibration function that determines the transmittance of the eye through the PNR values. In a second measurement, ten eyes of volunteer subjects were assessed, obtaining overall eye transmittance values between 35 and 45%. The transmittance values are lower than those found in the "post mortem" data based literature (around 80%). This could be because those measurements did not include the transmittance of the retina which is relatively low because it is a tissue that absorbs much of the light.
Do areas of retinal ganglion cell degeneration coincide with areas of decreased representation in V1 following stroke?

Colleen Schneider, Emily Prentiss, Ania Busza MD PhD, Zoe Williams MD, Bogachan Sahin MD PhD

Stroke in the territory of the posterior cerebral artery leads to cortical blindness in a hemifield or quadrant of the contralesional visual field. While about 50% of patients experience some degree of visual recovery within the first 6 months post-stroke, only 12.5% experience complete recovery (Tiel K., Kolmel, 1990). One limiting factor that may prevent further visual recovery is trans-synaptic retrograde degeneration of retinal ganglion cells, which has been observed in stroke patients starting as early as 3 months after stroke (Jindahra, Petrie, & Plant, 2009, 2012; Park, Park, Cho, & Park, 2013; Tanito & Ohira, 2013; Yamahachi, Marik, McManus, Denk, & Gilbert, 2009). Retinal ganglion cell thickness is easily measured in the clinic with optical coherence tomography, a technique that generates a 3-D image of the retina from which the thickness of the retinal ganglion cell complex can be measured. The visual cortex is organized in a retinotopic manner that can be measured with fMRI by presenting visual stimuli in various locations in the participant’s visual field and then determining the stimulus location for which each voxel maximally responds (Sereno et al., 1995). Here we test the hypothesis that chronic stroke patients exhibit a homonymous decrease in retinal ganglion cell thickness specifically for visual locations with poor representation in V1. This research has implications for timely rehabilitative treatment because once the retina degenerates, visual recovery in that retinotopic location is impossible. Furthermore, this research may highlight the need for novel treatment strategies that prevent retinal ganglion cell degeneration in order to prolong the window of effective rehabilitation.


Sereno, M. I., Dale, A. M., Reppas, J. B., Kwong, K. K., Belliveau, J. W., Brady, T. J., ...
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Selective photoreceptor changes after ultrashort pulse laser exposure in the infrared

Christina Schwarz, Robin Sharma, Matthew Keller, David R. Williams, and Jennifer J. Hunter

For two-photon excited fluorescence (TPEF) retinal imaging, infrared (IR) ultrashort pulse lasers are used to excite fluorophores such as all-trans-retinol and NADH in the ultraviolet (UV), a spectral range that is usually blocked by the ocular media. Previously, we have shown that in vivo TPEF retinal imaging can test photoreceptor function at light levels below the 2014 ANSI MPE without detectable damage (20.4 J/cm², ~0.26x ANSI). Here, our goal was to investigate which photoreceptor class was most susceptible to ultrashort pulse laser exposures in the IR that were much higher (856 J/cm², ~5x ANSI). Following dark adaptation for 15 min, the photoreceptor layer of two macaques was exposed to a 55 fs, 730 nm pulse laser with an adaptive optics scanning light ophthalmoscope. Reflectance videos and TPEF, prevailing from retinol, were recorded simultaneously and the TPEF time course of rods and cones was tracked separately. After repeated exposures, a subset of cones (11-15%) emitted ~3x less TPEF and appeared atrophied in corresponding reflectance images. These changes persisted for several weeks without noticeable recovery. Structure and TPEF responses of the remaining photoreceptors were largely preserved. No changes could be detected after the same exposures when the likelihood of a two-photon event was decreased by temporally broadening the pulse duration. Retinal exposures with IR ultrashort pulsed light can cause selective photoreceptor damage. The relative quantity, the scattered but regular distribution and the distinct stimulation by the imaging laser suggest that the affected cones are S cones. Interestingly, S cones are the receptor class with the lowest sensitivity in the IR but are known to be particularly susceptible to UV and blue light. This effect of intense IR light is probably not a consequence of photopigment bleaching in the affected cones, but is conceivably a nonlinear effect that has not been considered in the safety standard for ultrashort pulse exposures.


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Effects of luminance levels and chromaticities on perception of continuous color shift

Kazutoshi Takahashi, Yuki Kawashima, Takehiro Nagai and Yasuki Yamauchi

Angular-dependent color shift is one of the features that should be properly evaluated for OLED panels as their performance. In order to develop an index for this evaluation, we have tried to propose a metric to evaluate this color shift in conjunction with the human perception for continuous color shift. We conducted psychophysical experiments to rate the perceived magnitude of continuous chromatic change. The subjects observed a stimulus whose chromaticity was changed according to the orientation of the tablet which they could freely manipulate. This was intended to mimic the performance of an OLED panel. Three luminance levels and eight different trajectories of color shifts were tested. Our results indicate that the sensitivity for the perception of the continuous color shift decreased as the luminance level increased. On the contrary, the sensitivity increased as the color temperature increased.
Local short-term variability of retinal thickness measurements with SD-OCT

R. Tzekov, B. Madow, M. Chikovsky, D. Richards

The purpose of this work was to investigate the short-term reproducibility and variability of total retinal thickness in Heidelberg Spectralis SD-OCT. 18 eyes of 9 healthy volunteers (2M and 7F, age range 19-60 yrs.) were imaged with posterior pole SD-OCT scans on the same day in 3 consecutive sessions (“tests”). Total retinal thickness was evaluated automatically, but checked manually by the instrument software. The average difference between the three comparisons was analyzed.

The average variability of the total retinal thickness was less than 1 micron between any tests. These differences in thickness translated to variations of < 1% of the total retinal thickness. However, locally, the maximal difference between tests was on average 2.4-3.3% for the right eye and 1.8-1.9% for the left eye. These variations were much smaller compared to the variations of the RNFL (7.6-10.6%) or GCL (2.7-18.7%).

The ranking of short-term local variability in the macular region (best to worst) is: total retinal thickness, RNFL, GCL. This needs to be taken into account when planning and designing future clinical studies or for short-term follow-up of patients.
Independence of brown induction and brightness induction

Joris Vincent, Hohjin Im, Steven L. Buck

Both brightness and brownness are induced by high-contrast articulated surrounds, in White’s illusion, a checkerboard variation, and a set of concentric rings. Overall, brightness assimilation and brown assimilation were observed more frequently than contrast, but the frequencies differ across surround stimuli. The frequency of assimilation was similar for brightness and brown induction with rings and checkerboards, but not with White’s illusion. The direction of brightness and brown induction was independent with White’s illusion, but more observers showed congruent direction of induction than expected with rings and checkerboards. When individual observers show congruent direction of effects, brown induction tends to be weaker than brightness induction (regardless of direction). Thus, brightness and brown induction are set apart by the likely direction of effect for different stimuli, the degree of congruence for each stimulus, and the amount of induction for each stimulus.
In vivo imaging of photoreceptor structure and function in a non-human primate model of retinal degeneration

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Here we employ adaptive optics scanning light ophthalmoscopy (AOSLO) to assess cellular-scale changes in photoreceptor structure and function in a non-human primate model of retinal degeneration. The retinas of four macaques were subretinally injected with an adeno-associated viral construct designed to locally damage photoreceptors [1]. Before and after injection, OCT and fundus SLO imaging was performed. Post-injection fundus SLO reflectance images revealed regions of decreased intensity, suggesting retinal damage. OCT of affected regions showed a reduction of intensity in outer retinal layers, primarily in the interdigitation zone. In two retinas, photoreceptors in both affected and unaffected regions were imaged with AOSLO in three modalities (λ=730nm): confocal reflectance, two-photon autofluorescence, and multi-offset detection. Confocal reflectance was used to capture directly backscattered light primarily originating from the inner/outer segment boundary and outer segment tip [2]. Photoreceptors in affected regions exhibited reduced waveguiding, suggesting outer segment damage. In multi-offset detection, the confocal pinhole was displaced to capture multiply scattered light. Images from several aperture positions were combined to visualize inner segments [3], which were present in both affected and unaffected regions. Two-photon autofluorescence was used to excite all-trans-retinol and track its kinetics in response to light, which are indicative of retinoid production necessary for visual function and thus the functional state of the photoreceptors [4]. In affected photoreceptors, there was no detectable increase in autofluorescence at light onset as was observed in unaffected photoreceptors. Therefore, photoreceptor assessment using AOSLO and OCT is consistent with inhibition of retinoid production due to outer segment damage while inner segments are preserved. This model of retinal degeneration shows promise for preclinical testing of vision restoration methods.


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A two-dimensional model simulating the pupil image in eccentric photorefraction

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Eccentric photorefraction and Purkinje image analyses of video can be used to estimate refractive state and eye position simultaneously (Schaeffel, Wilhelm, & Zrenner, 1993). They are used in screening and visual development studies (Choi et al., 2000). They are also helpful in understanding atypical development, but little is known about the effect of a number of variables (e.g. the impact of spectacle power and vertex distance). A two-dimensional model was built in Zemax to simulate eccentric photorefraction using sequential ray tracing. The two sub-models were: a forward version with appropriate light sources to create the retinal image and a backward version to create the camera image using the retinal image as the source (Chen, Tan, & Lewis, 2003). The slope of the luminance distribution across the pupil image was plotted against refractive state (±15D) and trial lens power (±8D) for a number of conditions. As shown previously (Roorda, Campbell, & Bobier, 1997), the results demonstrated slope saturation for significant refractive errors (>+4 & <-6D) and significant effects of pupil size. Refractive correction resulted in slope changes of up to 40% due to image magnification effects.


A novel method to evaluate the closeness of two colors

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In order to reproduce an image on different color reproduction apparatus, it is important to match their color appearance. Most of the color difference metrics are suggested to use when the color differences are relatively small. We would need a new metric, which can well express large color differences. We assume each color has several "corresponding colors", which give the impression or the appearance to be identical or very close. If those colors form a trend-line, it would be possible to evaluate how far a given color is from its trend-line instead of direct comparison. We conducted an experiment to find the trend-lines, and it turned out that the behaviour showed similar trends as the constant hue loci. Then we tried to find the "closest" color on the trend-line with the reference color off trend-line. The selected colors on the trend-line would be applicable to use as an intervening color. Our results indicated that the intervening color is not always the closest point from the reference color.