Program Book

OSA Fall Vision Meeting
Fairmont Hotel
San Jose, California
October 16-18, 2015

OSA

CAMBRIDGE RESEARCH SYSTEMS

UNIVERSITY of ROCHESTER

Fall Vision Meeting
Fairmont Hotel
San Jose
Oct 16-18
2015

Welcome to San Jose! We are pleased to reunite the Fall Vision Meeting with the OSA's principal meeting Frontiers in Optics (FiO) once again, and we hope you will take advantage of the complimentary one-day FiO registration offered to OSA members who register for the Fall Vision Meeting.

Unlike previous years, much of the organization has been done by the OSA staff, particularly **Alexia Marquez** and **Shantelice White**. **Cambridge Research Systems** provided generous financial support (more info on page 4). **Alex Wade** at the University of York once again provided the conference web site. **Sara Peterson** at the University of Rochester handled abstract submission, and the preparation of this booklet. The members of the technical committee (see below) were responsible for organizing the invited sessions and reviewing the contributed abstracts. To all we are deeply grateful, the meeting would not have been possible without the support of each and every one. Finally, we are grateful to all of our colleagues who submitted abstracts to the meeting, and all of the other attendees, without whom there would really be no meeting.

We hope you enjoy the meeting! Please don't hesitate to let us know what worked well, and what, if anything, was not up to par.

Jeff Mulligan, NASA Ames Research Center, chair, local organizing committee
jeffrey.b.mulligan@nasa.gov

Jennifer Hunter, University of Rochester, chair, OSA Vision and Color Division
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OSA Vision and Color Division

Chair: Jennifer Hunter, University of Rochester

Technical Groups

Applications of Visual Science
Chair: Brian Vohnsen, University College Dublin, Ireland
Vice-chair: Stacey Choi, College of Optometry, The Ohio State University, USA

Clinical Vision Sciences
Chair: Rowan Candy, Indiana University, USA
Vice-chair: Krystel Huxlin, University of Rochester, USA

Color
Chair: David Brainard, University of Pennsylvania, USA
Vice-chair: John Mollon, University of Cambridge, UK

Vision
Chair: Jeff Mulligan, NASA Ames Research Center, USA
Vice-chair: Duje Tadin, University of Rochester, USA

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The Fall Vision Meeting thanks CRS for their continued support of the meeting.

Conference Program

Friday, October 16

9:00 AM - 11:00 AM

Session 1 (Invited) – Enhancing Vision with Technology

Moderator: Jeff Mulligan, NASA Ames Research Center

Scott Daly Dolby Laboratories, Inc.	Perceptual Issues in the Design of a High Dynamic Range Ecosystem (Pg. 14)
Gordon Wetzstein Stanford University	Emerging Trends and Applications of Light Field Displays (Pg. 14)
Glenn Schuster UCSD	Wearable Wink-controlled Telescopic Contact Lens with Liquid Crystal Shutter Glasses (Pg. 14)
Steve Ellis NASA Ames Research Center	Visual Stability of Virtual Objects and Virtual Environments During Movement (Pg. 15)

11:00 AM - 11:30 AM

Coffee Break

11:30 AM - 12:15 PM

Session 2 (Contributed) – Vision Potpourri

Moderator: Vicki Volbrecht, Colorado State University

Adam M Dubis Moorfields Eye Hospital and University College London	Multimodal Imaging of the Tapetal-like Reflex in Carriers of RPGR-associated Retinopathy (Pg. 15)
Jonathan He Alcon Laboratories Inc.	Simulating Defocus Curve for Monofocal Intraocular Lenses (IOL) with Different Spherical Aberrations (Pg. 16)
John Erik Vanston University of Reno	Minimally Distinct Border Judgments and Contrast: Effects of Eccentricity (Pg. 17)

12:30 PM - 2:00 PM	**Lunch on Your Own**	
2:00 PM - 4:00 PM	**Session 3 (Contributed) – Eye Movements or Binocularity** Moderators: Mike Crognale, University of Nevada at Reno / Mike Landy, New York University	
	Michael S. Landy New York University	Sub-optimal Integration of Orientation Across Saccades (Pg. 18)
	Bruce Bridgeman University of California Santa Cruz	Scanpaths Can Enhance Saliency Estimation in Photographs (Pg. 19)
	Natela Shanidze Smith-Kettlewell Eye Research Institute	Relative Eye Position During Monocular and Binocular Pursuit in Central Field Loss (Pg. 20)
	Shoji Yamamoto Tokyo Metropolitan College of Industrial Technology	The Difference of Velocity between Eye and Head Movement under Mental Fatigue Condition (Pg. 20)
	Holly E. Gerhard Stanford University	Stereopsis Development in Human Infants: Sensitivity to Relative Versus Absolute and Horizontal Versus Vertical Disparity Using Sweep SSVEPs (Pg. 21)
	Tanner DeLawyer University of Washington	Dichoptic Presentation Separates Brown Induction from Red/Green Balance Change (Pg. 22)
	Jamie K. Opper Colorado State University	Binocular and Monocular Color Perception (Pg. 23)
4:00 PM - 4:30 PM	**Coffee Break**	
4:30 PM - 6:30 PM	**Session 4 (Invited) – Classics of Vision Science** Moderator: Angela Brown, Ohio State University	
	Celeste McCollough Howard	How a New Color Aftereffect Happened To Turn Up at Oberlin, 50 Years Ago (Pg. 24)

	Norma Graham Columbia University	Summation of Sine-waves at Detection Threshold: One Way of Investigating Spatial-Frequency Channels (Pg. 24)
	Colin Blakemore University of London & University of Oxford	Into the Third Dimension (Pg. 24)
	Julie Schnapf UCSF	The Spectral Tuning of Primate Cones: A History (Pg. 25)
7:00 PM - 10:00 PM	**Friday Evening Social (open to all): Mosaic, 211 S. First St.**	

Saturday, October 17

9:00 AM - 11:00 AM	**Session 5 (Invited) – Working Memory for Color** Moderator: David Brainard, University of Pennsylvania	
	Steven K. Shevell University of Chicago	Binocular Color Rivalry Reveals Underlying Process of Working Memory (Pg. 25)
	Maria Olkkonen Durham University	Color Memory and Visual Processing (Pg. 26)
	Wei Ji Ma NYU	Probabilistic Reports of Working Memory for Color (Pg. 27)
	Declan McKeefry University of Bradford	The Retention and Disruption of Colour Information in Human Visual Short Term Memory (Pg. 27)
11:00 AM - 11:10 AM	**Poster Blitz #1**	
	William Grussenmeyer University of Nevada	Tactile Perception of Spatial Distances in Blind Humans (Pg. 28)
	Alex Kale University of Washington	Natural Scenes are a Possible Source of Luminance-dependent Long-term Chromatic Adaptation (Pg. 28)

	David Kane Universitat Pompeu Fabra	The Impact of ‘Crispening’ upon the Perceived Contrast of Textures (Pg. 29)
	Delwin T. Lindsey Ohio State University	The Color Communication Game: Performance vs. Competence (Pg. 30)
	Takuma Morimoto Tokyo Institute of Technology	Luminance-balance Based Estimation of an Illuminant in Chromatically Biased Scenes (Pg. 31)
	Jacek Turski University of Houston-Downtown	The Geometric Horopter and Perception (Pg. 32)
	Joris Vincent University of Washington	Is Brown Induction Just Brightness Induction? (Pg. 32)
11:10 AM - 11:40 AM	**Coffee Service**	
11:15 AM - 12:30 PM	**Poster Session 1**	
12:30 PM - 2:00 PM	**Lunch on Your Own**	
	Lunchtime Event for Students & Post-docs	
	Wei Ji Ma NYU	Growing Up in Science (Pg. 33)
2:30 PM - 3:30 PM	**Session 6 (Invited) – Navigation and Oculomotor Considerations in Visual Rehabilitation** Moderator: Bruce Bridgeman, University of California at Santa Cruz	
	Cynthia Owsley The University of Alabama at Birmingham	Visual Risk Factors and Screening Tests for Motor Vehicle Collision Involvement: A Population-Based Study (Pg. 33)
	Miriam Spering University of British Columbia	Seeing and Moving: How Eye Movements Improve Hand Movements (Pg. 33)

Preeti Verghese Smith Kettlewell Eye Research Institute	Oculomotor Considerations in Macular Degeneration (Pg. 34)

3:30 PM - 4:00 PM

Panel Discussion: The Role of Electronic Media in Vision Science (Pg. 35)

Moderator: Jeff Mulligan, NASA Ames Research Center

Steve Shevell, University of Chicago
Hoover Chan, Sacred Heart School
Beau Watson, NASA

4:00 PM - 4:30 PM

Coffee Break

4:30 PM - 6:00 PM

The Boynton Lecture

Introduction: Mike Webster, University of Nevada at Reno

Donald I.A. MacLeod UC San Diego	Color, Cones and Connectivity (Pg. 13)

7:00 PM - 10:00 PM

Saturday banquet (ticket required): Gordon Biersch, 33 E. San Fernando St.

Sunday, October 18

9:00 AM - 11:00 AM

Session 7 (Invited) – Quantifying Visual Performance and Acuity

Moderator: Lynn Olzak, University of California Berkeley School of Optometry

Andrew B Watson NASA Ames Research Center	Modeling Visual Acuity (Pg. 36)
Ian L Bailey University of California, Berkeley	The Visual Acuities and Their Clinical Measurement (Pg. 37)
Ayeswarya Ravikumar University of Houston	Quantifying Visual Acuity from Image Quality Metrics (Pg. 38)
Susana T.L. Chung UC Berkeley	Do Fixation Strategies Change with Target Size? (Pg. 38)

11:00 AM - 11:10 AM	**Poster Blitz #2**	
	Kunihiro Hatakeyama Yamagata University	Examination of the Color Matching Function with Narrow-band LED System (Pg. 39)
	Giovanni Fusco The Smith-Kettlewell Eye Research Institute	Assessing Patients with Central Field Loss Using a Low-Cost Virtual Reality System with Head Tracking (Pg. 40)
	Saeideh Ghahghaei The Smith-Kettlewell Eye Research Institute	SKERI-Optos: A Graphical User Interface to Map Scotoma and PRL with the Optos OCT/SLO (Pg. 40)
	Jeffrey B. Mulligan NASA Ames Research Center	Measurement of Visual Reaction Times using Hand-held Mobile Devices (Pg. 41)
	Lauren E. Welbourne University of York	Population Receptive Field (pRF) Mapping Using Chromatic and Achromatic Stimuli (Pg. 41)
	Sanae Yoshimoto Japan Women's University; NTT Communication Science Laboratories	Individual Differences in Visual Motion Perception and the Associated Excitatory and Inhibitory Neurotransmitter Concentrations in the Brain (Pg. 42)
11:10 AM - 11:40 AM	**Coffee Service**	
11:15 AM - 12:30 PM	**Poster Session 2**	
12:30 PM - 2:00 PM	**Lunch on Your Own**	
2:00 PM - 2:30 PM	**Presentation of the Young Investigator Award / Business Meeting**	

2:30 PM - 3:45 PM

Session 8 (Contributed) – With Ties to Physiology

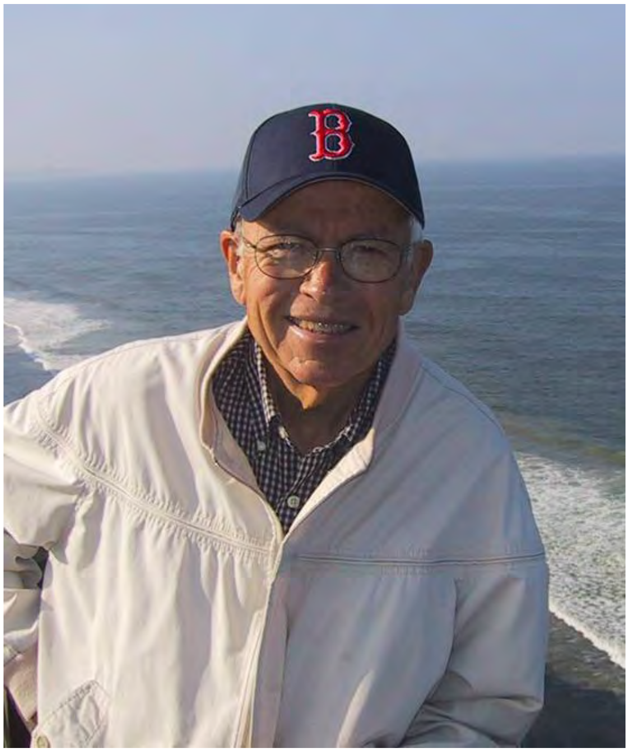
Moderator: Beau Watson, NASA Ames Research Center

Albert Ahumada NASA	Learning L/M Specificity for Ganglion Cells (Pg. 43)
Brian P. Schmidt University of Washington	How Does the Brain Interpret Signals from Single Cones? (Pg. 44)
Jihyun Kim Universitat Pompeu Fabra	Brightness Assimilation Predicted Already at Retinal Level Due to the Effect of Wide Receptive-fields of Inhibitory Feedback Cells (Pg. 44)
Amithavikram R. Hathibelagal Queensland University of Technology	Correlated and Uncorrelated Invisible Temporal White Noise Alters Mesopic Rod Signaling (Pg. 45)
Jamie M. Zeitzer Stanford University	Temporal Integration of Light in a Human Non-visual Circuit (Pg. 46)

3:45 PM

Meeting Ends

The Boynton Lecture



The Boynton Lecture is named in honor of Robert M. Boynton (1924-2006). Known to his friends as "Bob," he began his career as an early student of Lorrin Riggs, took his first position at the University of Rochester (where he founded the Center for Visual Sciences), and in 1974 moved to the University of California at San Diego. Bob was a member of the OSA and the National Academy of Sciences, and was recognized by the OSA with the Tillyer medal, and the society's highest honor, the Ives medal. Bob's work was primarily in the field of color vision. The Boynton lecture was established in 2001.

This year the Boynton Lecture will be presented by Professor Donald I. A. MacLeod, of the University of California at San Diego. Don began his life in the outer Hebrides of Scotland, began his studies at the University of Glasgow, and completed his Ph.D. at Cambridge University under the tutelage of Paul Whittle. Following a post-doc with William Rushton, he joined the faculty at UCSD. Don has wide-ranging interests in vision, but is perhaps best known for his work on the early visual system, using nonlinearities to perform "psychophysical dissection." His many honors include the OSA's Tillyer medal.

Color, Cones and Connectivity

Donald I.A. MacLeod, UC San Diego

Although we understand that a trichromatic color match is a match for the cones, we have no idea how the appearance of the matched colors relates to their neural representation. For instance, proposals about the colors seen by the red/green color blind require highly suspect assumptions about the relation between neural events and color experience. The limited evidence available does not support a simple view of that relation: in particular, color blindness cannot be explained by a cone pigment swap with normal postreceptoral organization.

In anomalous trichromats, the reduced separation between the long-wave and mid-spectral cone absorption spectra will lead to a commensurate reduction in red/green differentiation if the pigment swap is the only difference between anomalous and normal trichromatic systems. But here again the pigment swap model seems to be incomplete. Anomalous observers differentiate red from green more strongly than the pigment swap model predicts. And they display exaggerated orientation-contingent color aftereffects, that are explainable only if the cortical representation of color benefits from a compensatory post-receptoral gain enhancement that compensates for the effects of the pigment swap.

Support: NIH EY01711.

Session 1 (Invited): Enhancing Vision with Technology

Perceptual Issues in the Design of a High Dynamic Range Ecosystem

Scott Daly, Dolby Laboratories, Inc.

In the design of a high dynamic range (HDR) ecosystem including the key stages of image capture, image synthesis, post-production, encoding, transmission, decoding, and display, the foundation relied on visual system models and new perceptual experiments. For example, this design took a future-proof approach by basing the system limits on the visual system as opposed to existing or near-term expectant display hardware. The substantially increased luminance ranges of HDR require more careful consideration of light adaptation, the role of diffuse and specular reflections, interactions of emissives with the color volume, quantization nonlinearities as well as other factors that existing video standards (i.e., rec709) never had to consider. This talk will give an overview of these applied visual system designs, as well as the new creative opportunities opened up by this HDR ecosystem.

Emerging Trends and Applications of Light Field Displays

Gordon Wetzstein, Stanford University

What if your mobile phone's display would correct your vision deficiency instead of your glasses? What if we could address the vergence-accommodation mismatch in stereoscopic displays? Light field display technology has the potential to address some of these issues. In this talk, we discuss the state of the art of light field displays and a range of unconventional applications that are facilitated by this technology.

Wearable Wink-controlled Telescopic Contact Lens with Liquid Crystal Shutter Glasses

Glenn M. Schuster, Ashkan Arianpour, Scott Cookson, Eric J. Tremblay, Igor Stamenov, Arthur Zhang, Lee Hendrik, Tyrone O'Brien, Agusto Alvarez, Alex Groisman, Jerry Legerton, William Meyers, Goretty Alonso Amigo, and Joseph E. Ford, UCSD

A wink-controlled, military hands-free binocular system using polarization switching and eye-borne optics embedded within wearable scleral contact lenses is described. The lenses provide both refractive unmagnified and peripheral vision and a 2.8x magnification catadioptric telescope using four concentric annular mirrors. Self-contained eyewear with liquid crystal shutters combined with orthogonal linear polarizers within the contact lens allows for selection between the optical paths. A temple-mounted controller monitors reflection of NIR light from a diffusing retroreflector in each lens, ignoring blinks, and switching between paths in response to right- and left-eye winks. The results of testing the prototype system using a scale-model human eye with mechanical "eyelids" as well a small scale clinical (nondispensed) demonstration are discussed.

Visual Stability of Virtual Objects and Virtual Environments During Movement

Stephen R. Ellis and Bearnard D. Adelstein, NASA Ames Research Center

Virtual Environments (aka Virtual Reality) is again catching the public imagination and a number of startups (e.g. Oculus) and even not-so-startup companies (e.g. Microsoft) are trying to develop display systems to capitalize on this renewed interest. All acknowledge that this time they will "get it right" by providing the required dynamic fidelity, visual quality, and interesting content for the concept of VR to take off and change the world in ways it failed to do so in past incarnations. Some of the surprisingly long historical background of the technology that the form of direct simulation that underlies virtual environment and augmented reality displays will be briefly reviewed. An example of a mid 1990's augmented reality display system with good dynamic performance from our lab will be used to illustrate some of the underlying phenomena and technology concerning visual stability during movement. In conclusion some idealized performance characteristics for a reference system will be proposed. Interestingly, many systems more or less on the market now may actually meet many of these proposed technical requirements. This observation leads to the conclusion that the current success of the IT firms trying to commercialize the technology will depend on the hidden costs of using the systems as well as the development of interesting and compelling content.

Session 2 (Contributed): Vision Potpourri

Multimodal Imaging of the Tapetal-like Reflex in Carriers of RPGR-associated Retinopathy

Adam M Dubis[1], Rola Ba-Abbad[1], Jonathan Aboshiha[1], Alfredo Dubra[2], Andrew Webster[1], Joseph Carroll[2], Michel Michaelides[1]

[1]Moorfields Eye Hospital and University College London
[2]Medical College of Wisconsin

Purpose: Retinal structure and function deficits in carriers of X-linked retinitis pigmentosa (RP) caused by mutations in RPGR have been shown to be heterogeneous. One particularly interesting feature is the retinal tapetal-like reflex (TLR).[1-3] In this study we assessed the photoreceptor mosaic changes in a group of unrelated obligate carriers of X-linked RP and examined the TLR patterns using multimodal retinal imaging.

Methods: Female carriers of X-linked RP and unaffected females underwent multimodal ophthalmic imaging including spectral domain optical coherence tomography (SDOCT), and fundus autofluorescence imaging. Adaptive optics scanning light ophthalmoscope (AOSLO) images of the photoreceptor mosaic were obtained for the fovea and temporal parafoveal region.

Results: Nine female carriers (age 28-61) and three non-carrier females (ages

23-35) were examined. A TLR was clinically detectable in all but one carrier. One subject had reduced acuity due to RPGR associated degeneration. On SDOCT, inner segment ellipsoid (ISe) and retinal pigment epithelium (RPE) local contrast was reduced in areas of TLR. AOSLO images showed zones of decreased cone density with mosaic irregularity and increased photoreceptor reflectivity. Increased reflectivity on AOSLO was co-localized to areas of TLR. No localized areas of decreased density or increased reflectivity were seen in non-carrier females.

Conclusion: AOSLO reflectance patterns in X-linked carriers of RP appear to identify the cellular origin that underlie the TLR. Similar cellular changes have been observed with AOSLO in affected males [4], which, supports the notion that such reflexes are related to random X-inactivation in females.

1. Acton JH, Greenberg JP, Greenstein VC, et al. Evaluation of multimodal imaging in carriers of X-linked retinitis pigmentosa. Exp Eye Res 2013;113:41-8.

2. Cideciyan AV, Jacobson SG. Image analysis of the tapetal-like reflex in carriers of X-linked retinitis pigmentosa. Invest Ophthalmol Vis Sci 1994; 35(11):3812-24.

3. Bregnhoj J, Al-Hamdani S, Sander B, et al. Reappearance of the tapetal-like reflex after prolonged dark adaptation in a female carrier of RPGR ORF15 X-linked retinitis pigmentosa. Mol Vis 2014; 20:852-63.

4. Dubis AM, Aboshiha J, Sulai Y, et al. Structure/function variability in RPGR-associated retinal dystrophy. JOV 2014; 14: 34.

The work was supported by grants from the National Institute for Health Research Biomedical Research Centre at Moorfields Eye Hospital National Health Service Foundation Trust and UCL Institute of Ophthalmology, a multiuser equipment grant from The Wellcome Trust [099173/Z/12/Z], National Institutes of Health (US) grants R01EY017607, P30EY001931, C06RR016511, Fight For Sight (UK), Moorfields Eye Hospital Special Trustees, Moorfields Eye Charity, the Foundation Fighting Blindness (USA), Retinitis Pigmentosa Fighting Blindness, Research to Prevent Blindness (RPB), Michel Michaelides is supported by an FFB Career Development Award. This project was supported in part by the National Center for Advancing Translational Sciences, National Institutes of Health, through grant UL1TR000055.

Simulating Defocus Curve for Monofocal Intraocular Lenses (IOL) with Different Spherical Aberrations

Jonathan He, Rajaraman Suryakumar, Alcon Laboratories Inc. (a Novartis company)

Purpose: To evaluate how spherical aberration affects defocus curve and depth of focus in pseudophakic eyes with monofocal IOLs implanted.

Methods: One-hundred virtual eyes were generated based on a two-surface model eye including corneal and IOL surface profiles. Ocular biometry including corneal aberrations and power, anterior chamber depth and pupil size was adopted from literature data for the purpose of combining the two surfaces. Light-in-the-bucket (LIB) metric was computed from point spread function of individual virtual eye. Three monofocal IOLs with spherical aberrations of +0.17μm (ACL#1), +0.08μm (ACL#2) and -0.20μm (ACL#3) were evaluated using the two-surface model and LIB metric at defocus ±2.0D. After correlating simulated LIB metric to clinical visual acuity of ACL#1, a calibration function was generated and applied to ACL#2 and ACL#3.

Results: Monocular visual acuity and LIB metric was best correlated using an exponential function: VA = 0.48*e^(-0.17*lnLIB)-0.60. By applying the calibration function, monocular defocus curves for all the three lenses can be simulated. Prediction error for ACL#2 between simulated and clinical visual acuity within defocus of ±2.0D was all smaller than 0.10 logMAR. Simulated intermediate logMAR visual acuity at -1.5D was 0.32 (ACL#1), 0.33 (ACL#2) and 0.38 (ACL#3). Depth of focus defined using 0.2 logMAR as cut-off was 1.05D (ACL#1), 0.98D (ACL#2) and 0.96D (ACL#3), all of which differences are less than 0.25D.

Conclusions: The two-surface model eye and LIB metric are useful in predicting clinical defocus curve. Simulated results suggest by adding positive spherical aberration in IOLs will hardly extend depth of focus to a clinically significant level.

1. Thibos, L.N., Hong, X., Bradley, A., & Applegate, R.A. (2004). Accuracy and precision of objective refraction from wavefront aberrations. Journal of Vision, 23(4),329-51.

Minimally Distinct Border Judgments and Contrast: Effects of Eccentricity

John Erik Vanston, Michael A. Crognale, University of Reno

Precise isolation of individual chromatic mechanisms is useful for investigations of vision. One technique for isolating chromatic pathways is “silent substitution” (modulating along specific color directions). The minimally distinct border (MDB) technique can be used to determine the specific color direction that isolates the S-cones (tritan axis). However, macular pigment distribution may render a foveally-measured tritan line imprecise when stimuli are large or peripheral. We had subjects make MDB judgments at five retinal eccentricities, and compared the results to a model of macular distribution. The model predicted the direction of chromatic rotation but the predicted magnitude was less than observed. We hypothesized that the neural properties that underlie MDB judgments foveally may not be valid peripherally. For example a decrease in L-M sensitivity across the visual field may result in minimum border detection shifted near the L-M axis.

We investigated this issue by using a suprathreshold contrast matching task to examine the perceptual scaling of chromaticity and luminance as a function of eccentricity. Subjects made matches between Gabor patches across the visual field, comparing chromatic and achromatic stimuli to a foveal achromatic stimulus. Our results show falloffs in L-M and luminance sensitivity, relative to S-cones, with increasing eccentricity. Our suprathreshold results mirror threshold measures for chromatic pathways but not for luminance, consistent with known physiology of magno/parvo luminance pathways. Our results indicate that MDB may not be a valid peripheral indicator of the tritan axis.

1. Curcio, C. A., Allen, K. A., Sloan, K. R., Lerea, C. L., Hurley, J. B., Klock, I. B., & Milam, A. H. (1991). Distribution and Morphology of Human Cone Photoreceptors Stained with Anti-Blue Opsin. Journal of Comparative Neurology(312), 610-624.

2. Derrington, A. M., Krauskopf, J., & Lennie, P. (1984). Chromatic mechanisms in lateral geniculate nucleus of macaque. Journal of Physiology(357), 241-265.

3. Lee, B. B., Pokorny, J., Smith, V. C., Martin, P. R., & Valberg, A. (1990). Luminance and chromatic modulation sensitivity of macaque ganglion cells and human observers. J. Opt. Soc. Am. A, 7(12), 2223-2236.

4. Livingstone, M. S., & Hubel, D. H. (1988). Do the Relative Mapping Densities of the Magno- and Parvocellular Systems Vary with Eccentricity? The Journal of NeuroScience, 8(11): 4334-4339.

5. Mullen, K. T., & Kingdom, F. A. A. (2002). Differential distributions of red-green and blue-yellow cone opponency across the visual field. Visual Neuroscience(19), 109-118.

6. Smith, V. C., & Pokorny, J. (1997). Psychophysical signatures associated with magnocellular and parvocellular pathway contrast gain. J. Opt. Soc. Am. A, 14(9), 2477-2486.

7. Switkes, E. (2008). Contrast salience across three-dimensional chromoluminance space. Vision Research(48), 1812-1819.

8. Switkes, E., & Crognale, M. A. (1999). Comparison of color and luminance contrast: apples versus oranges? Vision Research(39), 1823-1831.

9. Tansley, B., & Boynton, R. (1978). Chromatic border perception: the role of red- and green-sensitive cones. Vision Research, 18(6), 683-697.

10. Tansley, B. W., & Boynton, R. M. (1976). A Line, Not a Space, Represents Visual Distinctness of Borders Formed by Different Colors. Science, 191(4230), 954-957.

Session 3 (Contributed): Eye Movements or Binocularity

Sub-optimal Integration of Orientation Across Saccades

Michael S. Landy, Elad Ganmor, Eero P. Simoncelli, New York University

Humans change their point of gaze thousands of times per day, redirecting the high-resolution fovea to objects of interest previously viewed in the periphery. Is peripherally viewed information merely used to redirect gaze, or are the two sources of information integrated to improve performance possible from either view alone? We examine this question for orientation discrimination. Method. Observers viewed a small grating patch either in the periphery prior to a saccade, in the fovea after saccading to it, or both. The task was orientation discrimination relative to the vertical.

Contrast was reduced during the saccade to equate peripheral and foveal performance. Results. Performance was better with two views than with either view alone, indicating integration across the saccade. A perturbation method (rotating the foveal relative to the peripheral grating) showed that the two orientation estimates were averaged, the weights depended on the reliability of each estimate, and the weight on the foveal estimate was higher than predicted by the ideal observer. A similar result was obtained if the foveal view occurred first, followed by a saccade away from the patch. The saccade was required for integration; there was no evidence of integration with the same sequence of retinal views without the intervening saccade. Conclusion. Humans integrate orientation information across saccades, giving priority to the foveal view. This is consistent with observers using a prior distribution on cue reliability that expects foveal to have higher acuity than peripheral information, as is usually true in natural vision.

Acknowledgements: NIH EY08266 (MSL), James S. McDonnell Foundation (EG), Howard Hughes Medical Institute (EPS).

Scanpaths Can Enhance Saliency Estimation in Photographs

Bruce Bridgeman, Steven Scher,
University of California Santa Cruz

Automatic saliency algorithms have become useful in identifying important areas in photographic images. We compare two popular algorithms with scanpaths of human eye movements on the same images. Eye movements are sampled at 1kHz with a Bouis infrared high-resolution eye tracker, calibrated on a 5x5 point grid. We estimate the average time spent looking at each pixel by convolving with a gaussian filter that spreads the contribution of each measurement over an area matched to the accuracy of the measurement. The saliency algorithms are the 'Itti' algorithm (Itti, Koch & Niebur, 1998) and the Graph Based Visual Saliency (GBVS) algorithm (Harel, Koch & Perona, 2006). Both find salient areas in several steps by normalizing an image and finding regions of maximum contrast between adjacent regions. By brightening regions where eye fixations are longest and most frequent we can compare the performance of the automatic algorithms with human exploratory behavior. We find that the algorithms and the human data from three observers correlate well for many images, but for others there are significant discrepancies. Specifically, the automatic methods sometimes pick up incidental background texture that humans ignore. Also, there are individual differences in the human scanpaths. Both algorithms perform about equally well.

1. Harel, J., Koch, C. & Perona, P. (2006). Graph based visual saliency. Proceedings of Neural Information Processing Systems (NIPS).

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Supported by LANL ISSDM and NSF #CCF-0746690.

Relative Eye Position During Monocular and Binocular Pursuit in Central Field Loss

Natela Shanidze, Stephen J. Heinen, Preeti Verghese, Smith-Kettlewell Eye Research Institute

Smooth pursuit eye movements are used to stabilize a moving stimulus on the retina. In the case of a spot stimulus, the fovea closely tracks the moving target. As such, eye movements are likely conjugate during binocular tracking in the fronto-parallel plane, with the foveas of both eyes following the object of interest. Here, we investigate whether this conjugate nature is maintained in patients with central field loss (CFL), who commonly use eccentric, often non-corresponding, retinal locations during monocular viewing. Kabanarou et al. (2006) showed changes in gaze position, in CFL patients, between monocular and binocular fixation. To extend these data to when the eyes are in motion, we present eye position data (EyeLink 1000) from 7 patients and 2 controls, who performed a step ramp (Rashbass 1961) smooth pursuit paradigm at 5, 10 and 15 degrees/s. Eye movements were recorded during binocular and monocular viewing (with the non-viewing eye occluded with an infrared filter that allowed for recording). Differences in left-right eye position were computed for the duration of the trial. For all participants, the relative position of the two eyes changed between monocular and binocular viewing (ANOVA, $p<0.05$). However within a viewing condition, the relative positions stayed constant between the beginning and end of pursuit (t-test, $p>0.2$), suggesting that the same retinal location was used throughout the trial in both eyes.

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The Difference of Velocity between Eye and Head Movement under Mental Fatigue Condition

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Eye movement diagnosis for cerebral nerve have been researched by many medical agency to assess a psychotic disorder, such as schizophrenia and post traumatic stress disorder (PTSD) [1]-[3]. As well as checking the symptomatic state, diagnosis of eye movement is expected to find an indication at the earlier stage of mental disorder. Especially, by means of measuring an abnormal reaction of eye movement, we challenge to develop the novel method for early detection of mental disorder.

It is well-known that eye movement involves a head movement as well as extraocular muscles movement [4]. Since only a behavior of eye is believed to be influenced by the state of cerebral activity, a conventional measurement of eye movement was performed by using an instrument of head fixation to separate each movement. However, we assume that a slight change caused by mental disorder is hard to detect with only the behavior of eye which consists of powerful extraocular muscles. Therefore, we focus on a relative change of velocity in both eye and head movement, which have different muscular system and neural control.

In our proposed method, we compare the change of each velocity in antisaccade examination before and after stress task, which is continuous mental arithmetic [5]. To separate the movement between eye and head, we adopted two measurement instruments; one is eye tracking system and the other is image processing system with digital camera and laser maker. As the results for healthy 10 subjects mentally, the speed of head movement with most subject becomes slow after stress task, even though the speed of eye movement is almost equivalent before and after. Since this compensation between eye and head movement is stable without the influence of individual variation, the proposed method has a possibility to be useful for early detection of mental disorder.

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Stereopsis Development in Human Infants: Sensitivity to Relative Versus Absolute and Horizontal Versus Vertical Disparity Using Sweep SSVEPs

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Stanford University

Stereopsis is the primary cue underlying our ability to make fine depth judgments. In adults, depth is perceived only for horizontal rather than vertical disparities, and depth discriminations are supported primarily by relative rather than absolute disparity. Although human infants begin to exhibit disparity responses between three and five months of age (Norcia & Gerhard, in press), it is not known how sensitivity profiles to the different types of disparity develop. Two possibilities are: 1) like adults, even young infants already rely primarily on relative and horizontal disparities, 2) infants are first sensitive to absolute disparities of either orientation and only later develop an adult-like reliance on relative and horizontal disparities. Here we use a sweep steady state visual evoked potential paradigm and dynamic random dot stereograms to measure disparity sensitivity in human infants (3-7 months) and in adults. The core conditions were: 1) a relative disparity sweep, 2) a sweep changing from absolute to relative disparity. Each condition was run with both vertical and horizontal disparities yielding four conditions total. Our results suggest that infants do not have the strong preference for horizontal over vertical disparities that adults do and do not demonstrate adult-like relative disparity responses. Our results are consistent with several behavioral studies showing that stereoacuity thresholds improve over an extended developmental course reaching beyond preschool, e.g. (Birch & Salomao, 1998; Ciner, Schanel-Klitsch, & Herzberg, 1996; Ciner, Schanel-Klitsch, & Scheiman, 1991).

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Dichoptic Presentation Separates Brown Induction from Red/Green Balance Change

Tanner DeLawyer, Lisa Huang, Rina Nakamura, Steven L. Buck, University of Washington

Yellow targets change to brown when presented in sufficiently bright surrounds. In addition, the L/M cone excitation ratio needed to produce a red/green balance shifts between yellow and brown: Yellow requires lower L/M, while brown requires higher L/M. Here we use a dichoptic display to assess the relationship between the yellow/brown hue change and the shift of red-green balance. We presented a 4°-diameter foveal target disk to one eye and a bright or dark contiguous surround annulus (2° width) to either the same eye (MONOCULAR condition) or the opposite eye (DICHOPTIC condition). The target and surround were physically contiguous only under monocular conditions but were perceptually contiguous under both conditions. Observers freely adjusted the luminance and red/green balance of the target to the highest light level at which the target appeared exclusively brown with no percept of yellow and appeared neither reddish nor greenish.

For MONOCULAR conditions, the bright contiguous surround induced brown at higher light levels and with a lower L/M ratio at red/green balance, compared to the dark contiguous surround. However for DICHOPTIC conditions the bright and dark surrounds showed no differences for luminance, unlike the monocular conditions, but continued to show the same difference for red/green balance found in the monocular conditions. This suggests the luminance contrast and red/green balance effects may be controlled by separate mechanisms that occur at different points in the visual pathway. This also demonstrates that red/green balance shifts between yellow and brown can be mediated cortically.

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Binocular and Monocular Color Perception

Jamie K. Opper, Vicki J. Volbrecht,
Colorado State University

Historically, color perception research has been conducted monocularly; however, under normal conditions, humans primarily view objects with both eyes, which means that the retinal image of a stimulus viewed peripherally along the horizontal meridian falls on the temporal portion of one eye and the nasal portion of the other. Given that previous research has shown differences in monocular color perception for the nasal versus the temporal retinas, we used a “4 + 1” hue-naming procedure to investigate the relative contribution of the individual retinas to binocular color perception, both in the fovea and approximately 10° along the horizontal meridian, for stimuli varying in size from 1.0° to 3.7°. We found that peripheral binocular color perception more closely resembled monocular color perception in the temporal retina, particularly for green. Observers also reported that smaller middle-wavelength stimuli presented to the nasal retina were less saturated than similar stimuli presented to the temporal retina. Additionally, the percentage of perceived green was greater for short-wavelength stimuli viewed monocularly and binocularly in the peripheral retina than for stimuli in the fovea. Perhaps most surprisingly, observers reported that short-wavelength stimuli viewed binocularly in the fovea appeared to have a greater blue component than stimuli in the binocular peripheral conditions. Taken together, these results indicate that binocular color perception differs from monocular color perception, and that, rather than averaging across the two eyes, the temporal retina appears to dominate our color perception.

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Session 4 (Invited): Classics of Vision Science

How a New Color Aftereffect Happened To Turn Up at Oberlin, 50 Years Ago

Celeste McCollough Howard

At Oberlin in the ‘60s, Introductory Psychology was a full-year course introducing general experimental psychology as a biosocial science. Single cell recordings from cat and monkey visual cortex had recently enabled visual science to move beyond the retina to the early cortical stages of visual processing. Ivo Kohler had reported studies of behavior during continuous wearing of prism spectacles that displace the retinal image laterally. They showed that one can regain fairly normal visuomotor coordination in a few weeks. His reports made adaptation to prism glasses a hot topic for investigation.

Laboratory studies lasting a few hours are long enough to get measurable shifts in perceived visual direction. They’re not long enough to get the “chromatic fringe” aftereffect, another outcome of continuous prism-wearing. Kohler himself attributed it to learning, but his words “conditioned color perception” did not sit well with rigorously trained visual scientists. It was about time to connect some dots!

Summation of Sine-waves at Detection Threshold: One Way of Investigating Spatial-Frequency Channels

Norma Graham, Columbia University

Sine-wave gratings were once a novel stimulus in the study of vision, and multiple spatial-frequency channels not yet proposed. Being involved in some of the research that made both popular was exciting and frustrating. In this talk, I'll attempt to recapture both the highs and the lows of measuring psychophysical summation using sine-wave gratings of different spatial frequencies and phases.

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Into the Third Dimension

Colin Blakemore, University of London & University of Oxford

Hubel & Wiesel's remarkable 1962 paper on the cat's primary visual cortex played a major part in my decision to abandon medicine and become a vision researcher, and I was fortunate to work for my PhD with Horace Barlow in

Berkeley from 1965-8. I wanted to follow up Hubel & Wiesel's discovery that V1 neurons are binocularly driven by looking at the similarity of preferred orientation in the two eyes (but didn't get around to it until Blakemore, Fiorentini & Maffei, 1972) and at the responses of binocular neurons under conditions of binocular rivalry (but didn't do that until Sengpiel & Blakemore, 1994). Horace Barlow, with characteristic insight, said that the first step was to explore whether binocular neurons had properties that would support stereopsis - selective facilitation for precisely aligned stimuli in the two eyes and variation in optimum retinal disparity. Armed with embarrassingly primitive equipment, I was recording from V1 neurons by October 1965. But early in November, Horace came back from a symposium at Caltech with the shocking news that Peter Bishop's lab in Sydney was also looking at binocularity in V1. To try to reduce competition, Horace invited Jack Pettigrew, a medical student who was working with Bishop, to visit Berkeley in the summer of 1966. Despite the distractions of political unrest, Flower Power and the call of the outdoors, within 2 months we had the evidence for both requirements for a neural mechanism of stereopsis. We published in 1967, followed quickly by papers from Bishop's lab, confirming and extending the findings. The discovery that single neurons could encode the third dimension of space energised the debate about the representation of 'trigger features', stimulated the study of stereopsis, and raised important questions about the role of early experience in determining the properties of visual neurons.

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The Spectral Tuning of Primate Cones: A History

Julie Schnapf, UCSF

The 1987 paper of Baylor, Nunn and Schnapf, Spectral Sensitivity of Cones of the Monkey Macaca Fascicularis, describes the action spectra of the red, green and blue cones in an old-world monkey, and its relationship to color-matching experiments in human observers. The action spectra were obtained using what was then a fairly new technique of suction electrode recording, applied for the first time to mammalian photoreceptors. Results will be discussed in the context of other concurrent discoveries in the field including microspectrophotometric measures of primate cones, the cloning of human cone photopigment genes, and the duplication and variation in cone photopigment genes in humans and monkeys.

Session 5 (Invited): Working Memory for Color

Binocular Color Rivalry Reveals Underlying Process of Working Memory

Steven K. Shevell, University of Chicago

Working Memory Capacity (WMC) is related to maintaining relevant visual representations while simultaneously inhibiting irrelevant ones. Are individual differences in WMC related specifically to inhibitory processes? Here, the perceptual phenomenon of color filling-in over chromatic, binocularly rivalrous stimuli reveals that inhibitory processes are indeed related to individual differences in WMC.

Participants viewed an array of equiluminant ‘red’ and ‘green’ dots within a ‘yellow’ background in each eye. Retinotopic locations that contained a red dot in one eye had a green dot in the other eye (after Kovács et al., 1996). This established binocular color rivalry for each dot in view. As reported by Kovács et al., observers sometimes reported seeing (1) an array of all red or all green dots or (2) filling-in of the yellow background, which gave the percept of a uniform yellow field (thus, visual inhibition of the binocularly rivalrous red and green dots). Separately, WMC was assessed individually for each participant using the RSPAN measure (Conway et al., 2005).

Greater WMC was directly related to the frequency ($r=0.41$, $p<0.01$) and stability ($r=0.26$, $p=0.056$) of only the filled-in uniform yellow percept. A control condition ruled out Troxler’s fading as the cause of these results. This experiment establishes a clear link between WMC and inhibitory processes. It also demonstrates a novel relation between WMC and visual percepts by highlighting the connection between human working memory capacity and lower-level processes determining perceptual coherence.

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Color Memory and Visual Processing

Maria Olkkonen, Durham University

Visually guided behavior often requires perception, working memory, and long-term memory. For example, selecting the ripest tomato requires an observer to compare the color of a tomato in view to the memory of recently seen tomatoes and the stored memory of ripe tomato color. In several studies, we manipulated both perceptual demands (changes in illumination or surrounding color) and memory demands while observers judged the color of test objects, and we measured the precision and bias of color representation. As expected, both perceptual uncertainty and temporal delays decreased precision; temporal delays also elicited biases for some colors, but not others. The pattern of results in both bias and precision was broadly consistent with a framework in which ideal observers combine noisy sensory information with prior information to arrive at decisions about color. In this framework, memory can be thought of as adding sensory uncertainty. Biases emerge because this increase in sensory uncertainty amplifies the effect of prior information and task constraints.

Probabilistic Reports of Working Memory for Color

Wei Ji Ma, NYU

Are working memory representations point estimates (e.g. a specific shade of red) or are they richer, consisting of a probability distribution over possible features? In a color memory task, subjects reported on each trial a segment of the color wheel that reflected both their estimate of the memorized color and their uncertainty. The reported uncertainty correlated with estimation error. In blocks in which a non-uniform prior over colors was used, estimates were biased towards the prior mean, and the bias was larger for larger reported uncertainty. Our findings are consistent with a Bayesian framework in which people reason with probabilistic color memories.

The Retention and Disruption of Colour Information in Human Visual Short Term Memory

Declan McKeefry, University of Bradford

Previous studies have demonstrated that the retention of information in short term visual perceptual memory can be disrupted by the presentation of masking stimuli during inter-stimulus intervals (ISIs) in delayed discrimination tasks. In this study we exploited this effect in order to determine to what extent short term perceptual memory is selective for stimulus colour. We employed a delayed hue discrimination paradigm to measure the fidelity with which colour information was retained in short term memory. The task required 5 colour normal observers to discriminate between spatially non-overlapping coloured reference and test stimuli which were temporally separated by an ISI of 5s. The points of subjective equality (PSEs) on the resultant psychometric matching functions provided an index of performance. Measurements were made in the presence and absence of mask stimuli presented during the ISI which varied in hue around the equiluminant plane in DKL colour space. For all reference stimuli we found a consistent mask-induced, hue-dependent shift in PSE compared to the ‘no mask’ conditions. These shifts were found to be tuned in colour space, only occurring for a range of mask hues that fell within bandwidths of 29 - 37°, centred on the reference stimuli. Outside of this range, masking stimuli had little or no effect on measured PSEs. The results demonstrate that memory masking for colour exhibits selectivity similar to that which has already been demonstrated for other visual attributes. The relatively narrow tuning of these interference effects suggests that the neural mechanisms which underpin short term perceptual memory for colour are dependent upon a stage in chromatic processing where there has been a transformation away from cone-opponency to higher order, non-linear colour coding.

Poster Blitz #1

Tactile Perception of Spatial Distances in Blind Humans

William Grussenmeyer, Leo Quijano, Fang Jiang, University of Nevada

Blind individuals show superior abilities in auditory spatial processing (see Collignon et al., 2009 for a review). Similarly blind braille readers show heightened tactile spatial acuity (e.g., Von Boven et al., 2000; Wong et al., 2011). Here we examined whether blind individuals show enhanced ability to integrate tactile vibration in order to estimate the relative displacement between the finger and surface.

Subjects were asked to compare two haptified lines and determine which of the two lines are longer. The haptification is dependent on the length of the line: the vibrations pulsate faster as the subject's finger moves closer to the end of the line. We tested three line orientation conditions: vertical, horizontal, and diagonal. The experiment was implemented on an Android tablet, which vibrated for the vertical orientation, and an Android Smartwatch, which vibrated for the horizontal orientation. Note that for diagonal orientation, both tablet and smartwatch vibrated. All lines originated from the lower left corner of the tablet. Subjects wore Smartwatch on their non-dominant hand and sighted subjects were blindfolded.

Thresholds were measured using a staircase procedure (3 down 1 up; 50 trials per condition) and calculated by fitting the data with Weibull psychometric function. We found similar thresholds across three orientation conditions. Despite huge inter-individual variability within both blind and sighted groups, we observed a trend towards lower threshold in blind subjects. Our preliminary results suggest that blind individuals might be better at forming a representation of spatial distance from tactile vibration cues.

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Natural Scenes are a Possible Source of Luminance-dependent Long-term Chromatic Adaptation

Alex Kale, Joris Vincent, Steven L. Buck, University of Washington

Our recent psychophysical work (ref 1) reveals different red-green balance points when long-wavelength stimuli appear dark in a bright context, than when the same physical stimuli appear bright in a dark context. Dark stimuli look greener; bright stimuli look redder. This suggests a difference in L- and

M-cone signal weights in processing of dark and bright stimuli.

The red/green shift might arise from adaptation to regularities in the environment. Past work shows that L/M weights shift with long-term adaptation both under experimental conditions (ref 2) and naturally over the lifespan (ref 3). Perhaps long-term adaptation of L/M weights occurs independently for bright and dark stimuli, driven by luminance-dependent differences in chromatic content. Thus, in the natural world, an abundance of L-cone stimulation in dark regions, or at lower luminances, might be compensated by stronger weighting of M-cone signals than in bright portions, or at higher luminances. We examine what luminance-chromaticity interactions exist within natural scenes.

Our analyses show some regularities in the natural world that could support luminance-dependent chromatic adaptation in the direction consistent with the observed psychophysical shift of red-green balance. Analysis of 238 natural scenes from calibrated databases reveals that bright clear sky is a strong and ubiquitous driver of the predicted interaction. On average, pixels in the most luminous quartile were shifted towards smaller L/M ratio compared to those in the least luminous quartile. This luminance-chromaticity interaction was less common and weaker for natural scenes not containing sky.

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The Impact of ‘Crispening’ upon the Perceived Contrast of Textures

David Kane, Marcelo Bertalmiío,
Universitat Pompeu Fabra

We investigate the role of lightness perception in determining the perceived contrast of simple textures. It is known that the background luminance of a display affects the relationship between onscreen-luminance and perceived lightness. This effect can be approximated by a power-law with an exponent that increases with the background luminance level (Bartleson & Breneman, 1967; Bartleson, 1975; Stevens & Stevens, 1963). Moreover, recent work has demonstrated that an adaptive lightness model is critical to understanding the perceived contrast of natural textures (Kane & Bertalmío, Submitted). However, a simple power-law cannot account for the effect of ‘crispening’, whereby subjects are more sensitive to luminance variations around the background luminance (Whittle, 1992). In this study we empirically estimated subject’s luminance-to-lightness functions via a bisection paradigm (Munsell, Sloan, & Godlove, 1933) for five background luminance levels, from 0 to 100%. The results reveal complex functions with clear evidence of ‘crispening’. We then computed the point-of-subjective-equality (PSE) for the contrast of a reference and test patches with a mean luminance of 25% and 75% respectively, using the background luminance conditions from experiment one. The PSE’s as a function of background luminance exhibit a peak and a trough around the mean luminance of the test and reference, respectively. We find that subjects’ PSE can only be modeled by first passing the stimulus through the empirically estimated lightness functions before estimating contrast. Future work will investigate whether the demonstrated impact of ‘crispening’ generalizes to more complex stimuli, and stimuli that subtend a greater angle.

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The Color Communication Game: Performance vs. Competence

Delwin T. Lindsey, Ohio State University
Angela M. Brown, College of Optometry

We have developed an information theoretic analysis of color naming [1,2,3]. We compute mutual information (MI, in bits) in a simulated “game” involving a “sender” (S) who names out loud, based on his color idiolect, the colors of samples selected randomly (with replacement) from an array of N samples. A “receiver” (R) attempts to identify S’s selections from her duplicate array of color samples, based only on S’s color term message and her own color idiolect. MI measures how much S’s messages improve R’s chances of guessing S's selections correctly. In the past, we have used R’s color naming data to predict her performance. However, this strategy does not consider what informants may know but do not volunteer. To address this issue, we have created an iPad application in which groups of informants actually play a networked version of our color game. Each player serves as sender, naming each of 30 color samples displayed randomly one at a time, then as receiver, selecting from the entire array of colors, the one that corresponds to each color name provided by himself and others in the first phase of the experiment. The MI for players identifying the samples corresponding to their own color terms was only slightly better than MI for the color terms deployed other players. Playing the game twice, once naïve to the identification phase and once in full knowledge of the game, produced slightly higher MI in the second round. However, in general, MI never reached its optimum value.

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Luminance-balance Based Estimation of an Illuminant in Chromatically Biased Scenes

Takuma Morimoto, Kazuho Fukuda, Keiji Uchikawa, Tokyo Institute of Technology

When an illuminant changes, both chromaticity and luminance of surfaces change. However, despite a substantial amount of color constancy algorithm, most methods rely on chromaticity change of a surface to estimate the illuminant. Based on the optimal color hypothesis, Uchikawa et al. (2012) recently revealed the importance of luminance-balance of surfaces although luminance-balance had smaller effect on estimating an illuminant than that of chromatic change. Since red or blue surfaces become lighter when an illuminant changes to red or blue, respectively, we assumed the larger number of reddish and bluish surfaces in a scene might enhance the effect of luminance-balance. In order to address this question we employed (1) balanced, (2) red-blue dominated and (3) yellow-green dominated sets of surrounding stimuli. In order to simulate the illuminant changes with no chromatic change of surrounding surfaces we manipulated only luminance-balance of each surface while its chromaticity was kept constant. Observers adjusted both chromaticity and luminance of the center test stimulus so that it looked as a full-white paper under the test illuminant. It was again shown that luminance-balance is useful to estimate the illuminant, but illuminants were estimated as being shifted towards the mean chromaticity of the scene in the red-blue and the yellow-green dominated scenes. Importantly, results showed better color constancy for the red-blue than the yellow-green dominated scene, indicating that the effect of luminance-balance depended on the chromaticity available in the scene. This suggests that the optimal color hypothesis would account for the mechanism to estimate an illuminant.

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The Geometric Horopter and Perception

Jacek Turski, University of Houston-Downtown

The eye model that continues to influence theoretical developments in binocular vision assumes that the optical node coincides with the center of rotation for eye movements. This anatomically incorrect assumption was originally made about two centuries ago in the construction of the Vieth-Müller circle (V-MC). In this presentation, we construct the precise geometry for binocular projections when the nodal point is placed at the anatomically correct location. We prove that, in this case, there is an infinite family of 3D geometric horopters with two perpendicular components. The first component consists of the horizontal horopters parametrized by vergence and the point of the V-MC. For a constant value of vergence, the horizontal horopters intersect at the point of symmetric convergence on the corresponding V-MC. The second component is formed by straight lines parametrized by vergence. Each of these straight lines is perpendicular to the visual plane and passes through the point of symmetric convergence. The main result is the relative disparity's dependence on the eye's position. We evaluate the difference between the geometric horopter and the V-MC for near-habitual fixation distances. Finally, we discuss the impact this difference may have for depth discrimination and other visual functions that make use of disparity processing.

Is Brown Induction Just Brightness Induction?

Joris Vincent, Steven L. Buck, University of Washington

A yellow stimulus surrounded by a sufficiently bright context will appear darker, but also categorically shift to brown. Is this brown induction modulated by features of the surrounding context (such as the luminance, area, duration) in the same way as brightness induction? Here we directly compare contextual modulation of achromatic brightness to the strength of brown induction using White's illusion, which causes two physically identical targets to differ in brightness.

Six participants matched the brightness of two achromatic targets in White's illusion. On average, participants adjusted the luminance of the two targets in a 1.76:1 ratio (SD = .38) to produce a brightness match.

Participants also adjusted both targets to the highest light level at which they looked pure brown (and not a mix of brown and yellow). On average, participants adjusted the luminance of the two targets in a 1.31:1 ratio (SD = .25) to produce these brown boundaries, in the same direction as the achromatic White's effect. The brown boundary ratios were smaller than predicted from regression of participants' brightness matches, and smaller than participants' actual achromatic brightness matches in their brown boundary range.

These results suggest that while White's illusion is very successful at producing consistent brightness differences for achromatic and brown stimuli, but the analogous White's effect produced for brown induction is smaller than expected from brightness matching. This indicates that brown induction is not a simple translation of brightness induction into the chromatic domain.

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Lunchtime Event

Growing Up in Science

Wei Ji Ma, NYU

Have you ever wondered what your advisor was like as a graduate student? What they struggled with? What they are struggling with now? This informal discussion for students and postdocs will not be about science, but about becoming and being a scientist. How do you deal with your own and others' expectations, and with impostor syndrome? How do you keep yourself motivated? Wei Ji Ma (NYU) will tell his personal story and then guide a conversation about the human factors that are universal undercurrents of working in academia but that too often remain unspoken. For more information, visit www.growingupinscience.com.

Session 6 (Invited): Navigation & Oculomotor Considerations in Visual Rehabilitation

Visual Risk Factors and Screening Tests for Motor Vehicle Collision Involvement: A Population-Based Study

Cynthia Owsley, The University of Alabama at Birmingham

Driving of the personal vehicle is the primary and preferred mode of travel for older adults in the U.S. More than fulfilling the critically important "getting around" or mobility function, driving in older adults profoundly impacts health status and thus has direct public health relevance. Being a driver has been linked to increased quality of life, reduced likelihood of depression and social isolation, and increased accessibility to healthcare. Therefore policies defining the vision standards for licensure as applied to the elderly population must be rational, i.e. evidence-based. In this presentation I will summarize the results of a population based study of older drivers ≥ 70 years old (N = 2,000) that addresses two questions: (1) What is the association between impairment in visual functions at baseline and incident motor vehicle collision rates three years later? (2) What is the sensitivity and specificity of alternative vision screening tests in older drivers for identifying those who have one or more collisions in the subsequent three years?

Seeing and Moving: How Eye Movements Improve Hand Movements

Miriam Spering, University of British Columbia

Good vision is paramount for a large variety of tasks such as taking a swing in baseball. One of the ways in which we achieve good vision is by moving our eyes. I will describe a set of psychophysical experiments showing that smooth pursuit eye movements improve motion perception in healthy adults. I will also discuss experiments in schizophrenia patients with motion perception deficits, where eye movements did not have beneficial effects on perception. Recently, we have extended this paradigm to examine the effect of eye movements on hand movements in a rapid interception task. We tested 32 varsity baseball players who tracked a small moving dot, back-projected onto a translucent screen, and intercepted it with their index finger in a designated hit zone. Only the first part (100-300 ms) of the trajectory was shown and observers had to extrapolate and intercept the assumed dot position anywhere within the hit zone. Better smooth pursuit resulted in more accurate interceptions. A Hazard analysis yielded two interception strategies: early interceptors relied on feedback given at the end of each trial whereas late interceptors depended on tracking accuracy. A regression model identified low tracking error and small catch-up saccades as best predictors of interception accuracy. These results may guide the development of vision training protocols for sports and clinical rehabilitation.

Oculomotor Considerations in Macular Degeneration

Preeti Verghese, Smith Kettlewell Eye Research Institute

Individuals with macular degeneration often have central field loss that includes the fovea, which results in impaired high-acuity visual function and impacts eye movements that previously used the fovea as an oculomotor reference. When both eyes are affected, individuals often adopt a peripheral preferred retinal locus (PRL) for fixation. This talk addresses some of the challenges that arise from the loss of foveal vision and the adoption of an eccentric PRL, and discusses potential ways to address them.

One challenge that arises due to a central field loss is the lack of scotoma awareness. The scotoma fills in, so patients are often not aware that they are missing information in the region of the scotoma (Fletcher et al., 2012), which impacts information gathering in daily life. Low vision rehabilitation therapy is often directed towards increasing scotoma awareness. Our own work shows that practice with directing the PRL towards the scotoma to uncover a hidden target can improve information gathering and enhance performance in a visual search task.

Another challenge is that patients have to learn to use their eccentric PRL as an oculomotor reference. The difficulties associated with directing the PRL are evident in tasks such as reading, or directing eye movements to targets of interest, away from the current fixation locus. Studies show that only a small fraction of individuals with CFL direct their PRL to a jumping target (White & Bedell, 1990), or to a target that is the goal of reaching movement (Tyson et al., 2015). However, two practice regimens that use active eye movement strategies have shown success: horizontal eye movements between simple stimuli improve reading speeds in patients with CFL (Seiple et al); active search for a target in clutter and active following of a jumping target helps the development of a stable PRL and its use as an oculomotor reference, in control participants with an artificial scotoma (Kwon et al., 2013). Studies from our own lab show that individuals with CFL are able to smoothly pursue a moving target, although pursuit gain depends on the target trajectory with respect to the scotoma.

Thus it appears that scotoma awareness training and eye movement practice with dynamic targets can improve the potential of residual vision in individuals with CFL.

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Panel Discussion: The Role of Electronic Media in Vision Science

Panelists:

Steve Shevell, University of Chicago
co-founder, Color and Vision email network (CVNet)

Hoover Chan, Sacred Heart Schools (San Francisco)
CVNet moderator/administrator

Andrew “Beau” Watson, NASA Ames Research Center
founder and former editor-in-chief, Journal of Vision (JOV)

In 1982, the SMTP standard for email interchange was published, and email rapidly became the preferred method for informal scientific communications. In 1986, Color and Vision email network (CVNet) was founded, providing an early electronic community for vision scientists. In 1997, the VisionScience site and its companion VisionList were born. In 2001, the vision community's first electronic journal, Journal of Vision (JOV), published its first issue. Digital media and communications of all sorts now dominate the exchange of information among vision scientists by offering instantaneous communication unhindered by the complexity of the information itself or the distance it must travel. The available tools have greatly multiplied, with additional on-line journals, and web sites such as ResearchGate and LinkedIn. This panel will examine the origins of vision science on the internet, discuss the strengths and weaknesses of the various on-line tools, and provide a forum for the discussion of ideas for future enhancements.

Session 7 (Invited): Quantifying Visual Performance & Acuity

Modeling Visual Acuity

Andrew B Watson, NASA Ames Research Center

Acuity is the most widely used measure of visual function, employed in both research and clinical settings. It is an estimate of the minimal size at which a particular set of symbols (optotypes) can be identified reliably. To understand the role of optical and neural contributions, we have developed a computational model of visual acuity.

Our model includes rendering of the retinal image by an optical point-spread function, anisoplanatic filtering of the retinal image by an array of midget retinal ganglion cells, perturbation by ganglion cell noise, and classification using an optimal template-matching procedure. We call this the Neural Image Classifier (Watson & Ahumada, 2015).

This model builds on ideas from optical simulation (Artal et al., 1989), ideal observer models (Geisler, 1989), and letter identification (Beckmann & Legge, 2002; Chung et al., 2002; Dalimier & Dainty, 2008; Gold et al., 1999; Nestares et al., 2003; Parish & Sperling, 1991; Watson & Fitzhugh, 1989).

For a given optical and neural configuration, acuity values can be estimated by conducting psychophysical trials using Monte-Carlo simulation. The model relies on other models we have developed of pupil diameter (Watson & Yellott, 2012), optical point-spread (Watson, 2013), and distribution of retinal ganglion cells (Watson, 2014).

The model has been used to predict effects on acuity of particular wavefront aberrations (Watson & Ahumada, 2008), to predict acuity for optotypes varying in complexity (Watson & Ahumada, 2012), and to predict the effects of size on contrast thresholds for letter identification (Watson & Ahumada, 2015).

Here we describe elements of the model and illustrate how it is used to compute predictions of acuity.

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The Visual Acuities and Their Clinical Measurement

Ian L Bailey, University of California, Berkeley

There is a multitude of options available for the clinical measurement of visual acuity. Variations in the characteristics of the tests and their administration can affect the scores of visual acuity. And the test task influences acuity scores can be very dependent on the nature of any ocular disorders.

Acuity scores are affected by whether the optotypes are Landolt rings, tumblingE's various families of letters, numbers, pictures or symbols. Reading acuity tests might include flowing text or unrelated words.. Other acuity tests use gratings, checkerboards or vanishing optotypes. Optotypes might be presented singly, in rows, in chart format and sometimes flanking bars are used. The visual acuity score is invariably a measure of angle dependent on the viewing distance and the size of a specific feature of the test target, but it is not always clear what that specific feature should be.

There is no one "true" visual acuity. All presentations of visual acuity results should include a full description of the test and procedures. The score of visual acuity on one test cannot reliably predict the score from another. For example, in many persons with abnormal macular function, the ability to identify visual acuity targets can be very dependent on the congestion of detail within the test task.

Computer driven displays enable more variations in optypes, formats and testing protocols, but there are associated limits imposed by pixellation and screen sizes.
Accordingly, we can expect to see more variations in visual acuity testing procedures, changes to simpler tests when visual acuity is poorer, and new special tests to quantify visual efficiency and the effects of task congestion, luminance and contrast.

Quantifying Visual Acuity from Image Quality Metrics

Ayeswarya Ravikumar, University of Houston

Wavefront error (WFE) of the eye has been shown to vary from individual to individual and within an individual as a function of pupil diameter. Of current interest in the area of refractive correction development is the relationship between the aberration experienced by an eye, and resulting visual performance. In a set of experiments, WFE for both normal and keratoconic eyes were selected from published datasets. These WFEs were then used to generate computationally blurred logMAR acuity charts, simulating retinal image quality under a variety of test conditions. Test subjects read the computationally blurred charts to assess the impact of the residual WFE on resulting acuity. These experiments demonstrated that the visual quality metric visual Strehl calculated in the frequency domain (VSOTF) can detect blur before clinically significant change in acuity occurs. These experiments also demonstrated that change in log neural sharpness (logNS) and log visual Strehl ratio in the spatial domain (logVSX) were both highly correlated and predictive of change in VA in both the normal and highly aberrated eyes, independent of pupil diameter. Studies are in progress that utilize these metrics to objectively predict sphero-cylindrical correction, to optimize the design of wavefront guided corrections, and to evaluate optical corrections objectively for both normal and highly aberrated eyes prior to dispensation of the correction.

Do Fixation Strategies Change with Target Size?

Susana T.L. Chung & Girish Kumar, UC Berkeley

The resolving power of the retina is the highest at the center of the fovea and decreases with eccentricity from the fovea. In this study, we asked the question of whether normally sighted subjects use different retinal locations for fixation when targets have different resolution requirements, rather than always fixating using the retinal locus with the highest resolution capability. To address the question, we evaluated the fixation behavior of nine normally sighted young adults using a Tracking Scanning Laser Ophthalmoscope (TSLO) that allows for precise registration of the stimulus location on the retina. Stimuli were Sloan letters, presented singly or in groups of three (trigrams) or five (pentagrams). Letter sizes (full-height) ranged between 5 and 40 arcmin, corresponding to letter size of 20/20 to 20/160 on an acuity chart. Subjects were instructed to fixate at the center of the stimulus (single letter, trigram, pentagram), presented at a random location within the TSLO imaging raster. Three trials (10 sec each) were tested for each condition (letter size x stimulus type). Subjects' retina during each trial was recorded as a video, from which eye movements were extracted using a cross-correlation technique at a sampling rate of 540 Hz. The retinal locus for fixation; fixation stability (quantified using the Bivariate Contour Ellipse Area, BCEA); and the slope of the amplitude spectrum of the eye movements were compared across subjects, letter sizes and stimulus types. Across the different conditions and subjects, BCEA ranged from 0.04 to 0.76 deg2. There are no systematic changes in the retinal locus for fixation, fixation stability and the slope of the amplitude spectrum of fixational eye movements when letter size increases, or for the different stimulus types. Instead, fixation strategies of individual subjects appear to be idiosyncratic, even though the perceptual performance of the subjects was highly similar.

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Poster Blitz #2

Examination of the Color Matching Function with Narrow-band LED System

Kunihiro Hatakeyama, Tsubasa Kamei, Yuki Kawashima, Takehiro Nagai, Yasuki Yamauchi, Yamagata University

It has been reported that the colorimetric color match sometimes does not ensure the visual color match between different medias such as a display and a print. One of the reasons is that the color matching functions (CMFs) used in the colorimetric systems (CIE1931 standard observer) do not necessarily represent the observers' CMFs owing to the individual differences. Although we have constructed a device for measuring the individual CMFs, the validity of these measured CMFs has not been fully evaluated. When metameric match is completed by an observer, color difference calculated with his CMFs should be smaller than those calculated with CIE1931 CMFs. In our preliminary experiment, we carried out the color matching experiment between a LCD display and a color chart. Mean color difference (ΔE*ab) calculated with individual CMFs and with CIE1931 were 5.51 and 6.02, respectively. However, the effects of the compensation of individual differences were not so distinct. One of the reasons is that the stimuli used in this experiment had broadband spectral distributions. If we use a stimulus with narrowband spectral distributions, the effects would be further highlighted as the differences in CMFs reveal more clearly. In order to verify this hypothesis, we constructed a stimulus generator with LEDs, and conducted color matching experiments between LED light and a LCD display. In the presentation, we will report our experimental results and effects of compensation of CMFs, which might lead to a "customized" color management system.

Assessing Patients with Central Field Loss Using a Low-Cost Virtual Reality System with Head Tracking

Giovanni Fusco, Natela Shanidze, Preeti Verghese, The Smith-Kettlewell Eye Research Institute

Central visual field loss is a common and debilitating problem, especially among the elderly. These individuals experience significant difficulties in performing daily tasks, and navigating streets is both challenging and potentially hazardous. The recent development of low-cost virtual reality (VR) technologies provides a potential assessment and training platform that emulates many aspects of daily life, without the associated risks. We introduce a novel testing environment with both monocular and binocular cues to depth, using a custom handheld VR simulation on an Android smartphone. Five CFL patients and 1 age-matched control were included in the study. Participants were asked to wear a VR headset. Each session consisted of two parts. First, acuity was tested in the VR device, using single letters whose size was controlled by a 2 up-1 down staircase, until threshold was reached. The threshold letter size was used for the rest of the experiment. In the second part, patients were presented with a looming wagon-wheel stimulus in fovea-centered coordinates. Observers reported the number of spokes (3, 5, or 7 randomly assigned) when the wagon wheel came into view and then identified a letter in the center, while interacting with the device via provided levers. Head movements could be resolved to a fraction of a degree, and were clearly evident in switching between the centering task (wagon wheel) and fixational task (letter identification) for the participant with a very eccentric fixation locus. All participants found the tasks compelling and engaging, reporting no motion sickness or other discomfort.

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Natela Shanidze was supported by NIH Grant No. F32 EY025151

Preeti Verghese was supported by NIH Grant No. R01 EY022394

SKERI-Optos: A Graphical User Interface to Map Scotoma and PRL with the Optos OCT/SLO

Saeideh Ghahghaei, Laura Walker, The Smith-Kettlewell Eye Research Institute

Walker et al (Renninger, Psomadakis, Dang & Fletcher, 2008) suggested a novel method to estimate the monocular scotoma area from perimetry data in macular degeneration based on (i) an optic-disc based estimation of the location of the fovea and (ii) the increase in the receptive field size with eccentricity. Here, we introduce a new GUI that applies this method to data from the Optos OCT/SLO. With OCT, it is sometimes possible to locate the foveal pit, giving a better estimation of the fovea. The GUI takes the perimetry, fixation stability and OCT image of each eye as input. It outputs the scotoma area and map relative to the PRL and the estimated fovea. This helps clinicians and researcher to have an objective measure of monocular scotoma and its geometric relation to the PRL and the estimated fovea. The GUI computes BCEA of the PRL and reports the fovea-PRL distance which is valuable information for PRL training. A prediction of the binocular scotoma map/area is computed, assuming that the foveae in the two eyes are aligned. This map informs the user of potential benefits of binocular vision. The GUI has been used by different labs, including ours, at the Smith-Kettlewell Eye Research institute. The GUI is available to the public. A user guide is provided.

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Measurement of Visual Reaction Times using Hand-held Mobile Devices

Jeffrey B. Mulligan[1], Lucia Arsintescu[2], Erin E. Flynn-Evans[1]

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Modern mobile devices provide a convenient platform for collecting research data in the field. But, because the working of these devices is often cloaked behind multiple layers of proprietary system software, it can be difficult to assess the accuracy of the data they produce, particularly in the case of timing. We have been collecting data in a simple visual reaction time experiment, as part of a fatigue testing protocol known as the Psychomotor Vigilance Test (PVT) (Dinges et al., 1994). In this protocol, subjects run a 5-minute block consisting of a sequence of trials in which a visual stimulus appears after an unpredictable variable delay. The subject is required to tap the screen as soon as possible after the appearance of the stimulus. In order to validate the reaction times reported by our program, we had subjects perform the task while a high-speed video camera recorded both the display screen, and a side view of the finger (observed in a mirror). Simple image-processing methods were applied to determine the frames in which the stimulus appeared and disappeared, and in which the finger made and broke contact with the screen. The results demonstrate a systematic delay between the initial contact by the finger and the detection of the touch by the software, having a value of 80 +- 20 milliseconds.

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Population Receptive Field (pRF) Mapping Using Chromatic and Achromatic Stimuli

Lauren E. Welbourne, Freya Lygo, Su Zhao, Fraser Aitken, Alex R. Wade, Department of Psychology, University of York

Population receptive field (pRF) mapping developed by Dumoulin and Wandell (2008) traditionally uses 100% contrast black and white checkerboard patterns to produce retinotopic maps and receptive field information from across the visual cortex. pRF maps therefore reflect the spatial tuning of the neuronal populations responding to high contrast achromatic stimuli. However, psychophysical and single unit studies show that chromatic pathways tend to be spatially low-pass compared to luminance pathways. To date, there are no reports of fMRI-based pRF techniques being applied to chromatic pathways. In this study, we attempted to use pRF mapping techniques to measure these innate resolution differences in human subjects.

A modified version of Dumoulin and Wandell's 'drifting bars' stimulus was used to produce three pRF mapping conditions: L+M+S cone achromatic, L-M cone 'red/green' and S-cone isolating 'yellow/blue'. Isoluminance was set by radiometric calibration of the scanner display system, followed by individual minimum motion settings for each subject (N=5). The bars for each condition contained a randomly-updated (2Hz) spatially pink noise (1/f) carrier so that neurons responsive to all spatial frequencies could, in theory, respond to the stimulus.

We replicated the pRF parameters from Dumoulin and Wandell's paper: pRF size increased with eccentricity and with ascending hierarchy of visual areas. However, we did not observe any differences for the chromatic conditions. We report the pRF properties obtained for each condition, and discuss our findings in the context of pRF mapping stimulus design. We also consider potential applications of this method for investigating neuronal population tuning in dichromats.

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Individual Differences in Visual Motion Perception and the Associated Excitatory and Inhibitory Neurotransmitter Concentrations in the Brain

Tatsuto Takeuchi[1], **Sanae Yoshimoto**[1], Yasuhiro Shimada[2], Takanori Kochiyama[2], Hirohito M. Kondo[3]

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The interaction of excitatory and inhibitory processes is one of the key principles used to explain various perceptual phenomena. For example, perception of directionally ambiguous stimulus is affected by a preceding moving stimulus: prolonged presentation of a preceding stimulus induces motion contrast that might reflect an inhibitory process whereas a briefly presented preceding stimulus induces motion assimilation that might reflect an excitatory process (Takeuchi et al., 2011). Meanwhile, the presentation duration of a preceding moving stimulus at which motion assimilation changes to motion contrast is different across observers. Thus, individual variability exists in the functioning of excitatory/inhibitory processes that induce motion assimilation/contrast. In the present study, we investigated the underlying neural mechanisms of individual variability by measuring the cortical concentrations of neurotransmitters. Using magnetic resonance spectroscopy (Edden et al., 2009), we measured the concentration of γ-aminobutyric acid (GABA), which is a proxy for the inhibitory process, and the concentration of glutamine/glutamate (Glx), which is a proxy for the excitatory process, in the frontal and visual cortical areas. We found that the presentation duration of the preceding moving stimulus at the motion assimilation-contrast transition zone was positively correlated with Glx concentration in the frontal areas, but not with that in the visual areas. Thus, observers who exhibited a higher concentration of Glx had a greater tendency to report motion assimilation. In contrast, no correlation was found between transition dynamics and GABA concentrations in either cortical area. These results suggest that individual variability in the perception of motion assimilation/contrast depends on the excitatory process in the higher cortical areas.

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Session 8 (Contributed): With Ties to Physiology

Learning L/M Specificity for Ganglion Cells

Albert Ahumada, NASA

Unsupervised learning models have been proposed based on experience (Ahumada and Mulligan, 1990; Wachtler, Doi, Lee and Sejnowski, 2007) that allow the cortex to develop units with L/M specific color opponent receptive fields like the blob cells reported by Hubel and Wiesel (), on the basis of visual experience. These models used ganglion cells with L/M indiscriminate wiring as inputs to the learning mechanism, which was presumed to occur at the cortical level. Since much research has indicated L/M specific wiring at the ganglion cell level (Reid and Shapley, 2002), an unsupervised learning model for developing L/M specific wiring at the ganglion cell level is proposed. The model takes as input the ouputs of simulated bipolar cells and, for the single cone center case, it is assumed that the surround for an on-center bipolar is restricted to off-center bipolars and vice versa. The learning mechanism needs only reduce the weight of the surround cells connected to the same type of cone. In the previous models, the ganglion cell center-surround mechanism provided the decorrelation of the L and M cones necessary for learning the distinction. In this model the decorrelation is provided by a simple model of the horizontal cells, which provides an average L+M signal that defines the on-off boundary. The possible value of this mechanism in terms of improved color discrimination is discussed.

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How Does the Brain Interpret Signals from Single Cones?

Brian P. Schmidt[1], Ramkumar Sabesan[2], William S. Tuten[2], Jay Neitz[1], Austin Roorda[2]

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We studied the colors reported by subjects in response to stimulation of individual cones. We targeted cones, whose spectral type was previously identified, with AO-corrected flashes of light (543 nm) and the subjects indicated the color of the flash. Cones were targeted on both white and blue backgrounds. Reports from repeated stimulation of single cones were consistent, but were not predicted by the spectral sensitivity of the stimulated cone alone. Both the background and the local neighborhood of the cone influenced the sensation reported. On a white background, the majority of L and M cones (N=221) were dominated by white responses (71%), while a small group of cones elicited red (19%) and green (10%) percepts. Contrary to classical theories, L or M cones surrounded by neighbors of opposing spectral class generated white percepts, not red or green. Against a blue background (N=181) most cones again mediated white (72%) responses and the remainder reliably signaled red (11%) or blue (18%). Across background conditions cones associated with white and red percepts tended to maintain the same behavior, whereas green signaling cones switched to blue. In a subset of cones, the intensity of the stimulus was varied, but color naming behavior did not differ. Together, our results were consistent with the idea that the brain associates elementary color and achromatic sensations with the output of a group of opponent neurons – separate from foveal L–M midget ganglion cells – early in the visual pathway.

Brightness Assimilation Predicted Already at Retinal Level Due to the Effect of Wide Receptive-fields of Inhibitory Feedback Cells

Jihyun Kim, Marcelo Bertalmío,
Universitat Pompeu Fabra

Brightness depends on the spatial scale of the inducers. For example, using a disk-and-ring stimulus, Ried & Shapley (1988) showed that a larger width of ring (the inducer) induced strong brightness contrast to the disk (the inducee) compared to a narrower ring, and brightness of the disk in a narrower ring was instead affected much by the luminance of the background field (assimilation). From these results, the authors argued that brightness depends not only on the local contrast between the inducer (ring) and the inducee (disk) but also on long-range interaction among surfaces (disk and background) that produces assimilation, counteracting contrast effect. The spatial scale of the inducer affects relative contributions of contrast and assimilation on brightness computation. It was further argued that the local contrast is readily attributed to the retinal lateral inhibition (antagonistic center-surround processing), but the origin of long-range interaction was deemed uncertain and perhaps post-retinal. However, recent neurophysiological studies discovered that the retinal inhibitory feedback interneurons, horizontal cells (Packer & Dacey, 2005) and some amacrine cell types (Kolb, 1997), manifest spatially extended receptive-fields (wide RFs). We simulated Ried & Shapley's experiment in two different biophysical retinal model platforms (van Hateren, 2007; Wilson, 1997) in consideration of wide RF of interneurons and obtained results that qualitatively replicate their behavioral data. To the best of our knowledge this would be the first evidence that the local contrast and long-range surface interaction share the same neural locus and that brightness assimilation may already be taking place at retinal level.

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Correlated and Uncorrelated Invisible Temporal White Noise Alters Mesopic Rod Signaling

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Rods input to all the three

retinogeniculate visual pathways under mesopic illumination. The relative rod weights in these pathways vary with the temporal profile of the rod signal. Here, we determined how rod signalling is altered in the presence of correlated (pathway specific) and uncorrelated (rod photoreceptor specific) temporal white noise that does not provide a stimulus for visual perception. Temporal white noise was generated using a 4-primary photostimulator to provide independent control of rod and cone excitations (5 Troland). Psychometric functions (Weibull) were measured with a method of constant stimuli for rod incremental pulses (50 to 250 ms) in the presence (or absence; control) of perceptually invisible (subthreshold) temporal white noise with constant spectral density (0-255 Hz). Three types of correlated noise were generated: Magnocellular (MC) pathway L+M+S noise, Parvocellular (PC) pathway +L-M noise and Koniocellular (KC) pathway S-cone noise. We found that the 3 types of correlated noise differentially affected the rod psychometric functions. Rod threshold elevations were largest with correlated PC pathway noise, intermediate with correlated KC pathway noise and lowest with correlated MC pathway noise. Facilitation was observed in the presence of uncorrelated rod noise. Weibull slopes mostly decreased (16/19 conditions) in the presence of noise. The effect of noise on rod signalling is inversely related to the strength of the rod inputs to the retinogeniculate pathways. We infer that this could be due to a change in observer decision criterion or the relative rod weights in the retinogeniculate pathways.

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Temporal Integration of Light in a Human Non-visual Circuit

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Much of the circuitry of the human image-forming visual system is optimized to detect changes over very short time scales. It is only when individual photopic images are separated by gaps under 66 msec (15 Hz) can we consciously perceive these images as continuous. Retinal circuitry underlying non-image forming (NIF) photoreception is interspersed, yet distinct from that used for image formation. The NIF photoreceptive system appears, however, to be optimized to respond to a gestalt of the visual environment (specifically overall environmental illuminance levels rather than specific features. We tested whether the NIF system differed in its ability to integrate light over time by examining the NIF responses of circadian phase shifting, melatonin suppression, and improvement in alertness. Under controlled conditions of a 35-hour protocol, light was presented as a sequence of 2-msec flashes over an hour (hours 2-3 after habitual bed time) at frequencies ranging from 0.004 to 0.4 Hz. Circadian phase shifting displayed non-linear integration of light flashes. In fact, when given in a sequence every 10 seconds for an hour (0.72 seconds of light), flashes were at least two-fold more effective in phase delaying the circadian system as compared with an equiluminous continuous light exposure

5000-times the duration. The flash sequences did not, however, suppress melatonin concentrations or change alertness in a dose-dependent manner. The physiology of the retinohypothalamic circuitry underlying circadian phase shifting, therefore, has the capacity to integrate light over much longer time scales than is observed with image forming vision.

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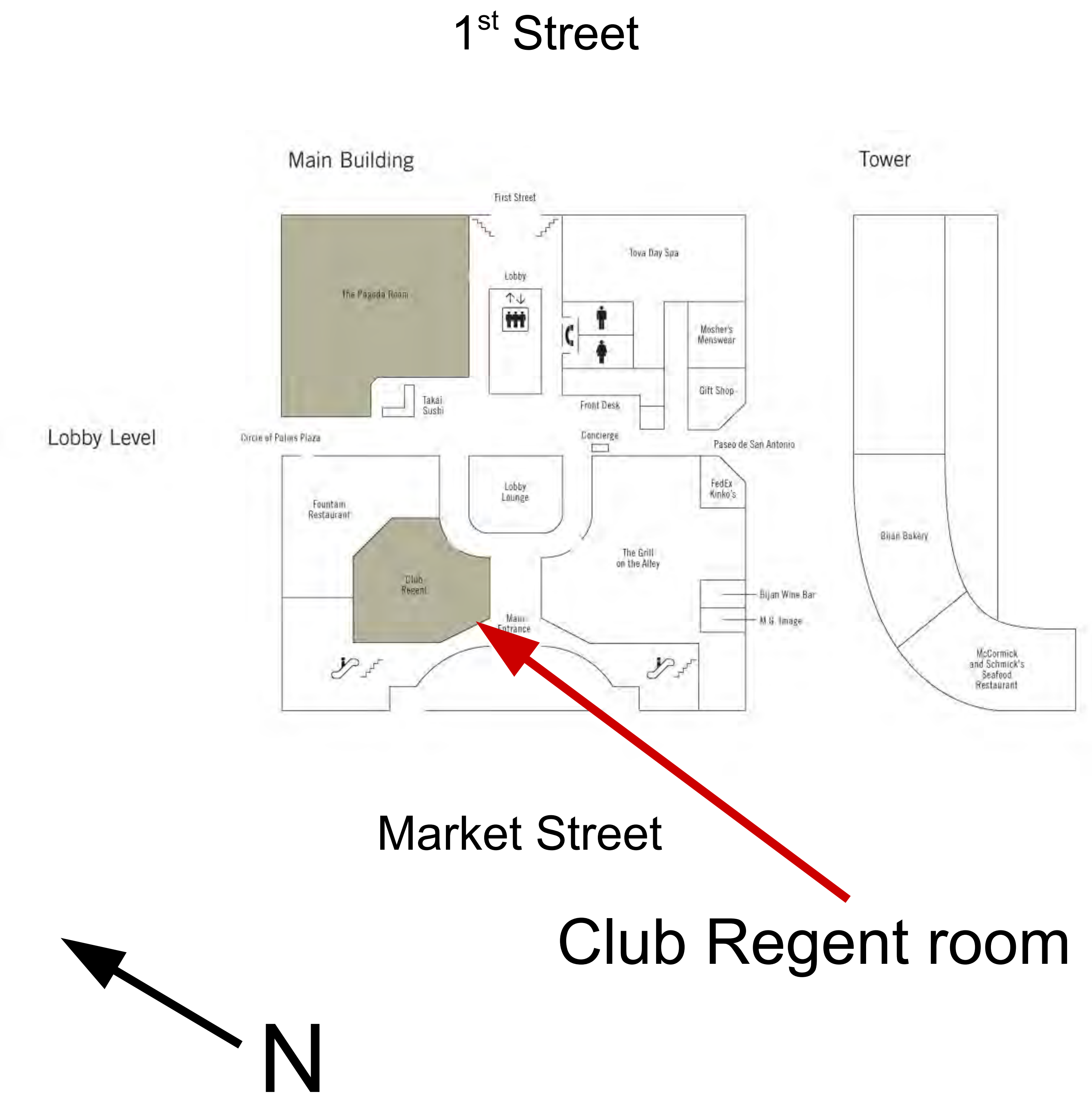
Downtown San Jose

1. Fairmont hotel
2. Sheraton Four Points hotel / Mosaic restaurant
3. Ramada Inn
4. Gordon Biersch brewery restaurant

Meeting room location (Fairmont hotel)



Downtown restaurants

This guide lists most of the restaurants closest to the Fairmont. There are many more downtown restaurants, particularly to the north on Santa Clara and San Pedro streets. The places listed on the left are mostly inexpensive counter-service, while the ones on the right are mostly more expensive with table service.

Quick Eats

1. Tandoori Oven
2. Johnny Rocket's
3. Baja Fresh
4. Asian Gourmet Express
5. Starbucks
6. Subway
7. Pita Pit
8. Pho 69
9. Whispers Cafe & Creperie
10. Kzzang
11. Zanotto's Express

Sit-Down Restaurants

A. The Grill on the Alley
B. McCormick & Schmick's
C. Mosaic
D. Il Fornaio
E. Arcadia
F. Original Joe's
G. Mezcal
H. Billy Berk's
J. La Nostra Pizza & Ristorante
K. Ozu Sushi
L. Nemea Greek Taverna
M. Hanuman Thai Cuisine
N. Gordon Biersch brewery/rest.
O. Tres Gringo's Cabo Cantina