Optica Fall Vision Meeting

October 21-23, 2022
Rochester, NY

Hosted by
University of Rochester

Center for Visual Science

Schedule at a Glance

Friday, October 21

8:20 am Welcome remarks
8:30-10:30 am Invited session: Vision restoration (*Location: SMD Large Auditorium, Rm 2-6424, URMC)*
10:30-10:40 am Break
10:40-11:40 am Contributed talks I *(Location: SMD Large Auditorium, Rm 2-6424, URMC)*
11:40 am-1:40 pm Lunch *(off-site)*
1:40–3:40 pm Invited session: Myopia and myopia control session (*Location: Sloan Auditorium, Goergen Hall)*
3:40-4:20 pm Break
4:20-5:30 pm Boynton Award Lecture: Andrew Stockman, UCL Institute of Ophthalmology
6:00 pm Poster Session I (*Location: Munnerlyn Atrium, Goergen Hall*): Dinner provided

Saturday, October 22

Location: Sloan Auditorium, Goergen Hall, unless noted otherwise
8:00-8:30 am Breakfast (*Location: Goergen Atrium)*
8:30-10:30 am Invited session: Neural network models of the visual system session
10:30-10:45 am Break
10:45-11:45 am Contributed Talk Session II
11:45 am-12:30 pm FVM Business Meeting
12:30-2:00 pm Poster Session II (***Location: Munnerlyn Atrium, Goergen Hall)***: Lunch provided
2:00-4:00 pm Invited session: Studies of the visual cortex with sub-millimeter resolution session
4:00-4:15 pm Break
4:15-5:25 pm 2021 Tillyer Award Lecture: David Brainard, University of Pennsylvania
5:25-5:40 pm Break
5:40-6:50 pm 2022 Tillyer Award Lecture: Mary Hayhoe, UT Austin
7:00 pm Tillyer and Boynton Award Banquet (*Location: Century Club of Rochester, 566 East Ave)*

Sunday, October 23

8:00-8:30 am Breakfast
8:30-10:30 am Invited session: The eye as a window to systemic and neurodegenerative health
10:30-10:50 am Break
10:50-11:50 am Contributed Talk Session III
11:50 am-12:00 pm Concluding Remarks & Presentation of Young Investigator Award

Wireless Information

The following are the guest networks for the University of Rochester
River Campus: UR_RC_Guest
Medical Center: UR_MCguest
Neither requires a login.

Friday Lunch: Directions & Restaurants

Visit https://www.cvs.rochester.edu/fvm/lunch.html or scan QR code for google maps and directions

Quick Lunch Option in UR Medical Center: Finger Lakes Coffee Roasters

Recommended Quick Lunch Options in College Town:
Chipotle Mexican Grill
Pita Mediterranean Cuisine
Moe's Southwest Grill
Mamasan's Noodle Caboodle

Sponsors

The 2022 Fall Vision Meeting is grateful for generous support from the following sponsors:

UC DAVIS HEALTH | Eye Center

UR MEDICINE | FLAUM EYE INSTITUTE

https://health.ucdavis.edu/eyecenter/

https://www.urmc.rochester.edu/eye-institute.aspx

Share on Social Media

Follow on Twitter
@CVSUoR
@OpticaWorldwide
@OSAFVM
@ucd_eyecenter
@FlaumEye

Use the hashtag **#OpticaFVM**

Follow us on Facebook:
https://www.facebook.com/CenterforVisualScience

https://www.facebook.com/opticaworldwide/

https://www.facebook.com/pages/UC-Davis-Eye-Center/186410918089034

https://www.facebook.com/visionROC

Full Schedule

University of Rochester, Oct 20-23, 2022

Thursday, October 20

5:00 – 7:00 pm Optica's Frontiers in Optics & Fall Vision Meeting: Paired Networking Event for trainees *(registration required)*
6:00 – 9:00 pm Welcome reception
Location: Flaum Eye Institute

Friday, October 21

8:20 am Welcome remarks, Jesse Schallek, Ravi Jonnal, Susana Marcos

8:30-10:30 am Invited session: Vision restoration
Location: SMD Large Auditorium, Rm 2-6424, URMC

From prosthetics to optogenetics to gene therapy, new approaches to the technologies and therapies used to restore lost vision have accelerated in the last decade. In this session, experts will provide an overview of the extent to which high-quality vision can be restored based on what we know now, and what might be possible to achieve in the near future.

> **Deep learning-based stimulus optimization for prosthetic vision**, Michael Beyeler, University of California, Santa Barbara
>
> **Restoring vision at the fovea**, Juliette McGregor, University of Rochester
>
> **Genetic therapies for inherited retinal disorders**, Rachel Huckfeldt, Massachusetts Eye and Ear
>
> **The new generation of visual cortical prosthetics**, Daniel Yoshor, University of Pennsylvania

10:30-10:40 am Break

10:40-11:40 am Contributed talks I
Location: SMD Large Auditorium, Rm 2-6424, URMC

Towards General Video Percepts Cone-by-Cone, Congli Wang, University of California, Berkeley

Spectral, Spatial and Temporal Response Properties of Foveal Ganglion Cells, Sara Patterson, University of Rochester

Layer-specific, retinotopically-diffuse modulation in human visual cortex by emotional faces, Tong Liu, NIMH

Foveal RGCs develop abnormal calcium clearance weeks after photoreceptor ablation, Zhengyang Xu, Institute of Optics, University of Rochester

11:40 am-1:40 pm Lunch offsite (suggested lunch options: https://www.cvs.rochester.edu/fvm/lunch.html)

1:40–3:40 pm Invited session: Myopia and myopia control session
Location: Sloan Auditorium, Goergen Hall

Myopia is an ocular condition where the focal length of the eye's optics is too short to appropriately focus distant objects and often comes with sequelae of ocular and retinal complications. It is a condition that is on the rise globally and is at epidemic levels, especially in East Asian countries. The goal of this session is to discuss the mechanisms and theories that drive this condition as well as treatments that are being deployed to address myopic development.

Interactions between light exposure and diurnal rhythms on the choroid, Lisa Ostrin, University of Houston

Early functional changes in the myopic retina compromise emmetropization, Frank Schaeffel, IOB; University of Tübingen

Ocular growth regulation and the complexities of optical defocus decoding: A perspective from studies in chicks, Christine F Wildsoet, Herbert Wertheim School of Optometry & Vision Science, UC Berkeley

Accommodation during myopia management is related to treatment efficacy, David Troilo, SUNY College of Optometry

3:40-4:20 pm Break

4:20-5:30 pm Boynton Award Lecture: Andrew Stockman
Location: Sloan Auditorium, Goergen Hall

Untangling visual processing and sensitivity regulation using data from normals and from patients missing key molecules required for normal visual function, Andrew Stockman, UCL Institute of Ophthalmology

6:00 pm Poster Session I
Location: Munnerlyn Atrium, Goergen Hall
Dinner provided

Saturday, October 22

Location: Sloan Auditorium, Goergen Hall, unless noted otherwise

8:00-8:30 am Breakfast
Location: Goergen Atrium

8:30-10:30 am Invited session: Neural network models of the visual system session

Research into network models of visual processing has seen exceptional progress over the past decade, driven largely by advances in machine vision systems based on deep neural networks which now equal or exceed human performance on a variety of tasks. However, the correspondence between machine vision systems and human visual cortex is still unclear and while there appear to be homologies early in the hierarchy, computations and capabilities clearly diverge at later stages. In this session we explore similarities and differences between machine and human visual systems from early visual cortex though to high level representations of objects and semantic information and ask how a constructive dialog between computer science and human neuroscience can benefit both fields.

Exploring the function of different forms of visual recurrence with artificial neural networks, Grace Lindsay, New York University

Robust information representation in hierarchical networks of the visual cortex, Hannah Choi, Georgia Institute of Technology

Neural population geometry: An approach for understanding biological and artificial neural networks, SueYeon Chung, New York University

Reverse-engineering neural code in the language of objects and generative models, Ilker Yildirim, Yale University

10:30-10:45 am Break

10:45-11:45 am Contributed Talk Session II

Detecting subclinical keratoconus by mapping corneal biomechanics using wave-based optical coherence elastography, Fernando Zvietcovich, Daza de Valdes Institute of Optics

Ex-vivo human crystalline lenses geometrical changes during simulated disaccommodation, Eduardo Martinez-Enriquez, Instituto de Óptica, Consejo Superior de Investigaciones Cientificas

***In vivo* imaging of immune cell activity in primate retina after photoreceptor ablation**, Drew Ashbery, University of Rochester

Immune cell speed changes over 5 orders of magnitude in response to inflammation in the retina, Kosha Dholakia, University of Rochester

11:45 am-12:30 pm FVM Business Meeting

12:30-2:00 pm Poster Session II
Lunch provided

2:00-4:00 pm Invited session: Studies of the visual cortex with sub-millimeter resolution session

Understanding the circuits that process information in early visual cortical areas is essential for the study of vision. This field has benefited from impressive advances in imaging that enable study of single cells and local circuits that mediate feedforward and feedback information in early visual areas. This session will focus on optical and physiological approaches that have enabled insights in the structural and functional architecture of the early visual cortex.

> **Imaging the visual brain at high spatiotemporal resolution**, Na Ji, University of California, Berkeley
>
> **Three-photon imaging reveals the neural basis of fMRI across cortical layers**, Prakash Kara, University of Minnesota
>
> **Toward an all-optical bi-directional interrogation of topographic population codes in primate cortex,** Eyal Seidemann, UT Austin
>
> **Development of natural scene processing continues after the critical period for ocular dominance plasticity closes,** Sandra J. Kuhlman, Carnegie Mellon University

4:00-4:15 pm Break

4:15-5:25 pm 2021 Tillyer Award Lecture: David Brainard

> **The Early Visual Encoding: Computations and Consequences**, David Brainard, University of Pennsylvania

5:25-5:40 pm Break

5:40-6:50 pm 2022 Tillyer Award Lecture: Mary Hayhoe

> **Visual Control of Locomotion in Natural Environments**, Mary Hayhoe, UT Austin

7:00 pm Tillyer and Boynton Award Banquet
Location: Century Club of Rochester, 566 East Ave

Sunday, October 23

Location: Sloan Auditorium, Goergen Hall

8:00-8:30 am Breakfast
8:30-10:30 am Invited session: The eye as a window to systemic and neurodegenerative health

The retina can serve as an easily accessible biomarker of vascular and neural health far beyond the eye. This potential is being realized with advances in imaging and analysis approaches, including machine learning. This symposium will explore markers of systemic and neurodegenerative disease revealed in the eye.

> **Disturbances of retinal structure in schizophrenia spectrum disorders and their clinical implications**, Steven M. Silverstein, University of Rochester
>
> **Early prediction of multiple sclerosis using scanning laser ophthalmoscopy (SLO) video sequence data with a Deep Learning (DL) based approach**, Joe Xing, C. Light Technologies, Inc.
>
> **Seeking Answers through a keyhole: Harnessing the Synergy of Dynamic OCT/OCT Angiography and Adaptive Optics SLO for Retinal Assessment of Systemic Disease**, Richard Rosen, New York Eye and Ear Infirmary of Mount Sinai
>
> ***In vivo* study of higher-order retinal hemodynamics in human retinal capillaries**, Yuhua Zhang, UC Los Angeles

10:30-10:50 am Break

10:50-11:50 am Contributed Talk Session III

In vivo **calcium imaging of macaque foveolar retinal ganglion cells reveals spatiochromatic receptive field properties**, Tyler Godat, University of Rochester

Identifying Specific Neural Substrates for Bayesian-like Computations in Binocular Vision and Multisensory Processing, Vincent A. Billock, Leidos, Inc. at the Naval Aerospace Medical Research Laboratory, Naval Medical Research Unit – Dayton

Preclinical & clinical evaluation of flavoprotein fluorescence as a label-free biomarker of retinal mitochondrial stress, Tiffany Heaster, Genentech

Characteristics of electrically-induced visual percepts in the first human with the Intracortical Visual Prosthesis, Michael P Barry, Illinois Institute of Technology

11:50 am-12:00 pm Concluding Remarks & Presentation of Young Investigator Award

Awards and Keynote Talks

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.

The Optica Fall Vision Meeting Planning Committee is pleased to announce that Andrew Stockman has been selected as the 2022 Boynton Lecturer.

Andrew's contribution to vision science has been enormous. He is best known for his development of the most widely-used cone spectral sensitivity functions and associated luminous efficiency function. He has made important contributions to sensitivity regulation in cone and rod photoreceptors, flicker sensitivity in cones, and many other basic scientific and clinical areas. His website, cvrl.org, hosts publicly available data sets, some generated in his labs and others that needed dissemination. Whether we know it or not, most of us have interacted with a CSV file or two that was originally downloaded from Andrew's site. Andrew has been an active member of Optica/OSA for decades; during his tenure as the chair of the Color and Vision Technical Division, he played a key role in the founding of the Fall Vision Meeting.

Edgar D. Tillyer Award

Information provided by Optica: https://www.optica.org/en-us/get_involved/awards_and_honors/awards/award_award_histories/tillyerhistory/

The award was established in 1953 in honor of Edgar D. Tillyer's important contributions to the advancement of better vision and the optical sciences.

Society Connection

Edgar D. Tillyer was an early member and aided with the founding of the Society. He received the first Tillyer Award in 1954 for outstanding research in vision.

Key Funders

American Optical Company, Chope Family Bypass Trust

About Edgar D. Tillyer

Tillyer was born in 1881 in Dover, New Jersey, USA. In 1898, he entered Rutgers University and excelled at mathematics and applied physics. After graduation, he took a position at the Almanac Office in Washington, DC. While working there, he was able to attend George Washington University, from which he earned his master's of science degree in differential equations and functional theory in 1903. He then returned to Rutgers and earned a master's of science degree.

In 1905, he went to work at the U.S. Naval Observatory in Washington, where he stayed until 1911. While at the observatory, he became involved in the congressional investigation aimed at determining whether Peary or Cook had discovered the North Pole first. He also developed an improved clock vault temperature control, resulted in more accurate standard time for the United States, as well as a system of reversing prisms for meridian circle observations, eliminated personal error, provided more consistent data, simplified the technique, and saved appreciable time in making observations.

Tillyer worked for the National Bureau of Standards (NBS) from 1911 until 1916 where he was responsible for the design and improvement of all image forming instruments. He redesigned and revised the old types of submarine periscopes, increasing their field of vision and illumination, and originated the first specifications to standardize periscopes

and gunsights used by the United States Navy. He also served in the capacity of consultant for both the Army and Navy in the design and specifications of optical instruments.
He was hired as director of the research laboratory at American Optical Corporation (AO) in 1916. In this role he made important contributions to the advancement optical sciences. The Tillyer Lens provided the first ophthalmic lens corrected for marginal astigmatic and focal error that could be made on a production basis. The Ful-Vue and monocentric bifocal lenses, conceived by Tillyer, eliminated image displacement, and, in the case of the Ful-Vue, a virtually unnoticeable segment is achieved. His development of a transparent reflector improved the retinoscope, an instrument used in eye examinations, and made it possible for ophthalmologists and optometrists to make more accurate diagnosis.

He held 150 patents for glass lenses and other optical devices. Among his inventions were a type of blade able to admit or shut out any desired portions of the range of colored light rays, heat rays, or ultra-violet rays. He is known for a metascope produced during World War II which enabled soldiers to see in the dark and new eye protection devices for welders. Tillyer remained at AO until his death Christmas Day 1970.

David Brainard earned an A.B. degree from Harvard University, USA and M.S. and Ph.D. degrees from Stanford University, USA. He held positions at the University of Rochester, USA and the University of California at Santa Barbara, USA before joining the University of Pennsylvania (Penn) as RRL Professor of Psychology. He is also director of Penn's Vision Research Center and Associate Dean for the Natural Sciences in Penn's School of Arts and Sciences. Brainard's most well-known contributions are from his studies of color constancy, which have led to a quantitative model. Notable achievements in his work include his development and distribution of the Psychophysics Toolbox (a software package for visual psychophysics), psychophysical measurements, his ability to link psychophysical data to quantitative models, and his ability to translate insights from biological vision into practical image processing solutions. Recently, he has applied the underlying principles of color constancy to how the visual system resolves ambiguity in the visual pathway, and has developed a computational model.

Edgar D. Tillyer Award

He has received the Macbeth Award from the Inter-Society Color Council and the Ira H. Abrams Memorial Award for Distinguished Teaching from the University of Pennsylvania. He is a Fellow of OSA and the Association for Psychological Science. In 2021, he received OSA's Edgar D. Tillyer Award "for groundbreaking experimental and theoretical contributions to our understanding of how the visual system resolves the ambiguities inherent in sensory signals to produce a stable percept of object color."

Mary Hayhoe received her BA from the University of Queensland, Australia, and her PhD from the University of California at San Diego, USA. She is currently a Professor in the Center for Perceptual Systems at the University of Texas Austin. Previously, she was a member of the Center for Visual Sciences at the University of Rochester, USA.

Hayhoe has been a leader in developing virtual environments and experimental paradigms for the investigation of natural visually guided behavior, and for innovative use of technology for recording eye, head and body movements in natural contexts. Her work reveals the factors that influence sensory-motor decisions in the context of active behavior, and how gaze behavior relates to attention, working memory, and cognitive goals.

She is on the Editorial Board of the Journal of Vision. She is a Fellow of Optica and the Society of Experimental Psychologists, and received the Davida Teller Award. In 2022, she received the Edgar D. Tillyer Award "for outstanding contributions to our understanding of visual perception and cognition in natural tasks through the innovative use of technology for recording eye, head, limb, and body position in both natural and virtual environments."

Poster List

Poster presenters are expected to be at or near their posters at the following times:

Friday 6:00 pm Poster Session I (*Location: Munnerlyn Atrium, Goergen Hall)*

Saturday 12:30-2:00 pm Poster Session II (*Location: Munnerlyn Atrium, Goergen Hall)*

P1: Yonatan Abrham, *Brain and Cognitive Sciences, University of Rochester*, Dynamic visual processing in post-saccadic V1 visual responses of the marmoset monkey

P2: Jason B. Atlas, *University of Rochester School of Medicine & Dentistry*, Retinal Changes Associated with Football-Related Concussions and Head Impacts

P3: Shashank Bhandary, *L.V Prasad Eye Institute*, High myopia and macular pigment optical density (MPOD) study

P4: Judith S. Birkenfeld, *Instituto de Óptica "Daza de Valdés", Consejo Superior de Investigaciones Científicas (IO-CSIC), Madrid, Spain*, Estimation of scleral biomechanical properties from air-puff-coupled optical coherence tomography

P5: Amy Bucklaew, *University of Rochester*, Laminar and cell class distinctions for pre-saccadic attention in marmoset MT/MTC

P6: Matthew Cavanaugh, *University of Rochester*, Evidence for preserved conscious orientation discrimination in perimetrically-blind fields early after V1-damage

P7: Ashley M. Clark, *University of Rochester,* Fixational Eye Movements in Myopia

P8: Michele A. Cox, Center for Visual Science, *University of Rochester,* Oculomotor influences on retinal input signals in myopia

P9: Gislin Dagnelie, *Johns Hoplins University,* The Intracortical Visual Prosthesis (ICVP) project: Opportunities for artificial vision and cortical exploration

P10: Andres De La Hoz, *Instituto de Óptica "Daza de Valdés", Consejo Superior de Investigaciones Científicas (IO, CSIC),* Estimation of crystalline lens mechanical properties from patient accommodation data

P11: Prutha Deshpande, *The Ohio State University*, Lexical effects on 3D color matches in short- and long-term memory

P12: Alex Diamond, *University of Rochester*, Visual System Assessment for Predicting a Transition to Psychosis

P13: Hannah K. Doyle, *Department of Electrical Engineering & Computer Sciences, University of California Berkeley, Berkeley, CA, United States,* Eliciting Color Percepts over Extended Fields through Cone-by-Cone Stimulation

P14: Bruce Drum, *FDA/CDRH/OPEQ/OHT1,* Observations and Implications of Temporary Erythropsia in a Color-Normal Observer

P15: Khai Du, *University of Rochester,* Reaching Accuracy Assessment in Cerebellar Stroke using Virtual Reality

P16: Eduardo Esteban-Ibañez, *Institute of Optics (CSIC)/ 2EyesVision SL,* Perceived image quality of natural images through different bifocal corrections after adaptation to sharp or blur

P17: Samantha I. Fradkin, *Department of Psychology, University of Rochester, Rochester, NY, USA,* Deep retinal layer microvasculature alterations in first episode and chronic schizophrenia

P18: Luke Hellwig, *Rochester Institute of Technology,* Chromatic Adaptation to Heterochromatic Illumination

P19: Andrew Mark Herbert, *RIT, Psychology,* Eye-tracking while learning greebles

P20: Daniel Joyce, *University of Nevada, Reno,* Achromatic biases in noise images

P21: Sharif Amit Kamran, *Human-Machine Perception Laboratory, Department of Computer Science and Engineering, University of Nevada, Reno, Nevada, United States,* Detecting spaceflight associated neuro-ocular syndrome (SANS) using light-weight convolutional neural networks

P22: Arathy Kartha, *Johns Hopkins University,* Development and validation of a virtual reality based toolkit to assess functional vision in Ultra Low Vision

P23: Mohana Kuppuswamy Parthasarathy, *University of Nevada, Reno,* A direct measure of adaptation and visual salience

P24: Yanjun Li, *University of Minnesota,* Learned rapid adaptation to environmental color changes generalize to a large range of colors

P25: Yuanhao H. Li, *University of Rochester,* Spatial-frequency-selective enhancement of visual sensitivity from saccade dynamics

P26: Ying Lin, *University of Rochester,* A unifying framework for perceptual decision-making

P27: Jake Manalansan, *University of Nevada Reno,* Bayesian inference and adaptation in neural responses

P28: Samantha Montoya, *University of Minnesota, Graduate Program in Neuroscience,* Quantifying Visual Snow Symptoms with a Matching Task

P29: Peter Murphy, *University of Rochester, Center for Visual Science, Institute of Optics,* Optogenetic Stimulation and Calcium Imaging of Single Ganglion Cells in the Living Macaque Fovea

P30: Ipek Oruc, *University of British Columbia,* Explainable diagnosis based on retinal fundus images using deep learning

P31: Phani Paladugu, *Brigham and Women's Hospital, Harvard Medical School, Boston, MA and Sidney Kimmel Medical College, Thomas Jefferson University, Philadelphia, Pennsylvania, United States,* Extended Reality-based Minifying Lens Effects Decreases Dynamic Visual Acuity

P32: Samuel Paré, *Université de Montréal,* Reading with your tongue

P33: JT Pirog, *Herbert Wertheim School of Optometry & Vision Science, University of California, Berkeley, Berkeley, CA USA,* Towards Understanding Retinal Processing of Single-Cone Scale Stimulation

P34: Derek Power, *University of Rochester, Center for Visual Science,* Deep retinal laser lesions recruit resident microglia without involvement of labeled neutrophils

P35: Nicole M. Putnam, *Arizona College of Optometry, Midwestern University,* Fixational Eye Motion Measured with Tracking Scanning Laser Ophthalmoscopy in ABI/TBI and Control Subjects

P36: Prithul Sarker, *University of Nevada, Reno,* An Arduino-based Lightweight and Reliable Solution to Detect Relative Afferent Pupillary Defect

P37: Eric Seemiller, *711th Human Performance Wing, United Stated Air Force,* Event-related Changes in Pupil Size in a Simulated Air Refueling Task

P38: Fei Shang, *University of Rochester, Center for Visual Science,* After up to a year of hyperglycemia Ins2Akita mice show minimal capillary change

P39: Idris Shareef, *Department of Psychology, University of Nevada, Reno, Reno NV,* Perceptual scaling and natural image statistics

P40: Yangyi Shi, *Northeastern University,* Achromatic increments and decrements are different: the relationship between scaling and discrimination

P41: Yesenia Taveras-Cruz, *Northeastern University, Boston, MA,* Threshold versus intensity curves measured with a new high-brightness display system

P42: Lupe Villegas, *"Daza de Valdes" Institute of Optics, The Spanish National Research Council - CSIC, Madrid, Spain,* Experimental assessment of scleral anisotropy using multi-meridian air-coupled ultrasonic optical coherence elastography

P43: Maria Vinas-Pena, *Wellman Center for Photomedicine and Harvard Medical School, Massachusetts General Hospital, Boston, MA, USA,* Optical coherence elastography for In situ measurement of stiffness increase in posterior sclera after crosslinking

P44: Alex Wade, *University of York,* Time resolved modulation of neuronal activity associated with attention to low-level visual features

P45: Tadayuki Wakata, *Waseda University,* Comparison of brightness and vividness of colors with different background colors in PCCS

P46: Piotr Franciszek Wegrzyn, *ICTER – International Centre For Translational Eye Research,* Optoretinography-based frequency characterization of the retinal response to a chirped flickering light

P47: Yunlong Xu, *University of Rochester,* Investigating temporal evolutions of perceptual choice within biological and artificial neural networks

P48: Yasuki Yamauchi, *Yamagata University,* A Simple Method for the Measurement of the Color Matching Functions

P49: Jingyi Yang, *University of Rochester,* The impact of retinal excitotoxic lesions on parallel visual streams in the ferret dorsal lateral geniculate nucleus

P50: Nasif Zaman, *Human-Machine Perception Laboratory, Department of Computer Science and Engineering, University of Nevada, Reno, Reno, Nevada, United States,* Comparison of Dynamic Visual Acuity Assessments in Head-Mounted Technology and Traditional Laptop-based Method

P51: Yifan Zhang, *C. Light Technologies, Inc.; Department of Computer Science, University of California, Berkeley; Department of Statistics, University of California, Berkeley,* Deep Active Learning Using Retinal Image Embedding Vectors to Optimize Training Data Selections

P52: Yanbo Zhao, *Centre of Micro/Nano Manufacturing Technology (MNMT-Dublin), University College Dublin, Dublin 4, Ireland,* Dynamic optomechanical eye model for the validation of peripheral aberration measurement

P53: Len Zheleznyak, *Clerio Vision, Inc.,* Peripheral blur may provide the eye with a cue for the sign of defocus

P54: Emily Isenstein, *Brain and Cognitive Sciences, University of Rochester,* Neural Correlates of the Visual Expectation of Active and Passive Touch

Talk Abstracts

Deep learning-based stimulus optimization for prosthetic vision

Michael Beyeler, *University of California, Santa Barbara*

Visual neuroprostheses are emerging as a promising technology to restore a rudimentary form of vision to people living with incurable blindness. However, phosphenes elicited by current devices often appear artificial and distorted. Although current computational models can predict the neural or perceptual response to an electrical stimulus, an optimal stimulation strategy needs to solve the inverse problem: what is the required stimulus to produce a desired response? Here we frame this as an end-to-end optimization problem, where a deep neural network encoder is trained to invert a psychophysically validated phosphene model that predicts phosphene appearance as a function of stimulus amplitude, frequency, and pulse duration. As a proof of concept, we show that our strategy can produce high-fidelity, patient-specific stimuli representing handwritten digits and segmented images of everyday objects that drastically outperform conventional encoding strategies by relying on smaller stimulus amplitudes at the expense of higher frequencies and longer pulse durations. Overall, this work is an important first step towards improving visual outcomes in visual prosthesis users across a wide range of stimuli.

Funding acknowledgements: NIH R00-EY029329

Restoring vision at the fovea

Juliette McGregor, *Department of Ophthalmology and Center for Visual Science, University of Rochester, Rochester NY, USA*

Currently little can be done to restore high quality vision to patients with retinal degeneration. Tasks like recognizing faces require high acuity vision which is mediated by the fovea, a specialized retinal structure unique to humans and non-human primates. Signals from the fovea dominate visual cortex and optimizing vision restoration therapies at this retinal location has the potential to yield higher quality outcomes. Adaptive Optics Scanning Light Ophthalmoscopy provides an innovative preclinical development platform for evaluating therapies in non-human primates, allowing photoreceptor ablation and cellular scale functional recording of restored responses from foveal retinal ganglion cells in the living eye. Recent work has also enabled observation of immune cell activity in primate retina at the cellular scale. I will describe experiments using *in vivo* calcium imaging to demonstrate optogenetic restoration of RGC activity in primate fovea and efforts to accelerate progress toward more naturalistic restored vision, using stem cell-derived photoreceptor replacement therapy. Key to the success of all of vision restoration therapies is understanding the impact of periods of long term vision loss on the retina and I will share results examining changes in foveal RGCs in the weeks and months following deafferentation. Finally I will consider the unique perceptual challenges which may arise when restoring light sensitivity to foveal tissue.

Funding acknowledgements: I acknowledge funding support from the AGI initiative NIH U24 EY033275, CVS core support from NIH P30 EY0001319, an unrestricted grant to the Flaum Eye Institute from Research to Prevent Blindness and the Steven. E. Feldon Scholarship from the Flaum Eye Institute.

Genetic therapies for inherited retinal disorders

Rachel Huckfeldt, *Massachusetts Eye and Ear*

The accessibility of the retina makes it an attractive target for genetic therapies to treat inherited retinal disorders (IRDs). The FDA's approval of voretigene neparvovec-rzyl in 2017 for biallelic RPE65-associated retinal dystrophies demonstrated that the safety and efficacy needed for regulatory approval of such therapies could be achieved. Clinical trials assessing a growing array of genetic strategies are offering valuable insight on the potential of these therapies for the treatment of IRDs while also emphasizing ongoing challenges in their development. This presentation will review the range of genetic therapies for IRDs being tested in clinical trials and the results to-date as well as discuss challenges including those related to evaluating efficacy.

The new generation of visual cortical prosthetics

Daniel Yoshor, *University of Pennsylvania*

Since the 1960s, the prospect of developing a visual cortical prosthesis for restoration of useful vision to the blind has tantalized scientists, engineers, and clinicians. After two decades of relative inactivity, interest in this approach has been renewed. There are now multiple active efforts to develop next generation visual prostheses and to bring these devices to clinical implementation. We will review the current state of the field, with a particular emphasis on our own work, and will highlight advances in the field as well challenges that must be overcome to produce a clinically useful prosthetic device.

Funding acknowledgements: NIH R01EY023336, NIH UH3NS103442, DARPA

Layer-specific, retinotopically-diffuse modulation in human visual cortex by emotional faces

Tong Liu, *NIMH*

Co-authors: Jason Fu, NIMH; Yuhui Chai, NIMH; Shruti Japee, NIMH; Gang Chen, NIMH; Leslie Ungerleider, NIMH; Elisha Merriam, NIMH

Emotionally expressive faces evoke enhanced neural responses in multiple brain regions, a phenomenon thought to depend critically on the amygdala. This emotion-related modulation is evident even in primary visual cortex (V1), providing a potential neural substrate by which emotionally salient stimuli can affect perception. How does emotional valence information, computed in the amygdala, reach V1? Here we use high-resolution functional MRI to investigate the layer profile and retinotopic distribution of neural activity specific to emotional facial expressions. Across three experiments, human participants viewed centrally presented face stimuli varying in emotional expression and performed a gender judgment task. We found that facial valence sensitivity was evident only in superficial cortical layers and was not restricted to the retinotopic location of the stimuli, consistent with diffuse feedback-like projections from the amygdala. Together, our results provide a feedback mechanism by which the amygdala directly modulates activity at the earliest stage of visual processing.

Funding acknowledgements: This work was supported by the Intramural Research Program of the National Institute of Mental Health (ZIAMH002918; NCT00001360).

Spectral, Spatial and Temporal Response Properties of Foveal Ganglion Cells

Sara Patterson, *University of Rochester*

Co-authors: Tyler Godat, University of Rochester; Kendall Kohout, University of Rochester; Qiang Yang, University of Rochester; William Merigan, University of Rochester; David Williams, University of Rochester

While the fovea is best known for its high spatial acuity mediated by a high density of midget ganglion cells (RGCs), anatomy and transcriptomics show ~15 rarer RGC types are also present. However, our understanding of the visual information these RGCs convey to the brain is limited as both the fovea and rarer RGC types have been difficult to address with standard physiology techniques. We addressed this gap in knowledge *in vivo*, with two macaques expressing GCaMP6s in the foveal ganglion cell layer. Using a fluorescence adaptive optics scanning light ophthalmoscope, we presented stimuli to the cones while measuring the responses of hundreds of distinct cells. We classified cells with stimuli assessing polarity, spectral tuning, receptive field size, temporal tuning and motion sensitivity. 21% of cells had response properties inconsistent with midget RGCs, including ON-OFF responses, non-canonical spatial receptive fields, direction selectivity and suppressed-by-contrast responses. Our classification enables *in vivo* functional identification of the rarest foveal RGCs, laying the foundation for future experiments targeting these elusive cells to determine their roles in vision. While the dominance of midget RGCs observed is consistent with the fovea's specialization for acuity, the unappreciated functional diversity we observed indicates that far more visual processing occurs within the primate fovea than classically thought.

Funding acknowledgements: NIH Grants F32 EY032318, P30 EY001319, R01 EY031467, R01 EY021166, R01EY028293, R01 EY032116, T32 EY007125, U24 EY033275 and Research to Prevent Blindness

Towards General Video Percepts Cone-by-Cone

Congli Wang, *University of California, Berkeley*

Co-authors: James Fong, University of California, Berkeley; Hannah K. Doyle, University of California, Berkeley; Sofie R. Herbeck, University of California, Berkeley; Jeffrey Tan, University of California, Berkeley; Austin Roorda, University of California, Berkeley; Ren Ng, University of California, Berkeley

We aim to reprogram visual perception through an Adaptive Optics Scanning Laser Ophthalmoscope (AOSLO) Display, using a GPU renderer that rasterizes a target color image or video into cone-by-cone single-wavelength laser light pulses ("microdoses"). We imaged and tracked at ~ 2° eccentricity a 0.9° x 0.9° field of view of the retina in 840 nm. Stimulated in 543 nm, all resolved, spectrally classified cones receive microdoses of varying intensities. The renderer updates for each AOSLO frame (30 frames / sec) an underlying stimulation image buffer, encoding a desired color percept pattern that takes into account the cone locations, cone spectral sensitivity to the 543 nm stimulation light, and the corresponding color percept pixel values. Within one frame, the buffer gets pixelated strip-by-strip at 1 kHz into actual world-fixed microdose intensity values, each centered on a cone within that strip at that instant. The resulting frame of microdoses visually occupies the whole raster view. We showed multiple color percepts to a cone-classified subject, with logging data. The subject saw spatially-varying colors, e.g. a red box moving on a green canvas – these percepts validated the accuracy of the prototype. These initial prototyping experiments allude to the potential of presenting general percepts to a cone-classified subject, at cone-level accuracy in a fully programmable way. The technology allows us to probe neural plasticity and towards generation of novel percepts.

Funding acknowledgements: This work was supported by the Air Force Office of Scientific Research under award numbers FA9550-20-1-0195 and FA9550-21-1-0230.

Foveal RGCs develop abnormal calcium clearance weeks after photoreceptor ablation

Zhengyang Xu, *Institute of Optics, University of Rochester*

Co-authors: Karteek Kunala, Center for Visual Science, University of Rochester Medical Center; Peter Murphy, Institute of Optics, University of Rochester; Edith Koo, Institute of Optics, University of Rochester; Teresa Puthussery, Herbert Wertheim School of Optometry & Vision Science, University of California Berkeley | Helen Wills Neuroscience Institute, University of California Berkeley; Juliette E. McGregor, Flaum Eye Institute, University of Rochester Medical Center | Center for Visual Science, University of Rochester Medical Center

Vision restoration therapies aim to restore light sensitivity to the retina following photoreceptor (PR) degeneration. Physiological changes in retinal ganglion cells (RGCs) have been reported in rodent models of PR loss but this has not been investigated in primates. By expressing both a calcium indicator (GCaMP6s) and an optogenetic actuator (ChrimsonR) in foveal RGCs of a macaque, we reactivate RGCs and assess activity in the weeks and years following PR loss. Cones were ablated with an ultrafast laser delivered through an adaptive optics scanning light ophthalmoscope (AOSLO). A 0.5 s optogenetic stimulus (1 mW, 640 nm) was delivered to the deafferented RGCs, and GCaMP fluorescence was recorded for 90 s. The calcium response was collected with AOSLO over 10 weeks and the signal decay was fitted with an exponential model. Optogenetic responses in RGCs persisted over 2 years following PR ablation. The mean time to peak calcium response was stable in deafferented RGCs over the 10 weeks (paired t-test, $p<0.001$), while the mean decay constant of the calcium response decreased 2.1 fold (2.5±0.5 s to 1.2±0.2 s SD) in the 8 weeks post PR ablation. The presence of optogenetic responses 2 years after PR loss and the stable rise time is promising for vision restoration therapies with RGCs. However, the 2-fold reduction in the decay constant of the calcium response suggests that restored activity may be impacted by physiological changes in the inner retina weeks after PR loss.

Funding acknowledgements: Funding from the AGI initiative NIH U24 EY033275, CVS core support from NIH P30 EY0001319 An unrestricted grant to the Flaum Eye Institute from Research to Prevent Blindness and the Steven. E. Feldon Scholarship from the Flaum Eye Institute

Early functional changes in the myopic retina compromise emmetropization

Frank Schaeffel, *Institute of molecular and clinical ophthalmology Basel (IOB), Switzerland; Ophthalmic Research Institute, University of Tuebingen, Germany; Zeiss Vision Science Lab, Ophthalmic Research Institute, University of Tuebingen, Germany*

Co-authors: Barbara Swiatczak, Institute of molecular and clinical ophthalmology Basel (IOB), Switzerland

There is abundant evidence that emmetropization is controlled by visual experience, and that the retina is able to extract the information necessary to fine-tune axial eye growth during development. Emmetropization represents a closed-loop feedback system that uses defocus as error signal. It involves two pathways, one stimulating eye growth and the other restraining it. Both are different at several levels (1) different genes (2) different biochemical pathways and pharmacological interventions (3) different modes of retinal image processing. Knowing all this, the question arises why myopia does not limit itself and why undercorrection does not inhibit eye growth as expected from experiments in animal models. We found that only the emmetropic human retina can generate the growth-inhibiting signals when the focal plane is in front of the retina while the myopic retina has largely lost this ability. The functional deficit concerns retinal image processing, not the biochemical signaling cascades to choroid and sclera. Most recently, we found that the emmetropic human retina uses chromatic differences in focus to determine the sign of defocus. Again, we found that the myopic retina has lost this ability. The questions are now: (1) why and when occur the changes in the myopic retina that make myopia an open loop system, (2) what is the biological sense of this functional loss at a time when vision is otherwise normal (with correction) and (3) what are the underlying retinal circuits that seem to “give up”?

Interactions between Light Exposure and Diurnal Rhythms on the Choroid

Lisa Ostrin, *University of Houston College of Optometry*

Purpose: Increasing evidence demonstrates that light exposure and circadian rhythms plays a role in myopia, with high intensity outdoor light being protective. The choroid may be involved in this mechanism. The goals of our studies were to examine the interaction between light exposure and circadian influences on the choroid.

Methods: In Experiment 1, choroid diurnal rhythms were investigated during monocular light deprivation in adults using spectral domain optical coherence tomography imaging (SD-OCT). The left eye was light deprived for 20 hours. In Experiment 2, the effects of two hours of high intensity outdoor light exposure on retinal and choroid thickness were investigated and compared to indoor illumination and darkness.

Results: For Experiment 1, choroid diurnal variation persisted and retinal diurnal variation was eliminated in light deprived eyes. Total retinal and inner segment thicknesses decreased ($P < 0.001$) and outer segment + RPE thickness increased ($P < 0.05$) with light deprivation. For Experiment 2, the choroid was significantly thinner during outdoor light exposure compared to indoors and darkness ($P < .01$), but returned to baseline at follow-up ($P > .05$). Total retinal thickness was significantly thicker during and after the outdoor compared to indoor and dark conditions ($P < .05$).

Conclusions: These studies demonstrate that the choroid is mediated by both intrinsic circadian mechanisms as well as light exposure. Choroidal thickness rhythms were not impacted by short-term light deprivation. Surprisingly, high intensity sunlight resulted in an unexpected thinning of the choroid. These findings have implications regarding the interaction between light exposure, circadian rhythm, and the choroid on myopia.

Accommodation during Myopia Management is Related to Treatment Efficacy

David Troilo, *SUNY College of Optometry*

The relationship of accommodation to myopia development and progression has been the subject of speculation and debate for many years. In this presentation some of the key findings from past research will be discussed along with recent data showing that accommodative behavior during optical treatment with multifocal contact lenses is related to treatment efficacy. The results will be discussed along with some possible strategies for improving treatment outcomes.

Ocular growth regulation and the complexities of optical defocus decoding: A perspective from studies in chicks

Christine F Wildsoet, *Herbert Wertheim School of Optometry & Vision Science, UC Berkeley*

The COVID pandemic has seen a further rise in the prevalence of myopia world-wide, adding to the urgency of effective treatments that can prevent or slow myopia progression. In addition to multifocal soft contact lenses and orthokeratology lenses for myopia control, a variety of novel spectacle lenses involving modified peripheries are either currently under clinical trial or recently approved. Yet still unresolved questions related to underlying retinal mechanisms of action represent handicaps to their further refinement and improved efficacy. In this presentation, results will be presented from studies using young chicks as a model for manipulating the amount, retinal location and timing of imposed optical defocus, as well as the spatial frequency content of retinal images (with Bangerter foils), by way of offering some additional insights into mechanisms. The predictive values of choroidal thickness changes, as well as eye shape changes, as determinants of "myopia control", will also be considered.

Funding acknowledgements: National Eye Institute Grants R01EY012392 (CFW).

2022 Robert M. Boynton Award Recipient

Untangling visual processing and sensitivity regulation using data from normals and from patients missing key molecules required for normal visual function

Andrew Stockman, *UCL Institute of Ophthalmology*

An important way of characterizing normal and abnormal visual processing is to measure sensitivity to flicker. We can account for over 70 years of normal flicker-sensitivity measurements with a simple, physiologically relevant sequential model built from a cascade of low-pass filters that requires only two intensity-dependent model parameters: one that adjusts response speed, and the other that adjusts the overall gain at higher light intensities.

We have also applied this model to 20 years of flicker-sensitivity measurements obtained from groups of patients with molecularly characterised deficits that affect different stages of visual processing. We can characterise the resulting visual losses (or gains) in terms of changes that speed up the responses of one or more stages, or slow them down, or interpose additional stages. Remarkably, we find that other stages make compensatory adjustments to offset the abnormality and thus help to keep the overall system in a useful operating range. For example, if the abnormal stage slows down the visual response, another stage is likely to speed up or attenuate the response to rebalance performance.

Our approach also allows us to tease apart stationary and progressive effects, and the localised molecular losses help us to unravel and characterise individual steps in the normal and abnormal processing sequences. They have also led to a revised understanding of a classic problem in visual science: how the critical flicker frequency (the highest frequency that can just be seen) grows with light intensity.

Exploring the function of different forms of visual recurrence with artificial neural networks

Grace Lindsay, *New York University*

Behavioral studies suggest that recurrence in the visual system is important for processing degraded stimuli. There are two broad anatomical forms this recurrence can take, lateral or feedback, each with different assumed functions. I'll discuss work wherein I add four different kinds of recurrence—two of each anatomical form—to a feedforward convolutional neural network and find all forms capable of increasing the ability of the network to classify noisy digit images. By using several analysis tools frequently applied to neural data, the distinct strategies used by different networks were identified. The analyses used here can be applied to real neural recordings to identify the strategies at play in the brain. An analysis of an fMRI dataset weakly supports the predictive feedback model but points to a need for higher-resolution cross-regional data to understand recurrent visual processing.

Funding acknowledgements: Marie Curie Individual Fellowship

Robust information representation in hierarchical networks of the visual cortex

Hannah Choi, *Georgia Institute of Technology*

The mammalian visual system has an exquisite ability to encode relevant information from noisy sensory inputs in natural scenes. Such robust yet adaptable computation is believed to emerge from the uniquely complex connectivity structure of biological neural networks. In this talk, I will focus on the hierarchical organization of the cortical network, and discuss how this unique network structure shapes robust representations of noisy visual inputs via predictive coding. Using a predictive coding model of hierarchically-related visual cortical areas, we link feedback connections to top-down predictions of the lower cortical neural activity. Our model shows that hierarchical predictive coding explains the mechanisms of robust recognition of noisy objects in intermediate cortical areas. Secondly, we study how context-specific information may be represented and modified across learning in populations of neurons in a recurrent neural network model of hierarchically-related cortical areas. Motivated by an experimental study investigating neural activities in response to expected and unexpected natural images in mouse visual cortex, we test how the divergence of feedforward and feedback connections underlie differential representations of expected and surprising sensory information across cortical areas and layers. In sum, our study provides insights into how robust and adaptable visual encoding arise from biologically-motivated connectivity across the cortical hierarchy.

Funding acknowledgements: National Eye Institute of the National Institutes of Health under Award Number K99/R00 EY030840

Reverse-engineering neural code in the language of objects and generative models

Ilker Yildirim, *Yale University*

When we open our eyes, we do not see a jumble of light or colorful patterns. There lies a great distance from the raw inputs sensed at our retinas to what we experience as the contents of our perception. How in the brain are incoming sense inputs transformed into rich, discrete structures that we can think about and plan with? These “world models” include representations of objects with kinematic and dynamical properties, scenes with navigational affordances, and events with temporally demarcated dynamics. Real world scenes are complex, but given a momentary task, only a fraction of this complexity is relevant to the observer. Attention allows us to selectively form these world models, driving flexible action as task-driven, simulatable state-spaces. How in the mind and brain do we build and use such internal models of the world from raw visual inputs? In this talk, I will begin to address this question by presenting two new computational modeling frameworks. First, in high-level vision, I will show how we can reverse-engineer population-level neural activity in the macaque visual cortex in the language of three-dimensional objects and computer graphics, by combining generative models with deep neural networks. Second, I will present a novel account of attention based on adaptive computation that situates vision in the broader context of an agent with goals, and show how it explains internal representations and implicit goals underlying the selectivity of scene perception.

Funding acknowledgements: Air Force Office of Scientific Research FA9550-22-1-0041

In vivo imaging of immune cell activity in primate retina after photoreceptor ablation

Drew Ashbery, *University of Rochester Medical School and Center for Visual Science*

Co-authors: Hector Baez, University of Rochester Center for Visual Science and Biomedical Education Department; Karteek Kunala, University of Rochester Center for Visual Science; Derek Power, University of Rochester Center for Visual Science; Jesse Schallek, Flaum Eye Institute and Center for Visual Science; Juliette McGregor, Flaum Eye Institute and Center for Visual Science

The non-human primate (NHP) is the gold standard animal model for preclinical development of gene and cell based therapies for vision restoration. However, the ocular immune response to these interventions remains poorly understood. We conducted a proof of concept study using offset aperture adaptive optics scanning light ophthalmoscopy (AOSLO) to visualize cellular-scale changes in the primate retina following photoreceptor (PR) ablation. Ultrafast 730nm laser exposure at 26.6 - 32.5 J/cm2 was used to create six lesions in four NHPs. Offset aperture images focused on retinal vascular layers were collected with an offset distance of ~10 Airy Disk Diameters from 15 minutes up to three hours after PR ablation. We observed putative immune cells in and around vessels supplying the lesioned areas. Consistent with previous findings in murine models, cells within vessels adhered to the inner wall, exhibited crawling behavior, and had a diameter ranging from ~9.3 - 11.5 µm. Additionally, we observed the emergence of cellular-scale structures above the PR layer that originated in the center of the lesion 15 minutes post-insult and gradually radiated outward. Vascular perfusion was maintained in these regions. Our data suggest that offset aperture imaging offers cellular-scale, label free, *in vivo* assessment of the retinal response to insult in NHPs and could be employed to advance our understanding of the ocular immune response provoked by disease and therapeutic interventions.

Funding acknowledgements: Research reported in this publication was supported by the National Eye Institute of the National Institutes of Health under the AGI initiative NIH U24 EY033275 (to McGregor), R01 EY028293 (Schallek), CVS core support from NIH P30 EY0001319. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Inst. of Health. Additional funding from the Steven. E. Feldon Scholarship from the Flaum Eye Institute (McGregor), a Career Development Award, Career Advancement Award (Schallek) and Unrestricted Grant to the University of Rochester Department of Ophthalmology from Research to Prevent Blindness, New York, New York and a summer fellowship from the University of Rochester Medical School (Ashbery).

Immune cell speed changes over 5 orders of magnitude in response to inflammation in the retina

Kosha Dholakia*, University of Rochester*

Co-authors: Jin Won Huh, University of Rochester; Jesse Schallek, University of Rochester

Inflammation in vascularized tissues is mediated by circulating immune cells that are recruited to damaged tissue. Immune cells undergo dramatic changes in speed and motility indicating the severity and staging of inflammation. Here, we characterize the spectrum of retinal leukocyte kinetics in response to an acute inflammatory stimulus using adaptive optics scanning light ophthalmoscopy (AOSLO) in living mice.

C57BL/6J male mice were injected intravitreally with 1 µL lipopolysaccharide (LPS) and imaged at 6, 24 and 72 hours after LPS injection using phase contrast and fluorescence AOSLO. Speed of circulating leukocytes (n= 286 cells, 2 mice) was measured with 15kHz point-scan imaging using automated approach (Joseph et al. 2019). Rolling leukocytes (n=300 cells, 5 mice, 6 hrs after LPS) and extravasated cells (n=92 cells, 8 mice) were visualized with time-lapse imaging and manually tracked using ImageJ.

Using our custom AOSLO, we observed leukocyte speeds spanning 5 orders of magnitude in the living retina. The fastest speeds were the circulating leukocytes (13,257.37 ± 7,086.41 µm/s). After LPS, leukocytes roll along the venular wall, where cell speed was 1000x slower (11.45 ± 7.45 µm/s.) When immune cells extravasated into the tissue, cell speed dropped further by 100x (0.3 ± 0.15 µm/s).

Observed leukocyte speeds cluster around three distinct velocity bands that stratify the unique and purposeful behavior of these cells as they progress through the inflammatory cascade.

Funding acknowledgements: NIH Grant R01 EY028293, P30 EY001319, Career Development Award, Career Advancement Award (Schallek) and Unrestricted Grant to the University of Rochester Department of Ophthalmology from Research to Prevent Blindness, New York, New York , and a research collaboration grant from Genentech Inc.

Ex-vivo human crystalline lenses geometrical changes during simulated disaccommodation

Eduardo Martinez-Enriquez*, Instituto de Óptica, Consejo Superior de Investigaciones Cientificas, Madrid, Spain*

Co-authors: Bianca Maceo Heilman, Ophthalmic Biophysics Center, Bascom Palmer Eye Institute, University of Miami Miller School of Medicine, Miami, FL, United States; Department of Biomedical Engineering, University of Miami College of Engineering, Coral Gables, FL, United States. ; Alberto De Castro, Instituto de Óptica, Consejo Superior de Investigaciones Cientificas, Madrid, Spain.; Ashik Mohamed, Ophthalmic Biophysics, L V Prasad Eye Institute, Hyderabad, Telangana, India; Brien Holden Vision Institute Limited, Sydney, NSW, Australia.; Marco Ruggeri, Ophthalmic Biophysics Center, Bascom Palmer Eye Institute, University of Miami Miller School of Medicine, Miami, FL, United States.; Fabrice Manns, Ophthalmic Biophysics Center, Bascom Palmer Eye Institute, University of Miami Miller School of Medicine, Miami, FL, United States; Department of Biomedical Engineering, University of Miami College of Engineering, Coral Gables, FL, United States. ; Susana Marcos, Instituto de Óptica, Consejo Superior de Investigaciones Cientificas, Madrid, Madrid, Spain; Center for Visual Science. The Institute of Optics. Flaum Eye Institute, University of Rochester, Rochester, NY, United States.

The young crystalline lens changes its shape to focus targets at different distances, a capability (accommodation) that is lost with age. Quantifying crystalline lens morphology during accommodation and aging is essential for understanding basic mechanisms of function and disease (presbyopia and cataract).

We studied the geometrical changes of the ex-vivo human crystalline lens while simulating different levels of physiological disaccommodation using a motorized lens-stretcher system designed for this purpose. 14 human lenses (11-54 y/o) from donor eyes were radially stretched mounted in the lens-stretcher and immersed in a cuvette filled with balanced salt solution for preservation purposes. Lens geometry and power were characterized using custom-developed high resolution 3-D optical coherence tomography (OCT) and laser ray tracing system coupled with the OCT.

The lens thickness decreased linearly 81 microns/diopter (D) of simulated disaccommodation (-r=0.87, $p<0.001$), the diameter increased 76 microns/D (r=0.84, $p<0.01$), the radius of curvature of the anterior surface increased 0.63 mm/D (r=0.92, $p<0.001$), the lens surface area increased 1.9 mm2/D (r=0.62, $p<0.01$) and the lens volume remained constant. The same stretching displacement produced larger

deformations in younger than in older lenses.

Simultaneous high resolution optical and geometrical measurements of stretched lenses therefore match results *in vivo* and support the Helmholtz theory of accommodation.

Funding acknowledgements: European Project IMCUSTOMEYE H2020-ICT-2017 Ref. 779960; European Project SILKEYE H2020-ERC-2018-ADG Ref.833106; Spanish government grant PID2020-115191RB-I00, NIH Grants P30; Research to Prevent Blindness Departamental Funds to Flaum Eye Institute and Bascom Palmer Eye Institute; NIH NIE P30EY 001319; Unrestricted Funds Research to Prevent Blindness, NY; National Institutes of Health (R01EY021834; a National Institutes of Health Center Core Grant (P30EY014801); Florida Lions Eye Bank and Beauty of Sight Foundation; Hyderabad Eye Research Foundation.

Detecting subclinical keratoconus by mapping corneal biomechanics using wave-based optical coherence elastography

Fernando Zvietcovich, *"Daza de Valdes" Institute of Optics, The Spanish National Research Council - CSIC, Madrid 28006, Spain*

Co-authors: Judith Birkenfeld, "Daza de Valdes" Institute of Optics, Spanish National Research Council, Madrid, Spain; Nicolas Alejandre-Alba, Ophthalmology Department, Fundación Jiménez Díaz University Hospital, Madrid, Spain; Jesus Merayo, Fernandez-Vega Institute, University of Oviedo, Oviedo, Spain.; Susana Marcos, The Center of Visual Science, University of Rochester

The detection of subclinical keratoconus in human corneas remains a challenging task. It is hypothesized that the focal reduction in biomechanical properties of the cornea would be the primary initiating event of keratoconus before changes in topography and pachymetry are manifested. We propose to use an air-couple ultrasonic optical coherence elastography system to map the elasticity of the corneas of 15 patients with a clinical diagnosis of keratoconus (KC) in one eye, and subclinical keratoconus (SK) in the fellow eye. The fully non-contact system excites the corneal apex to produce Lamb wave propagation and measures wave speed and average corneal thickness along 16 semi-meridians. Measurements in 30 human healthy subjects (control group: CG, N = 60 corneas) defined a baseline of normal biomechanics in two biomarkers: Spatial Anisotropy of Wave Speed (SAWS < 0.207), and the Speed-Thickness Index (STI > 0). SAWS was significantly higher in KC (0.353, $p < 0.001$) and SK (0.249, $p < 0.001$) corneas when compared to the CG. Moreover, STI maps show abnormal elasticity in SK (STI = -1.22) and KC (STI = -0.375) compared to the CG. Our results show important biomechanical differences in SAWS and STI between normal, subclinical, and advanced stages of keratoconus, suggesting those as potential biomarkers to identify “at-risk” corneas before changes in topography and pachymetry become evident.

Funding acknowledgements: Horizon 2020 Framework Programme European Project Imcustomeye (H2020-ICT-2017 Ref. 779960); European Research Council (2018-ADG-SILKEYE-833106); Spanish Government10.13039/100014440 (CSIC JAE Intro Fellowship); L'Oréal-UNESCO “For Women in Science” Spain; Spanish Government Juan de la Cierva-Incorporation Fellowship (IJC2018-037508-I); Spanish Government PID2020-115191RB-I00; NIH NIE P30EY 001319; Unrestricted Funds Research to Prevent Blindness, NY

Imaging the visual brain at high spatiotemporal resolution

Na Ji, *University of California, Berkeley*

Since the discovery of orientation-selective neurons in the cat primary visual cortex (V1), how the mammalian nervous system computes the orientation of visual stimuli has been a flagship question in neuroscience. With the recent advances in *in vivo* imaging of neural activity using genetically encoded indicators and two-photon fluorescence microscopy, we can now achieve synapse-resolving functional imaging and kilohertz imaging of membrane voltage in the mouse V1. I will describe our recent advancements in imaging visual processing at high spatiotemporal resolution, as well as two studies on the orientation selectivity of neurons in the mouse visual pathway.

Three-photon imaging reveals the neural basis of fMRI across cortical layers

Prakash Kara, *University of Minnesota*

V1 is ideally suited to study the spatial organization of neurovascular coupling at the level of synapses, neurons, individual blood vessels and laminar-resolution fMRI. This is because at least in layers 1 and 2/3 of V1, the functional micro-architecture for neurons, synapses and blood vessels has been determined using 2-photon imaging (Ohki et al 2005 Nature; Kara and Boyd 2009 Nature; O'Herron et al 2016 Nature). Hence, feature selectivity, e.g., orientation and direction selectivity of spiking, synaptic and hemodynamic activity in layer 2/3 is known. However, the micro-architecture of layer 4 neural activity (spiking and synaptic) along with individual blood vessel responses is unknown because conventional 2-photon imaging cannot access deeper cortical layers. The organizing principles of neural maps and the selectivity of hemodynamic responses is of paramount importance for laminar processing because the thalamic inputs arriving into layer 4 are untuned. 3-photon imaging triples the imaging depth compared to 2-photon imaging. Using this optical technique and high-resolution fMRI, we have determined the extent to which different types of neural (spiking, synaptic) and vascular signals (blood flow from individual vessels and fMRI voxels) are coupled across cortical layers in the cat V1. Our data show systematic changes in selectivity of hemodynamic signals across cortical layers that have clear underpinnings in neural circuitry and the propagation of hemodynamic signals.

Development of natural scene processing continues after the critical period for ocular dominance plasticity closes

Sandra Kuhlman, *Carnegie Mellon University*

The development of the visual system is known to be shaped by early-life experience. How complex responses to naturalistic scenes emerge from neurons that are innately tuned to simple orientations is an active area of investigation. Using 2-photon calcium in awake mice, we found that natural scene discriminability increases by 75% between the ages of 4 to 6 weeks in primary visual cortex. This increase in decoding accuracy is accompanied by a shift in neuronal preference towards natural scenes. Natural scene discriminability, therefore, continues to improve past the peak of the critical period for ocular dominance plasticity at postnatal day (p) 28. Notably visual deprivation specifically from p28 to p42 interfered with the full development of this preference shift and impaired natural scene decoding accuracy. We are currently exploring the circuit basis for this protracted development. We speculate that a sequential progression in which neurons first prefer simple stimuli such as oriented bars of light (grating stimuli) prior to the development of selectivity for complex features may help ensure that the spatial organization of receptive fields is maintained as the system becomes refined to represent salient visual cues as animals expand their behavioral repertoire and learn to navigate complex environments.

2021 Edgar D. Tillyer Award Recipient

The Early Visual Encoding: Computations and Consequences

David Brainard, *University of Pennsylvania*

The visual system takes sensory measurements of the light incident at the eyes and uses these to make perceptual inferences about external world. The sensory measurements do not preserve all of the information available in the light signal. One approach to understanding the implications of the initial stages of visual processing is ideal observer analysis, which evaluates the information available to support psychophysical discriminations at various stages of the early visual representation. We are interested in extending this type of analysis to take into account the statistical structure of natural images. To do so, we developed an open-source computational model of the initial visual encoding, ISETBio (isetbio.org). ISETBio incorporates specification of visual displays, retinal image formation through the eye's optics, spatio-spectral sampling by the retinal cone mosaic, Poisson noise in the cone photopigment excitations, transduction of excitations to photocurrent, and fixational eye movements. In this talk, I will introduce ISETBio and illustrate a set of insights it enables about visual processing by reviewing a number of computational examples. These examples will include ways that combining ISETBio with Bayesian image-reconstruction methods helps us understand how the interaction of the visual encoding and the statistical structure of natural images shapes visual performance.

2022 Edgar D. Tillyer Award Recipient

Visual Control of Locomotion in Natural Environments

Mary Hayhoe, *UT Austin*

Control of locomotion is clearly an important role for vision, but one that we know little about. Considerable attention has been devoted to the potential role of retinal motion patterns, generated by self-motion, in steering towards a goal. These motion patterns are determined by an interconnected set of factors, including gaze location, gaze stabilization, the structure of the environment, and the walker's behavioral goals. We have collected measurements of the eyes, the body, and the 3D environment during locomotion in natural terrains. This has allowed us to explore the resulting retinal motion patterns, and how they might be used to guide behavior. Large variations in head direction during the gait cycle make it problematic for use in steering towards a goal, but gaze stabilization leads to regularities in the retinal motion patterns that could provide a postural control signal during locomotion. Another aspect of the visual control of locomotion is the choice of foot placement in rugged terrain. We examined the role of local height changes in the terrain, and showed that visual selection of footholds reflects a complex interplay between energetic costs and the need for stable foot placement. Thus visual signals about motion and depth act as time-varying local control signals for the momentary disposition of the body rather than steering toward more distant goals.

In vivo study of higher-order retinal hemodynamics in human retinal capillaries

Yuhua Zhang, *Doheny Eye Institute, Department of Ophthalmology, University of California - Los Angeles*

Pulsatile erythrocyte flow in human retinal capillaries reflects the capillary-blood flow system's mechanical condition and represents a fundamental functioning aspect of retinal microcirculation. Inside the capillary, the erythrocytes are continuously accelerated and decelerated by systemic pressure and hydrostatic and osmotic pressures periodically with the heartbeat. This process can be described by the Navier-Stokes equation: $\rho(\partial v/\partial t+v\cdot\nabla v)=-\nabla P+\nabla\cdot T$, ρ is the density, v is the velocity, P is the pressure, and T represents the stress tensor. The time variation of the flow velocity ($\partial v/\partial t$), i.e., the acceleration, is a higher-order dynamics term (compared to velocity) of the pulsatile flow, reflects the temporal variation of the hemodynamic forces, and informs the dynamic mechanical properties of the erythrocyte-capillary system. Higher-order dynamics relating to the acceleration of the erythrocytes in retinal capillaries have not been investigated in the human eye due to inadequate technical measures. This study aims to characterize the higher-order retinal hemodynamics and identify sensitive biomarkers for quantifying age-related changes in the retinal microcirculation using high-speed adaptive optics near-confocal ophthalmoscopy. In human subjects in normal physical health with different ages, we demonstrate that higher-order hemodynamic characteristics of the erythrocyte flow in the retinal capillary can disclose age-related differences in the retinal microcirculation.

Funding acknowledgements: NIH R01EY024378), W. M. Keck Foundation, Carl Marshall Reeves & Mildred Almen Reeves Foundation, and Research to Prevent Blindness/Dr. H. James and Carole Free Catalyst Award for Innovative Research Approaches for AMD.

Seeking Answers through a keyhole: Harnessing the Synergy of Dynamic OCT/OCT Angiography and Adaptive Optics SLO for Retinal Assessment of Systemic Disease

Richard Rosen, *New York Eye and Ear Infirmary*

Co-authors: Oscar Otero-Marquez[1]; Justin Migacz[1]; Davis Zhou[1]; Alexander Pinhas[1]; Maria Castanos[1]; Sofia Ahsanuddin[1]; Kara Rickford[1]; Brian Murillo[1]; Rebecca Zhou[1]; Lily Spellman[1]; Nrupin Sredar[2]; Peter Gillette[3]; Rishard Weitz[1]; Jeffrey Glassberg,[4]; Alfredo Dubra[2]; Toco Chui[1]

[1]New York Eye and Ear Infirmary, [2]Stanford University, [3]Kings County Hospital, [4]Icahn School of Medicine at Mount Sinai

The retina is our only non-invasive access to microworld of the body's capillaries and cellular activities. Leveraging the multimodal synergy of combining dynamic methods of OCT/OCTA, with Adaptive Optics SLO, clinicians have new opportunities to better appreciate some of the complexities of human disease. Serial OCTA imaging can reveal inconsistencies in retinal perfusion not appreciated on single images and can be used to measure activity status of sickle cell microvasculopathy. This approach facilitates earlier detection and immediate assessment of disease burden. AOSLO imaging provides cellular level resolution for confirmation of these OCTA events. En face OCT reflectance images which accompany OCTA studies offer a glimpse of the macrophage-like cellular activity above the retinal surface which responds to systemically instigated vascular events below. The complementary use of AOSLO to characterize morphology of these cells provides clues to their activation status and potential role in tissue maintenance and repair. Features of clinical OCT/OCTA interpreted by AOSLO imaging have the potential to become useful clinical biomarkers of disease activity and response to treatment.

Funding acknowledgements: National Eye Institute of the National Institutes of Health under award numbers R01EY027301, P30EY026877, R01EY031360, R01EY032147, R01EY032669, Marrus Family Foundation, Wise Family Foundation, J Milbank Foundation, New York Eye & Ear Research Foundation, Jorge N. Buxton Microsurgical Foundation, Violett Charitable Foundation, Challenge Grant award from Research to Prevent Blindness

Early prediction of multiple sclerosis using scanning laser ophthalmoscopy (SLO) video sequence data with a Deep Learning (DL) based approach

Joe Xing, *C. Light Technologies, Inc., San Jose, United States*

Co-authors: A. Green, University of California San Francisco, San Francisco, United States, C. Sheehy, C. Light Technologies, Inc., Boston, United States

Introduction: Multiple Sclerosis (MS) is a chronic immune-mediated inflammatory disease (IMID) of the central nervous system (CNS). Early identification of MS, especially as a screening method for at-risk individuals, is crucial to delay disease progression and improve patient outcomes by preventing future irreversible neurologic damage. In this work, we utilize well-validated tracking scanning laser ophthalmoscope (TSLO) image to predict MS compared to the unaffected controls. While traditional Machine Learning (ML) methods, such as Logistic Regression (LR), have demonstrated a strong predictive power [Mauro F. Pinto et al., 2020] in disease identification, we propose the use of a novel DL based model. Though the use of Deep Neural Network (DNN), this model can have a much higher learning capacity to capture latent features embedded in the retinal images. We hypothesize that such latent information, often hidden in ML feature engineering processes, plays an important role for the prediction of disease and can be well represented by DL models.

Objectives: To establish a DL based model capable of learning latent image features to provide predictive power for the presence of MS.

Aims: Utilize a deep convolutional neural network to extract the retinal coding and implement a recurrent neural network to learn the temporal correlations in video sequences.

Methods: Our approaches were tested using a 250-subject MS/control database collected at the UCSF. Patients with Expanded Disability Status Scale (EDSS)< 4 are compared to healthy subjects. Both raw retinal images and the frequency and spatial patterns of the eye motion are combined to construct a hybrid image, denoted as “retinal coding”, and directly fed to the DL model for training and testing.

Results: Preliminary results on predictive power were measured using Area-under-Curve (AUC) of the Receiver Operating Characteristics (ROC) curve, sensitivity, and specificity,

as well as an F-1 score. We observe an AUC of 0.920, sensitivity of 0.90, specificity of 0.89 and F-1 score of 0.89 using the DL model to distinguish MS from controls, which outperforms the baseline LR model by 24%.

Conclusions: This work can be considered as a proof-of-concept concerning the possibility of identifying MS disease using a DL based approach. The results demonstrate the possibility of predicting early-stage MS and understanding disease's dynamics. Such end-to-end model could be generalizable and trained on other disease states.

Disturbances of retinal structure in schizophrenia spectrum disorders and their clinical implications

Steven M. Silverstein, Ph.D., *Departments of Psychiatry, Neuroscience, and Ophthalmology, University of Rochester*

Schizophrenia (SZ) is a disabling psychiatric condition that is characterized by disturbances in reality testing (e.g., hallucinations, delusions) during its acute phase and by many brain-related impairments. It has become apparent, however, that the CNS disturbance in SZ extends to the retina. Studies have demonstrated retinal structural (neural and vascular) and functional (e.g., ERG) changes in SZ, although findings vary in effect size and confounds are often present. This presentation will review several studies from my lab that used OCT and OCTA to investigate retinal characteristics of people with SZ, with a focus on characterizing within-group heterogeneity. Results indicate that: 1) retinal thinning is present at the macula, but not until several years after the first psychotic episode; 2) reductions in microvasculature density are observable as early as the first episode and worsen over time at a greater rate than expected by age alone; 3) microvasculature reductions are present in both the superficial and deep retinal layers; and 4) issues such as diabetes, smoking, and obesity must be carefully considered when studying the retina in SZ. Findings will be discussed within the context of the emerging view that SZ is multi-system disorder with a significant vascular-ischemic component.

Funding acknowlegements: supported by a grant from the New York Fund for Innovation in Research and Scientific Talent (NYFIRST)

Characteristics of electrically-induced visual percepts in the first human with the Intracortical Visual Prosthesis

Michael P Barry, *Illinois Institute of Technology*

Co-authors: Roksana Sadeghi, Johns Hopkins University; Vernon L Towle, University of Chicago; Kelsey Stipp, Illinois Institute of Technology; Patricia Grant, The Chicago Lighthouse for People Who Are Blind or Visually Impaired; Frank John Lane, Illinois Institute of Technology; Janet P Szlyk, The Chicago Lighthouse for People Who Are Blind or Visually Impaired; Gislin Dagnelie, Johns Hopkins University; Philip R Troyk, Illinois Institute of Technology

The Intracortical Visual Prosthesis (ICVP) consists of multiple wireless floating microelectrode arrays (WFMAs), each with 16 stimulating electrodes. Stimulation of these electrodes can potentially provide artificial vision for people who are blind. Twenty-five WFMAs were implanted in the right occipital visual cortex of a participant in an FDA-approved, NIH-sponsored Phase 1 clinical trial (NCT04634383). Here, we report characteristics of visual percepts elicited by the WFMAs (frequency: 200 Hz, cathodic phase duration: 200 μs, amplitude and train length up to 60 μA and 900 ms). Stimulation of single electrodes in 10 WFMAs and groups of 4 or more electrodes in 7 additional WFMAs consistently produced percepts during >10 sessions across approximately 3 months of testing. Phosphenes generated within a single WFMA were typically similar in appearance. Descriptions included configurations of rings, bright or dark dots, and constant or flickering bars, with sizes of 0.3–12° across. Phosphenes appeared as blueish-white, or occasionally orange, red, or having an iridescent texture. Ten WFMAs produced phosphenes within a 4° cluster centered 4° below and to the left of fixation. Phosphenes from 4 other WFMAs were located 4° below or 20° left of the cluster. When using these phosphenes to scan a virtual line, the participant was able to discriminate horizontal and vertical lines (46/51 correct, $p < 10^{-8}$, binomial test), and 45° and 135° diagonal lines (12/14 correct, $p < 0.01$).

Funding acknowledgements: NIH Grant # 4UH3NS095557-03

Identifying Specific Neural Substrates for Bayesian-like Computations in Binocular Vision and Multisensory Processing

Vincent A. Billock, *Leidos, Inc. at the Naval Aerospace Medical Research Laboratory, Naval Medical Research Unit - Dayton*

Co-authors: Kacie Dougherty, Princeton Neuroscience Institute, Princeton University; M. Alex Meredith, Dept. of Anatomy & Neurobiology, Virginia Commonwealth University; Adam M. Preston, Naval Aerospace Medical Research Laboratory, Naval Medical Research Unit - Dayton

Bayesian thinking is influential in vision but the grounding of Bayesian computation in wetware is poorly understood. Bayesian reliability (inverse variance) weighting of inputs is predicted by Maximum Likelihood Estimation Theory and has some psychophysical support, but evidence for neural reliability weighting is sparse and neural modeling of reliability weighting is tricky. However, reliability averaging is just one possible perceptual weighted average. An alternative – nonlinear magnitude-weighted averaging – was suggested by Schrodinger in 1926 to account for suprathreshold binocular perception and is available to repurpose for other sensory cue combinations. We identified macaque suppressive binocular neurons that implement nonlinear magnitude-weighted averaging and approximate Bayesian averaging, without suffering the computational difficulties that Bayesian averaging implies. We then applied the binocular modeling to suppressive multisensory (visual-tactile, audio-tactile, and audio-visual) neurons. Although magnitude-weighting is a better fit than reliability-weighted averaging for cortical firing rates (in all four cases and in three different species), nonlinear magnitude-weighted averaging is well correlated with reliability averaging. Magnitude-weighted averaging could serve as a surrogate for Bayesian calculations; mildly suppressive binocular and multisensory bimodal neurons could be neural correlates of Bayesian-like computation in the brain.

Funding acknowledgements: MAM: NIH NS039460; KD: 1R01EY027402-02, T32EY007135, and core grant P30EY008126; VAB & AMP: Office of the Assistant Secretary of Defense for Health Affairs & the Defense Health Agency J9 Research and Health Directorate, Defense Health 6.7 Program #DP_67.2_17_J9_1757, work unit # H1814.

In vivo calcium imaging of macaque foveolar retinal ganglion cells reveals spatiochromatic receptive field properties

Tyler Godat, *University of Rochester*

Co-authors: Nicolas P. Cottaris, University of Pennsylvania; Sara Patterson, University of Rochester; Kendall Kohout, University of Rochester; Keith Parkins, University of Rochester; Qiang Yang, University of Rochester; Jennifer M. Strazzeri, University of Rochester Medical Center; Juliette E. McGregor, University of Rochester; David H. Brainard, University of Pennsylvania; William H. Merigan, University of Rochester; David R. Williams, University of Rochester

Here, we optically record responses to spatial and chromatic stimuli using a calcium indicator in the living macaque eye to characterize the receptive field (RF) properties of retinal ganglion cells (RGCs) serving the foveal center. GCaMP6s was expressed in three female macaques. Adaptive optics ophthalmoscopy was used to image fluorescence (488nm ex, 520/35nm em) from RGCs whose RF centers were driven by cones in the central 36 arcmin of the fovea and additional RGCs driven by cones in the central 6 arcmin of the foveola. Using cone isolating and luminance flicker (1.3deg, 0.15Hz, LED 420nm, 530nm, 660nm), we derived cone weights in over 250 RGCs. Using drifting gratings (1.9deg, 6Hz, 4-50c/deg, 561nm), we derived the spatial frequency responses of 15 L vs. M cone opponent RGCs at the foveolar center. Employing computational modeling (ISETbio), we inferred the full spatial difference of gaussians center and surround structure for those 15 cells. Of the 34 foveolar RGCs, 44% exhibited L vs. M cone opponency, 15% were L+M ON, 6% were -L-M OFF, and 35% showed only L or only M responses. The spatial frequency response functions of 12/15 L vs. M opponent cells peaked at high spatial frequencies (25-40c/deg) and had a strong bandpass characteristic. Our model indicates that the responses of all 15 L vs. M opponent cells are consistent with single cone input to their RF centers and that our data are consistent with extrafoveal data when the blurring of the optics is accounted for.

Funding acknowledgements: This work was supported by the National Eye Institute through grants NIH EY007125, NIH U01EY025497, NIH EY031467, NIH EY021166, and through an unrestricted grant to the Flaum Eye Institute from Research to Prevent Blindness.

Preclinical & clinical evaluation of flavoprotein fluorescence as a label-free biomarker of retinal mitochondrial stress

Tiffany Heaster, *Genentech*

Co-authors: Julia Kim, Genentech; Sofia De Arrigunaga, Massachusetts Eye and Ear, Harvard Medical School; Joyce Kang, Massachusetts Eye and Ear, Harvard Medical School; Sandra Freeman, Massachusetts Eye and Ear, Harvard Medical School; Michael Lin, Massachusetts Eye and Ear, Harvard Medical School; Simon Gao, Genentech; David Friedman, Massachusetts Eye and Ear, Harvard Medical School; Dolly Chang, Genentech; Justin Elstrott, Genentech

Retinal oxidative stress is linked to the development and progression of various retinal diseases including AMD and glaucoma. In response to oxidative stress, flavoproteins within the electron transport chain become oxidized and autofluoresce upon blue light exposure. We investigated the specificity of flavoprotein fluorescence (FPF) to mitochondrial oxidative stress in retinal cells in vitro and its reliability as a clinical biomarker for longitudinal monitoring of glaucoma. Preclinical FPF evaluation assessed mitochondria-specific FPF and reactive oxygen species (ROS) in retinal cells via confocal microscopy to characterize response to injury and oxidative stress perturbations. FPF intensity was directly correlated with increased stress-induced mitochondrial ROS (R2=0.693), confirming FPF signal origin. Clinical FPF measurements were evaluated using the OcuMet Beacon, a noninvasive retinal metabolic imaging device. FPF images were collected at macular and peripapillary regions of patients with stable glaucoma or glaucoma suspects (n=52) during baseline and three-month follow-up visits. Macular and peripapillary FPF scores showed strong correlation between patient baseline and follow-up measurements (r=0.996, lens-adjusted r=0.937, 0.972). These results confirm the relationship between FPF and oxidative stress in retinal cells and highlight FPF as a reproducible clinical imaging biomarker, supporting further discovery in rodent disease models and additional patient cohorts.

Funding acknowledgements: Genentech

Posters

P1

Dynamic visual processing in post-saccadic V1 visual responses of the marmoset monkey

Yonatan Abrham, *Brain and Cognitive Sciences, University of Rochester*

Co-authors: Jacob Yates, Vision Sciences, University of California at Berkeley; Jude F. Mitchell, Brain and Cognitive Sciences, University of Rochester

All animals with image-forming eyes sample visual information through a "saccade and fixate" pattern of eye movements (Land and Nilsson, 2012). Here, we investigated how perisaccadic neural responses during free-viewing of natural images relate to the tuning properties of neurons in primary visual cortex (V1). We recorded from V1 in two marmoset monkeys using linear arrays as they freely viewed full-field natural scenes. We found that on average neural responses time-locked to saccade onset exhibited an early suppression followed by a post-saccadic rebound in excitatory activity. To determine whether the latency of these saccade dynamics varied with neural tuning properties we mapped tuning for spatial and temporal frequency, and orientation selectivity. In those trials marmosets free-viewed flashed full-field gratings that varied in spatial frequency and orientation. Among the neurons with significant orientation tuning, we observe a significant correlation between spatial frequency preference and the latency of post-saccadic rebound, with neurons tuned to higher spatial frequencies responding later. These results support the idea that neural responses during the saccade-fixation cycle follow coarse-to-fine distinctions proposed to operate in early visual processing (Burr, 1981; Watt, 1987; Hedge, 2008, Boi et al., 2017).

Funding acknowledgements: JFM from NIH EY030998; JY from NIH R00EY032179

P2

Retinal Changes Associated with Football-Related Concussions and Head Impacts

Jason B. Atlas, *University of Rochester School of Medicine & Dentistry*

Co-authors: Mia Young, University of Rochester Medical Center; Lyvia Bertolace, University of Rochester Medical Center; Iwona Juskiewicz, University of Rochester Medical Center; Yonaton Abrham, University of Rochester Medical Center; Kian Merchant-Borna, University of Rochester Medical Center; Sarah Dermady, University of Rochester Medical Center; Brian Keane, University of Rochester Medical Center, Department of Psychiatry; Rajeev S. Ramchandran, University of Rochester Medical Center, Department of Ophthalmology; Jeffrey Bazarian, University of Rochester Medical Center, Department of Emergency Medicine; Steven Silverstein, University of Rochester Medical Center, Department of Psychiatry

This pilot study explored the sensitivity of retinal markers to CNS sequelae of concussive and subconcussive head hits. Three groups of college athletes were assessed at pre-season, post-season and 4-months later: Football players with a concussion history (FB+C) (n = 9), players without a concussion history (FB-C) (n = 11), and non-contact athletes (swimmers, track & field; Non-FB) (n = 12). Measures included optical coherence tomography (OCT), OCT angiography, electroretinography, and visual acuity testing. Head impacts during the season were tracked with in-helmet accelerometers. At pre-season, FB+C demonstrated thicker macular central subfields (CSF) (Hedge's g (effect size) = 1.05, p = 0.02) and retinal nerve fiber layers (RNFL) (g = 0.81, p = 0.08), relative to other athletes. Differences in CSF thickness were also observed at post-season and follow-up (gs > 1.00, ps < 0.04), reflecting their non-short-term nature. RNFL was thicker in FB+C at post-season (g = 0.93, p = 0.06) but not later. Total head impacts during the season correlated with increases in CSF thickness from baseline to follow-up only (r = -0.53, p = 0.02). High intensity head impacts in particular correlated with increases in cup-to-disc ratio at post-season and follow-up (rs > 0.53, ps < 0.03). These data suggest that concussion history is associated with retinal changes that are not short-term, and that severe head impacts are associated with acute changes whose duration is not yet known.

Funding acknowledgements: The Schmitt Program on Integrative Neuroscience, in conjunction with the Del Monte Neuroscience Institute at the University of Rochester

P3

High myopia and macular pigment optical density (MPOD) study

Shashank Bhandary, *L.V Prasad Eye Institute*

Co-authors: Payal Sangani, L.V Prasad Eye Institute; Brijesh Takkar, L.V Prasad Eye Institute; Raja Narayanan, L.V Prasad Eye Institute; Pavan Verkicharla, Verkicharla

Purpose:
To evaluate relationship between axial length, chorio-retinal structure and high Macular pigment optical density (MPOD) values in high myopia.

Methods:
This is a prospective ongoing cross-sectional study including healthy participants with myopia, high myopia and emmetropia. The current analysis presents preliminary data of 17 eyes. Ocular biometry, optical coherence tomography angiography, macular pigment eye (MP-eye) and Visucam 500 (MPOD module) was performed for each participant. Diet consumed by the participants was recorded using a previously developed food frequency questionnaire (FFQ) using Indian food composition table (IFCT)-2017 that specifically judges the intake of macular pigments.

Results:
Mean age was 25 +/- 3.4 yrs (20-33) with a male: female ratio of 4:12. Refractive errors such as myopia (9 eyes), emmetropia (4 eyes), high myopia (3 eyes) and unilateral myopia (1) were selected. There was a significant difference (C.I: 3.7 – 5.4, $p<0.05$) between MP-eye (4.7 ± 1.7) and mean MPOD (0.09 ± 0.02) scores using paired samples test.

Conclusion:
These preliminary results are promising and form the basis of our larger ongoing evaluation. MPOD may have a causal relationship and may serve as a preventive therapy for high myopia.

P4

Estimation of scleral biomechanical properties from air-puff-coupled optical coherence tomography

Judith S. Birkenfeld, *Instituto de Óptica "Daza de Valdés", Consejo Superior de Investigaciones Científicas (IO-CSIC), Madrid, Spain*

Co-authors: Lupe Villegas, Instituto de Óptica "Daza de Valdés", Consejo Superior de Investigaciones Científicas (IO-CSIC); Andrés de la Hoz, Instituto de Óptica "Daza de Valdés", Consejo Superior de Investigaciones Científicas (IO-CSIC); David Bronte-Ciriza, CNR – IPCF, Istituto per I Processi Chimico-Fisici; Alejandra Varea, Instituto de Óptica "Daza de Valdés", Consejo Superior de Investigaciones Científicas (IO-CSIC); Eduardo Martínez-Enríquez, Instituto de Óptica "Daza de Valdés", Consejo Superior de Investigaciones Científicas (IO-CSIC); Andrea Curatolo, ICTER and Institute of Physical Chemistry, Polish Academy of Sciences; James A. Germann, Instituto de Óptica "Daza de Valdés", Consejo Superior de Investigaciones Científicas (IO-CSIC); Susana Marcos, The Center for Visual Science, University of Rochester

Progression of myopia is usually accompanied by axial overgrowth of the eyeball, which affects scleral biomechanics (BM). To study scleral biomechanics, we propose the use of air-puff deformation swept-source OCT imaging. Air-puff deformation imaging was performed at different sites of *ex vivo* porcine (n=5) and rabbit (n=3) eyes, (<24hr postmortem): Nasal/temporal equatorial and posterior sclera (NE, NP, TE, TP), superior (S) and inferior (I) sclera, and cornea (C). Intraocular pressure was kept at 15mmHg. Deformation data were used as input to inverse finite element model (FEM) algorithms to reconstruct BM properties. Experimental deformation amplitudes showed dependence on the animal model, with porcine scleras exhibiting greater inter-site variation (displacement of S, I was up to four times greater than that of N, T), while rabbit scleras exhibited at most 40% of displacement differences between all sites. Both models showed significant ($p<.001$) differences in the temporal deformation profile between sclera and (C), but similarities in all scleral locations, suggesting that the scleral temporal profile is independent of scleral thickness variations. The FEM estimated an elastic modulus of 1.84 ± 0.30 MPa (I) to 6.04 ± 2.11 MPa (TE) for the porcine sclera. The use of scleral air-puff imaging is promising for noninvasive investigation of structural changes in the sclera associated with myopia and for monitoring possible modulation of scleral stiffness with myopia treatment.

Funding acknowledgements: Horizon 2020 Framework Programme European Project Imcustomeye (H2020-ICT-2017 Ref. 779960); European Research Council (2018-ADG-SILKEYE-833106); Spanish Government10.13039/100014440 (CSIC JAE Intro Fellowship); L'Oréal-UNESCO "For Women in Science" Spain; Spanish Government Juan de la Cierva-Incorporation Fellowship (IJC2018-037508-I); Spanish Government PID2020-115191RB-I00; Fundacja na rzecz Nauki Polskiej (MAB/2019/12); National Agency for Academic Exchange, Polish Government (NAWA ULAM/2020/1/00176); NIH NIE P30EY 001319; Unrestricted Funds Research to Prevent Blindness, NY

P5

Laminar and cell class distinctions for pre-saccadic attention in marmoset MT/MTC

Amy Bucklaew, *University of Rochester*

Co-authors: Shanna Coop, Stanford University; Gabriel Sarch, Carnegie Mellon University; Jude Mitchell, University of Rochester

Pre-saccadic attention has been related to enhanced neural responses before saccades made into a neuron's receptive field in macaque visual cortex (Moore and Chang 2009). However, much remains unknown about the underlying circuit mechanisms. Using the marmoset, a small New World monkey with a smooth brain, we examined laminar and cell class distinctions during pre-saccadic attention in motion selective areas MT/MTC. In a saccade foraging task, marmosets made a saccade from a central fixation point to one of three equally eccentric random dot field stimuli. We positioned the stimuli such that one foraged location overlapped the receptive fields of neurons under study and examined how tuning functions for motion direction changed. Tuning curves were fit with an adjusted Von Mises curve that estimates baseline, gain, and tuning width. We found in two animals that neurons on average exhibited increases in baseline and gain with pre-saccadic attention, but no changes in tuning width. In a single animal we were able to dissect the population by cell class and layer. We found that increases in gain were predominantly among broad spiking neurons in superficial layers whereas additive increases in rate were shared across layers and cell types. This suggests that superficial layer broad spiking neurons, the putative projection neurons that would relay information to downstream cortical areas, have a privileged role for encoding enhanced motion sensitivity during pre-saccadic attention.

Funding acknowledgements: SC, AB, and JFM from NIH EY030998; GS from NSF GRF 2020305476

P6

Evidence for preserved conscious orientation discrimination in perimetrically-blind fields early after V1-damage

Matthew Cavanaugh, *University of Rochester*

Co-authors: Jingyi Yang, University of Rochester; Berkeley Fahrenthold, University of Rochester; Elizabeth Saionz, University of Rochester; Michael Melnick, University of Rochester; Marisa Carrasco, New York University; Duje Tadin, University of Rochester; Krystel Huxlin, University of Rochester

Cortically-blind (CB) patients with stroke damage to the primary visual cortex (V1) lose conscious vision but many exhibit blindsight - the ability to unconsciously detect or discriminate moving or flickering targets inside their blind-fields. However, the prevalence of conscious visual abilities in CB is less clear. Having developed a new method to assess vision inside perimetrically-defined blind fields, we found that >50% of subacute CB patients (<6 months post-stroke) can consciously discriminate global motion inside their blind field. Here, we asked if they can also discriminate orientation of static targets, which do not typically elicit blindsight. In 10 subacute patients, we mapped their intact and blind hemifields using static, non-flickering, 1cpd Gabors across a wide range of luminance contrasts. Blind-field locations were labeled “preserved” if performance was >72.5% correct. Considering overall performance, only 1 participant had preserved static orientation perception in the blind-field. However, this increased to 4 participants when only considering performance at high contrasts (>50%), all of whom reported awareness of stimuli. Thus, early after V1 damage, conscious percepts for oriented, high-contrast, static targets can remain inside CB fields, similar in incidence to global motion discriminations. We are now testing additional patients to assess if these abilities persist into the chronic period and to detail their underlying neural substrates.

P7

Fixational Eye Movements in Myopia

Ashley M. Clark, *University of Rochester*

Co-authors: Michele A. Cox, University of Rochester; Ruei-Jr Wu, University of Rochester; Janis Intoy, University of Rochester; Michele Rucci, University of Rochester

During fixation, an incessant drift of the eye keeps the image impinging on the retina always in motion. Previous work indicated that luminance modulations from ocular drift serve important visual functions in emmetropes (Intoy & Rucci, 2020; Clark et al 2022). However, it remains unknown how ocular drift varies under myopia, a visual impairment commonly caused by eye elongation. We measured eye movements in 19 individuals with varying degrees of myopia (-0.25D to -6.5D) using a digital Dual-Purkinje Image eye-tracker, a recently developed system with sub-arcminute resolution. Subjects observed stimuli monocularly with vision corrected via a Badal optometer. They engaged in two high-acuity tasks: (a) resolution of a 20/20 line of an eye chart (5 evenly spaced tumbling E optotypes); and (b) a more natural task where subjects were presented with images of distant faces (1^0) and asked to report the image's gaze direction. We show ocular drift characteristics differ in myopes relative to emmetropes. Drift was faster and less curved in myopic observers. On the retina, these changes result in luminance modulations that amplify low spatial frequencies at the expense of high spatial frequencies, so that high-frequency signals are effectively weaker in myopes These results are consistent with the proposal that fine spatial vision strongly relies on oculomotor-induced luminance modulations and emphasize the importance of considering fine eye movements in myopia.

Funding acknowledgements: R01 EY018363, Meta/Facebook Reality Labs

P8

Oculomotor influences on retinal input signals in myopia

Michele A. Cox, Center for Visual Science, *University of Rochester*

Co-authors: Ashley M. Clark, Department of Brain and Cognitive Sciences & Center for Visual Science, University of Rochester; Janis Intoy , Center for Visual Science, University of Rochester; Benjamin Moon, The Institute of Optics & Center for Visual Science, University of Rochester; Ruei-Jr Wu, The Institute of Optics & Center for Visual Science, University of Rochester; Jonathan D. Victor, Weill Cornell Medical College; Michele Rucci, Department of Brain and Cognitive Sciences & Center for Visual Sciences, University of Rochester

Studies of emmetropization have traditionally focused on the spatial characteristics of visual input signals. Yet the input to the retina is not a two-dimensional pattern but a temporally-varying luminance flow. The temporal structure of this flow is predominately determined by eye movements, as the human eyes move incessantly. Even when fixating on a single point, a persistent motion known as ocular drift reformats the luminance flow in a way that counterbalances the spectra of natural scenes. It is established that emmetropes are highly sensitive to these luminance modulations. However, their visual consequences in myopia and hyperopia are unknown. Here, we first review how the temporal-frequency distribution of retinal input signals varies with the amount of ocular drift. We then use a detailed optical/geometrical model of the eye to study how the eye movements jointly shape retinal input as a function of refraction. We show that, within the temporal range of sensitivity of the retina, the spatial frequency distribution of the input signals conveys signed information about defocus. Specifically, for a given degree of defocus, myopic retinas experience more power from low spatial frequency stimuli than hyperopic retinas. These redistribution of input power may have a consequence during eye growth supporting the proposal that eye movements should be taken into consideration in the process of emmetropization.

Funding acknowledgements: Research reported here was supported by Meta Reality Labs and the NEI of the NIH under Award Numbers R01EY018363 (awarded to MR), R01EY07977 (awarded to JDV), and P30EY001319 (core grant).

P9

The Intracortical Visual Prosthesis (ICVP) project: Opportunities for artificial vision and cortical exploration

Gislin Dagnelie, *Johns Hoplins University*

Co-authors: Martin Bak, Microprobes LLC; Richard Byrne, Rush University School of Medicine; Stuart Cogan, University of Texas, Austin; Glenn De MIchele, Sigenics LLC; David Frim, University of Chicago; Janet Szlyk, The Chicago Lightnouse For People Who Are Blind Or Visually Impaired; Vernon Towle, University of Chicago; Philip Troyk, Illinois Institute of Technology; ICVP Study Team, Illinois Institute of Technology

In the quest to provide artificial vision to people with blindness, retinal prostheses were the first approach to demonstrate some clinical success, but their functional benefit remains limited. Cortical prostheses with large subdural electrodes have a longer history, and have recently shown a similar level of benefit in peripheral V1. Using current technology, intracortical electrodes provide the opportunity for creating higher resolution, but human cortical layout restricts this approach to occipital implantation, i.e., predominantly in extrastriate areas, with access to V1 limited to the fovea. The Intracortical Visual Prosthesis (ICVP) uses wireless floating microelectrode arrays (WFMAs), each with 16 stimulating electrodes. Following extensive in-vitro and in-vivo preclinical tests, the FDA issued an IDE and NINDS awarded funding for a phase 1 clinical trial (NCT04634383) in up to 5 volunteers. In February 2022, 25 WFMAs were implanted in the right occipital cortex of the first participant. In this presentation we will consider the implications of early findings for phosphene-based image presentation through WFMAs placed in multiple cortical areas, and the potential for functional artificial vision using this approach, to the extent allowed by data from a single implantee. We will also consider the unique opportunity provided by the 400 μm within-WFMA resolution to explore localized cortical processing in multiple cortical areas at the visual perceptual level.

Funding acknowledgements: UH3 NS095557

P10

Estimation of crystalline lens mechanical properties from patient accommodation data

Andres De La Hoz, *Instituto de Óptica "Daza de Valdés", Consejo Superior de Investigaciones Científicas (IO, CSIC)*

Co-authors: Eduardo Martinez-Enriquez, Instituto de Óptica "Daza de Valdés", Consejo Superior de Investigaciones Científicas ; Susana Marcos, Center for Visual Science, The Institute of Optics, Flaum Eye Institute

Presbyopia is thought to involve changes in stiffness of the crystalline lens. Quantifying such changes poses challenges due to the nature of the lens' materials. One approach has been to use finite element models and deformation profiles of lenses to estimate elastic moduli. In this work, this approach is extended to accommodation data for individual subjects. 11 subjects aged 20 to 30 were measured in an OCT system to record their accommodative response to a 4.5D stimulus. Lens surfaces were reconstructed from a diameter of 6mm and the periphery of the lens was estimated using eigenlenses method. The resulting profiles were used as input for a finite element model of accommodation. The lens was modelled with two primary components (nucleus and cortex) with elastic moduli for each region set as a variable. A load of 0.05-0.06N was used to approximate the accommodative process. An inverse modeling procedure was used to estimate cortical and nuclear moduli, by minimizing the difference between experimental and simulated surfaces at maximum deformed state. Estimated mean nuclear and cortical moduli values were 1.42 kPa (SD 1.16) and 7.07 kPa (SD 4.81). For all lenses evaluated, nuclear modulus was lower than cortical modulus. Age dependence was found for the average elastic modulus (R2 0.83) and for nuclear (R2 0.5) and cortical (R2 0.45) moduli. Results suggest that this method can be used to quantify stiffness of crystalline lens in subjects.

Funding acknowledgements: European project IMCUSTOMEYE H2020-ICT-2017 ref 779960, European prject SIlkeye H2020-ERC-2018-ADG Ref 833106, Spanish government grant PID2020-115191RB-100, NIH grants P30, Research to Prevent Blindness departmental funds to Flaum Eye Institute

P11

Lexical effects on 3D color matches in short- and long-term memory

Prutha Deshpande, *The Ohio State University*

Co-authors: Angela Brown, The Ohio State University; Delwin Lindsey, The Ohio State University

We report a comprehensive within-subjects study of color memory, using 22 colors widely spaced in 3D color space. 10 observers made isomeric color matches on iPads (method of adjustment, 3D CIELAB-based color palette) when the test color was simultaneously present or after delays = 10 or 300 sec (random block design).
To test for lexical effects on color memory, the same observers grouped 1625 Munsell samples before the memory experiment and provided focal colors and unconstrained color terms for the groups. They also named the remembered color after each 300-sec trial.

Delay affected every measure of matching performance. Matches were more variable for 10-sec delays than in the simultaneous condition. Simultaneous matches were near the test colors ($\Delta E=2.8$), but the distance from the test color (bias) increased for 10-sec delays, generally in the direction of increased saturation, with variation across test colors. These measures increased little between 10 and 300 sec.

To test for lexical effects, an "attraction score" measured how much matches were biased by the observers' unique focal colors. Attraction scores for simultaneous matches were near zero, but some colors showed substantial attraction to the focal colors at 10- and 300-sec delays. The 300-sec matches were highly significantly attracted to the focal colors of names provided after each trial. Observers' color idiolect complexity and test color codability were not impressively related to performance at any delay.

P12

Visual System Assessment for Predicting a Transition to Psychosis

Alex Diamond, *University of Rochester*

Co-authors: Steven Silverstein, University of Rochester; Brian Keane, University of Rochester

Visual system assessments are seldom regarded as a viable way to predict a future psychotic disorder. Here, we argue that may be a missed opportunity. From a large literature, we identify a set of visual tests that have distinguished individuals prior to or near the first psychotic episode or that have shown group differences independently of illness duration. Such tests have revealed moderate-to-large patient differences unexplainable by medication or generalized deficits. For example, self-reported visual perceptual distortions have already longitudinally predicted impending psychosis in large samples. Possibly predictive psychophysical tests include contrast sensitivity, backward masking, collinear facilitation, stereoscopic depth perception, contour integration, visual shape completion, and restricted fixational patterns during free viewing. Possible brain based markers include visual thalamo-cortical hyperconnectivity, decreased gamma band power during visual detection, and reduced occipital P1 amplitudes (EEG) during passive viewing. Promising retinal markers include reduced cone a- and b-wave amplitudes and photopic negative response (ERG). The foregoing assessments are often brief, well-tolerated, simple to administer, and well-described mechanistically. Across all major levels of analysis—from phenomenology to behavior to brain and retinal functioning—visual system assessment could help identify individuals who go on to develop a psychotic disorder.

Funding acknowledgements: This work was supported in part by a K01MH108783 to BPK, and by a University of Rochester Medical Center Department of Psychiatry Hendershot Pilot Award Program. Former department lab member Megan Serody contributed to initial literature searches for this project.

P13

Eliciting Color Percepts over Extended Fields through Cone-by-Cone Stimulation

Hannah K. Doyle, *Department of Electrical Engineering & Computer Sciences, University of California Berkeley, Berkeley, CA, United States*

Co-authors: James Fong, Department of Electrical Engineering & Computer Sciences; Congli Wang, Department of Electrical Engineering & Computer Sciences; Sofie R. Herbeck, Department of Electrical Engineering & Computer Sciences; John E. Vanston, Herbert Wertheim School of Optometry and Vision Science; Alexandra E. Boehm, Herbert Wertheim School of Optometry and Vision Science; Brian P. Schmidt, Herbert Wertheim School of Optometry and Vision Science; William S. Tuten, Herbert Wertheim School of Optometry and Vision Science; Austin Roorda, Herbert Wertheim School of Optometry and Vision Science; Ren Ng, Department of Electrical Engineering & Computer Sciences; University of California Berkeley, Berkeley, CA, United States

Purpose: Human color vision is informed by the relative activations of the long-, medium-, and short-wavelength sensitive cones. We have developed a display that can produce a variety of color sensations using only a single wavelength of light, by programming the activity levels of the three cone types at population scales.

Methods: With an Adaptive Optics Scanning Laser Ophthalmoscope, we image the retina at 840 nm over a 0.9° x 0.9° field and track the eye's fixational motion in order to deliver discrete microdoses of 543 nm light to ~2500 individual cones per frame. Using each cone type's spectral sensitivity to 543 nm, we can recapitulate the relative activations consistent with colors that are distinct from the stimulating laser, resulting in percepts of uniform colored squares that appear stable in the world.

Results: Using stimulation from only 543 nm light, we can elicit color percepts ranging from green to red-orange in 2 subjects who have cone spectral types classified in a region of their retina. Additionally, we find through color matching data that the distinct color percepts are lost for intentional misdeliveries that exceed 30% of the cone diameter in both subjects.

Conclusions: These results demonstrate our system's ability to track the retina at high speed, stimulate with cone-level precision, and generate color percepts by directly programming the activity of the human cone mosaic. These technical capabilities provide a novel platform for studying color vision.

Funding acknowledgements: This work was supported by the Air Force Office of Scientific Research under award numbers FA9550-20-1-0195 and FA9550-21-1-0230 and by the National Institutes of Health under award number R01EY023591.

P14

Observations and Implications of Temporary Erythropsia in a Color-Normal Observer

Bruce Drum, *FDA/CDRH/OPEQ/OHT1*

Erythropsia (red vision) is characterized by the reddish or pinkish appearance of surfaces that normally appear achromatic. Erythropsia has been observed historically by people whose retinas were exposed to ultraviolet (UV) light (e.g., aphakes or pseudophakes implanted with unfiltered intraocular lenses). Erythropsia is not fully understood, but has been thought to be related to photochemical damage to short-wavelength (S) cones. Erythropsia can also occur in normal phakic eyes during intense white light adaptation. When I stare at the sunlit white siding on the southern wall of my house, after several seconds, the color changes from white to a brilliant magenta, with the central 1-2º of visual angle spared. All details in the siding fade except for the spared center. In another 10-20 seconds, the magenta turns to bluish cyan, and the previously invisible details reappear with exaggerated contrast. These observations are reminiscent of the color of S-cone increments on white adapting fields (Drum & Sternheim (2005) JOSA A: 22, 2107-19). S cones are insensitive relative to M and L cones on dim backgrounds, but they do not light-adapt like M and L cones and become relatively more sensitive at moderate adapting levels. At still higher adapting levels, S cones saturate (become unresponsive) leaving the increment a tritanopic cyan. The present observations imply that S cones initially fail to adapt to a bright white field, but then saturate, leaving the observer tritanopic.

Funding acknowledgements: No funding or conflicts

P15

Reaching Accuracy Assessment in Cerebellar Stroke using Virtual Reality

Khai Du, *University of Rochester*

Co-authors: Leonardo Benavides, University of Rochester; Emily Isenstein, University of Rochester; Duje Tadin, University of Rochester; Ania Busza, University of Rochester

Objective: To investigate the application of virtual reality (VR) in the rapid quantification of reaching accuracy at the bedside for patients with cerebellar stroke (CS).
Introduction: Dysmetria, the inability to measure distance in muscular tasks correctly, is a common clinical feature of cerebellar injury. Objective quantification of reaching accuracy for clinical assessment is lacking, and the emerging VR technology with hand-tracking offers a promising opportunity to examine the speed, accuracy, and consistency of hand movements and proprioceptive function.

Methods: 29 individuals (10 CS patients and 19 age-matched not-disabled controls) performed a task measuring reaching accuracy on the VR headset (Oculus Quest 2). 50% of the trials displayed a visible rendering of the hand (visible hand condition), and 50% did not (invisible hand condition).

Results: Reaching error was higher in CS compared to age-matched controls in both visible and invisible hand conditions. Reaching error was higher in the invisible hand condition compared to the visible hand condition in healthy controls, right CS, left CS but not in bilateral CS patients. The average time per trial was higher in patients than in controls.

Discussion: VR technology promises to be a non-invasive and rapid approach to quantifying fine motor functions in clinical settings. Further studies are needed to examine quantitative changes in reaching accuracy during post-stroke progression.

Funding acknowledgements: $3000 summer research stipend through the U of R Office of Medical Education

P16

Perceived image quality of natural images through different bifocal corrections after adaptation to sharp or blur

Eduardo Esteban-Ibañez, *Institute of Optics (CSIC)/ 2EyesVision SL*

Co-authors: Enrique Gambra, 2EyesVision SL; Yassine Marrakchi, 2EyesVision SL; Lucie Sawides, 2EyesVision SL; Carlos Dorronsoro , Institute of Optics (CSIC)/ 2EyesVision SL

Simultaneous Vision, present in bifocal and multifocal contact or intraocular lenses, is a common clinical strategy for presbyopia. Neural adaptation is known to occur, but it is not predictable nor well understood. Previous works have studied the short-term neural adaptation to bifocal images using Adaptive Optics and digital convolutions of a face image (with pure defocus and simultaneous images) as adaptation images, and also as test images for perceptual judgments (Radhakrishnan et al., 2014). In this study, we use a programmable see-through head-mounted visual simulator (SimVis Gekko) to analyze the effect of neural adaptation on the perceived image quality of different bifocal corrections (BC) with different balances of energy between far and near, and for different transitions between adaptation and test. Eight subjects judged a video sequence of urban natural images, through two monofocal corrections (0 and 3D) and nine BCs (far/near balance from 90/10 to 10/90 and an addition of 3.00D), optically simulated monocularly. Two initial adaptation states of 10s were used: 0.00D-SHARP and 3.00D-BLUR, followed a transition from these states to the BC that can be ABRUPT (with 1, 5 or 30s of adaptation), or SMOOTH (linear transition lasting 1, 5 or 30s). Our results show a significant increase in perceptual quality after adaptation to BLUR, particularly for intermediate energy balances. However, subjects are quite insensitive to the type and duration of the transition.

Funding acknowledgements: Industrial PhD Grant (Comunity of Madrid) IND2020/BMD-17442

P17

Deep retinal layer microvasculature alterations in first episode and chronic schizophrenia

Samantha I. Fradkin, *Department of Psychology, University of Rochester, Rochester, NY, USA*

Co-authors: Deepthi Bannai , Department of Psychiatry, Beth Israel Deaconess Medical Center, Boston, MA, USA; Paulo Lizano , Department of Psychiatry, Beth Israel Deaconess Medical Center, Boston, MA, USA; Department of Psychiatry, Harvard Medical School, Boston, MA, USA ; Adriann Lai , Maryland Psychiatric Research Center, University of Maryland, Baltimore, MD, USA; Christen Crosta, Department of Cell Biology and Neuroscience, Rutgers University, Piscataway, NJ, USA; Steven M. Silverstein , Departments of Psychiatry, Neuroscience, & Ophthalmology, University of Rochester Medical Center, Rochester, NY, USA; Center for Visual Science, University of Rochester, Rochester, NY, USA

People with schizophrenia (SZ) demonstrate retinal microvasculature alterations that are similar to those observed in individuals with neurodegenerative disorders. Initial findings indicate that these changes are present in the superficial layer in SZ. This study examined whether changes are also present in the deep retinal layer level (DRL). Twenty-six individuals with SZ (10 with first episode psychosis [FEP]) and 37 healthy controls (HCs; 17 age-matched to FEP group) completed optical coherence tomography angiography scans. Compared to controls, people with SZ demonstrated reduced DRL perfusion density (ps < 0.04) and vessel diameter (ps < 0.01) in both eyes, and, in the left eye only, reduced vessel length and fractal dimension (ps = 0.01). We then tested for an illness progression effect by determining the degree to which the original 4 group means were characterized by a polynomial (linear) trend, using the following contrast coefficients: non-FEP SZ (-2), FEP (0), older controls (0), young controls (2). The hypothesized pattern was observed to a significant or trend level degree for 7 out of 8 variables, with effect sizes ranging from small to large. Findings also indicated that, within the SZ group, reduced DRL perfusion density and vessel length were associated with reductions in (previously reported) superficial layer indices (ps < .001). Overall, findings suggest that alterations in retinal microvasculature are present in both the superficial and DRL in SZ.

Funding acknowledgements: Research reported was supported by the NEI of the NIH under Award Number T32EY007125. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH.

P18

Chromatic Adaptation to Heterochromatic Illumination

Luke Hellwig, *Rochester Institute of Technology*

Co-authors: Mark D. Fairchild, Rochester Institute of Technology

Heterochromatic viewing enviroments—where scenes are illuminated by two or more colors of light—are a common tool for experiments studying chromatic adaptation and color (in)constancy. This study presents a new method for separating sensory (retina-based) chromatic adaptation from cognitive mechanisms in a heterochromatic viewing environment. Using a large, bipartite light booth lit by two separate 7-channel LED systems, observers were adapted to uniform and mixed illuminations of simulated illuminant A, illuminant D65, and 12000 K daylight. A psychophysical staircase method determined observers' white points and their state of sensory adaptation along the daylight and Planckian loci under each heterochromatic or single-color lighting condition. Under heterochromatic conditions, observers' state of chromatic adaptation fell in between the points of chromatic adaptation when adapted to each individual light source, although there was significant variation between observers. These results suggest that observers' white points should be individually determined for studies of color perception in heterochromatic environments using methods similar to those used in this study. Further research will then allow us to model how cognitive discounting of the illumination color sits on top of the sensory adaptation measured here.

P19

Eye-tracking while learning greebles

Andrew Mark Herbert, *RIT, Psychology*

Co-authors: Archana Pandurangan, RIT, Psychology; Ankita Girish Patel, RIT, Computer Engineering; Cory E. Merkel, RIT, Computer Engineering

There has been a lot of attention on so-called 'adversarial images' that fool machine learning models (MLM). Manipulations to an image or including an unexpected object in a scene can severely disrupt object labeling and parsing by state-of-the-art MLM such as convolutional neural networks (CNN). In contrast, human observers may not even notice these changes, highlighting a significant gap between the robustness of human vision and CNNs. One well-studied class of novel objects are 'Greebles,' introduced by Gauthier and Tarr (1997; Gauthier et al., 1998). A large number of 'families', 'genders' and individuals can be created by systematically varying the arrangements and shapes of Greeble components. We report on eye-tracking (SMI iRed 250) participants as they are taught to recognize Greebles following the procedure described by Gauthier, Tarr and colleagues. Greeble expertise is assessed using a naming task and a verification task. Once an individual became a Greeble 'expert' we assessed their tolerance for rotations of the Greebles around the y-axis. The pattern of eye movements when learning and being tested on the Greebles are compared to the output of CNNs trained to recognize Greebles.

Funding acknowledgements: RIT Global Cybersecurity Institute

P20

Achromatic biases in noise images

Daniel Joyce, *University of Nevada, Reno*

Co-authors: Emersongrace Bennett, University of Nevada, Reno; Michael Webster, University of Nevada, Reno

In a previous study, Winkler et al. (Current Bio 2015) examined the effects of luminance on the perceived color categories selected for uniform square patches. When the square was equiluminant with the background, the patch appeared colored as soon as it was detected, while for increments or decrements, the range of chromaticities that were classified as achromatic was expanded and more strongly along bluish axes. Here we extended these results to examine the color appearance of spatially varying patterns, which contain a wide range of luminance levels. The images were 1/f luminance noise and were briefly alternated with a gray background with the same mean luminance. The noise was shown on each trial with a uniform chromaticity, which was varied across trials over a grid of values spanning the LvsM and SvsLM cone-opponent axes. Observers categorized each noise image as gray or one of the four unique (RGBY) or binary (RB,BG,GY,YR) hues. The perceived achromatic gamut for the noise again tended to vary along bluish-yellowish directions, but was markedly broader compared to the uniform patches. The broadening of the gray category may partly reflect attributions of some of the color to the illuminant, a tendency which may be stronger in the spatially variegated patterns.

Funding acknowledgements: Supported by EY-010834

P21

Detecting spaceflight associated neuro-ocular syndrome (SANS) using light-weight convolutional neural networks

Sharif Amit Kamran, *Human-Machine Perception Laboratory, Department of Computer Science and Engineering, University of Nevada, Reno, Nevada, United States*

Co-authors: Khondker Fariha Hossain, Human-Machine Perception Laboratory, Department of Computer Science and Engineering, University of Nevada, Reno, Reno, Nevada, United States; Joshua Ong, MD., Michigan Medicine, University of Michigan, Ann Arbor, Michigan, United States; Andrew G. Lee, MD., Center for Space Medicine, Baylor College of Medicine, Houston, Texas, United States; Department of Ophthalmology, Blanton Eye Institute, Houston Methodist Hospital, Houston, Texas, United States; The Houston Methodist Research Institute, Houston Methodist Hospital, Houston, Texas, United States; Departments of Ophthalmology, Neurology, and Neurosurgery, Weill Cornell Medicine, New York, New York, United States; Department of Ophthalmology, University of Texas Medical Branch, Galveston, Texas, United States; University of Texas MD Anderson Cancer Center, Houston, Texas, United States; Texas A&M College of Medicine, Texas, United States; Department of Ophthalmology, The University of Iowa Hospitals and Clinics, Iowa City, Iowa, United States; Alireza Tavakkoli, PhD., Human-Machine Perception Laboratory, Department of Computer Science and Engineering, University of Nevada, Reno, Reno, Nevada, United States

Spaceflight-associated neuro-ocular syndrome (SANS) is a collection of neuro-ophthalmic findings that occurs in astronauts as a result of prolonged microgravity exposure in space. Due to limited resources on board long-term spaceflight missions, early disease diagnosis and prognosis of SANS become unviable. Moreover, the current retinal imaging techniques onboard the international space station (ISS), such as optical coherence tomography (OCT), ultrasound imaging, and fundus photography, require an expert to distinguish between SANS and similar ophthalmic diseases. With the advent of Deep Learning, diagnosing diseases (such as diabetic retinopathy) from structural retinal images are being automated. In this study, we propose a lightweight convolutional neural network incorporating an EfficientNet encoder for detecting SANS from OCT images. We used 6303 OCT B-scan images for training/validation (80%/20% split) and 945 for testing. Our model achieved 84.2% accuracy on the test set, i.e., 85.6% specificity, and 82.8% sensitivity. Moreover, it outperforms two other state-of-the-art pre-trained architectures, ResNet50-v2 and MobileNet-v2, by 21.4% and 13.1%. Additionally, we use GRAD-CAM to visualize activation maps of intermediate layers to test the interpretability of our model's prediction. The proposed architecture enables fast and efficient prediction of SANS-like conditions for future long-term spaceflight mission in which computational and clinical resources are limited.

Funding acknowledgements: NASA Grant [80NSSC20K183]: A Non-intrusive Ocular Monitoring Framework to Model Ocular Structure and Functional Changes due to Long-term Spaceflight.

P22

Development and validation of a virtual reality based toolkit to assess functional vision in Ultra Low Vision

Arathy Kartha, *Johns Hopkins University*

Co-authors: Roksana Sadeghi, Johns Hopkins University; Thom Swanson, BaltiVirtual; Will Gee, BaltiVirtual; Gislin Dagnelie, Johns Hopkins University

Ultra-Low Vision (ULV) refers to a level of vision that is ≦ 20/1600. There are a growing number of vision restoration treatments that recruit people with ULV or restore vision to the ULV level. At present, limited standardized outcome measures are available to assess visual potential before and after such vision restoration treatments. The ULV toolkit was developed as a standardized outcome measure for people with ULV. Three virtual reality (VR) based modules were developed to assess visual information gathering, hand-eye coordination and wayfinding in people with ULV. Each module consisted of a range of visually guided tasks related to activities of daily life (e.g., direction of motion of cars, flipping a light switch, boarding a train). Each correct/incorrect response was scored as '1'/'0'. These raw scores were then analyzed to estimate item difficulty (item measure) and person ability (person measure). Item measures showed a wide range of difficulty levels that can be used to evaluate visual performance in people with ULV. Person measures were correlated with estimated logMAR visual acuity as well as completion rates, number of collisions and reaction times. This study bridges a big gap in the field of ULV where little is known about visual potential and usefulness in activities of daily life. VR provides portability and consistency for testing across participants with ULV thereby allowing for standardization of measurements across vision restoration studies.

Funding acknowledgements: NEI R01EY028452 (GD), K99EY033031(AK), Research to Prevent Blindness

P23

A direct measure of adaptation and visual salience

Mohana Kuppuswamy Parthasarathy, *University of Nevada, Reno*

Co-authors: Kassandra Lee Corsini, University of Nevada, Reno; Craig K Abbey, University of California, Santa Barbara; Michael A. Webster, University of Nevada, Reno

One hypothesized function of adaptation is to increase the salience of novel targets by discounting the properties of the ambient environment. Previous studies have suggested this by finding faster search times for novel targets when searching on backgrounds observers are currently adapted to. However, this provides only an indirect measure of salience. Here, we developed a more direct measure of the impact of adaptation on feature salience. Backgrounds were oriented 1/f noise images with power confined within 15 deg of horizontal or vertical. Targets were 5 c/deg Gabor patches centered on the 8 deg backgrounds. Observers simultaneously adapted to the horizontal or vertical backgrounds shown on the left or right of fixation. A 250ms test probe then showed the Gabor patch on the same background (horizontal or vertical) on both sides. The target orientation was adjusted on one side until it appeared as conspicuous as a fixed target on the other side. Settings were made for fixed targets ranging from 10 to 45 deg from the backgrounds. For most conditions/observers, the salience matches required a smaller orientation offset on the same- vs. different-adapt background. These results support a functional role of adaptation in highlighting novelty by potentially “unmasking” the target from its background, and emphasize the importance of considering adaptation aftereffects not only for isolated targets but within the stimulus contexts they are embedded in.

Funding acknowledgements: CA-237827

P24

Learned rapid adaptation to environmental color changes generalize to a large range of colors

Yanjun Li, *University of Minnesota*

Co-authors: Katherine Tregillus, University of Minnesota; Stephen Engel, University of Minnesota

When the environment changes color, vision adapts, and the world gradually appears less tinted. For repeated color changes, vision may learn to adapt faster to maintain accurate perception. We previously reported that wearing red glasses repeatedly caused the world to appear less and less reddish when the glasses were first put on, as measured by the appearance of unique yellow. Here, we tested the appearance of a larger range of colors. 13 observers wore red glasses for 5hr/day for 5 days. Observers were tested with pairs of 1.5 deg filled color circles, centered within a 6deg black square on a background image. 13 colors were chosen from LAB space comprising unique and intermediate hues at two contrast levels, and one gray. Observers rated the difference between each possible color pair on a scale of 0 to 9. Observers performed the task before and immediately after putting the glasses on, and after 25, 50 and 75 min of wear. Wearing red glasses caused all colors to appear reddish and be rated as relatively similar. As observers adapted, colors gradually regained more normal appearance, and the similarity between color pairs decreased. Critically, over days, color pairs appeared more dissimilar immediately after putting on the glasses ($p<1e-6$). Multi-dimensional scaling analysis of the similarity data revealed a uniform expansion of color space across days. Thus, observers learned to immediately adjust their perception of many colors with repeated experience.

Funding acknowledgements: NSF-1558308

P25

Spatial-frequency-selective enhancement of visual sensitivity from saccade dynamics

Yuanhao H. Li, *University of Rochester*

Co-authors: Michele A. Cox, University of Rochester; Janis Intoy, University of Rochester; Jonathan Victor, Feil Family Brain and Mind Research Institute, Weill Cornell Medical College; Bin Yang, University of Rochester; Zhetuo Zhao, University of Rochester; Michele Rucci, University of Rochester

Eye movements transform a spatial scene into luminance modulations on the retina. Recent work has shown that this transformation is highly structured: within human temporal sensitivity, saccades deliver power that increases in proportion to spatial frequency (SF) up to a critical frequency and remains constant beyond that. Importantly, the critical SF increases with decreasing amplitude. Therefore, at sufficiently low SFs, larger saccades effectively deliver stronger input signals to the retina. Here we tested whether this input reformatting has the predicted perceptual consequences, by examining how large and small saccades (6o & 1o) affect contrast sensitivity. We measured relative sensitivity at two SFs: a reference (0.5 cpd), equal to the critical SF for the small saccade, and a probe at either a lower or higher SF (0.1/2.5 cpd). We predicted that large saccades enhance visibility only when the probe has a lower SF than the reference. Subjects (N=7) made instructed saccades while presented with a plaid of overlapping orthogonal gratings at the two SFs and reported which grating was more visible. Results closely follow theoretical predictions: psychometric functions following small and large saccades only differed with the lower SF probe, in which case the larger saccade significantly enhanced visibility. In sum, saccades enable selectivity not only in the spatial domain, but also in the spatial-frequency domain.

Funding acknowledgements: This work was supported by Meta Reality Labs and National Institutes of Health grants EY018363 (MR) and EY07977 (JV).

P26

A unifying framework for perceptual decision-making

Ying Lin, *University of Rochester*

Co-authors: Zhen Chen, University of Rochester; Jose Reynoso, The City College of New York; Ralf Haefner, University of Rochester; Duje Tadin, University of Rochester

Perceptual decision making (PDM) has been studied using two approaches. Threshold measurement is predominant used in psychophysics, while reaction times (RT) with associated models have been used to estimate components of PDM (i.e., drift rate). To test if these two approaches reflect overlapping mechanisms, we conducted 3 experiments: a motion, a static orientation, and a dynamic orientation task. DT is the shortest stimulus presentation time sufficient to make accurate perceptual decisions. RTs and choices were fitted by a drift diffusion model (DDM). We expected a close relationship between DTs and drift rates, allowing us to accurately predict DTs from RT. In the motion task, we found a close relation between the empirical DTs and the DTs predicted by the DDM. Surprisingly, in the static task, there was little correlation between the two; DTs, improved monotonically with higher contrast, but drift rates saturated at 6%. We hypothesize that this mismatch is due to the information being available immediately in the static task, without needing to accumulate new evidence. Thus, we developed a novel dynamic orientation task that mimics the dynamic nature of the motion task and found a similar relation between DTs and drift rates. In summary, we show a close link between DTs and drift rate for the two dynamic tasks. This result supports the conceptualization of drift rate as a proxy for perceptual sensitivity but only for task where new information becomes available over time.

P27

Bayesian inference and adaptation in neural responses

Jake Manalansan, *University of Nevada Reno*

Co-authors: Kara Emery, New York University; Michael Rudd, University of Nevada Reno; Michael Webster, University of Nevada Reno

Many of the perceptual changes induced by adaptation can be captured in a Bayesian framework, in which adaptation renormalizes neural responses to weak or strong stimuli, consistent with correcting the likelihood to match the prior (Emery and Webster VSS 2020). We explored what this model implies about Bayesian estimation at the level of an individual neuron or channel. The prior corresponds to what the neuron expects to see, but the adaptation causes responses to match what it expects. If the decoder does not "know" the neuron's adaptation state (Series et al 2009), these adjustments effectively flatten priors for dimensions the neuron adapts to, preserving expectations only for information that it does not adapt to, such as how signals deviate from the predicted value. Bayesian-like estimates of these deviations can be computed within the neuron because the shape of the prior is instantiated in the neuron's contrast response function (CRF). For example, for a Gaussian prior the corresponding CRF is a cumulative Gaussian. Steeper CRFs bias responses more toward the mean. The biases approximate but do not equal the Bayesian posterior. If, like adaptation, the decoding does not account for this approximation, then the interpreted stimulus value is distorted relative to the Bayes estimate. This may underlie the distortions evident in some perceptual dimensions, such as nonlinearities in perceived contrast.

Funding acknowledgements: Supported by EY010834

P28

Quantifying Visual Snow Symptoms with a Matching Task

Samantha Montoya, *University of Minnesota, Graduate Program in Neuroscience*

Co-authors: Michael Lee, University of Minnesota, Department of Ophthalmology and Visual Neurosciences; Carter Mulder, University of Minnesota, Department of Psychiatry and Behavioral Sciences; Stephen Engel, University of Minnesota, Department of Psychology; Michael-Paul Schallmo, University of Minnesota, Department of Psychiatry and Behavioral Sciences

The primary symptom of Visual Snow Syndrome (VSS) is a veil of dots/static flickering across the entire visual field. VSS is a serious but poorly understood disorder (prevalence 1.4-3.3%). Symptoms of VSS can interfere with daily tasks like driving and reading. However, few studies have examined VSS, and quantitative measurements of symptoms are lacking. We developed a matching task in which participants with VSS adjusted parameters of simulated visual snow on a computer screen; participants modified the contrast, density, speed, and size of an array of dots to match their visual snow. Simulated snow was generated by random independent draws from a binary distribution controlled by the contrast parameter. Snow density was adjusted by setting a proportion of pixels equal to the background luminance. The speed setting determined the lifetime of each snow element, after which it was replaced. Dot size was adjusted by moving closer or further from the display and recording the viewing distance, as perceived snow elements were generally smaller than one pixel viewed from 0.5 m. Individuals with VSS said the simulated snow closely resembled their perceived snow, and parameter settings were consistent across trials. Simulated snow contrast settings were relatively low and dot size was relatively small. This task provides a quantitative assessment of visual snow percepts, which may facilitate assessment of treatments/therapies and testing of hypotheses about underlying mechanisms.

Funding acknowledgements: This work was supported by funding from the National Institutes of Health and the National Science Foundation (T32 EY025187, DGE-1734815, R25 NS117356)

P29

Optogenetic Stimulation and Calcium Imaging of Single Ganglion Cells in the Living Macaque Fovea

Peter Murphy, *University of Rochester, Center for Visual Science, Institute of Optics*

Co-authors: Juliette McGregor, University of Rochester, Flaum Eye Institute, Center for Visual Science; Zhengyang Xu, University of Rochester, Institute of Optics, Center for Visual Science; William Merigan, University of Rochester, Flaum Eye Institute, Center for Visual Science; David Williams, University of Rochester, Flaum Eye Institute, Institute of Optics, Center for Visual Science

The perceptual roles of most retinal ganglion cell (RGC) classes are controversial in part because we lack a paradigm for measuring the perceptual consequences of activating cells of only one class in the living primate eye. Recent success in classifying single RGCs with *in vivo* calcium imaging and *in vivo* optogenetic activation of RGCs en masse now bring such a paradigm within reach. As a first step, we demonstrate the optogenetic stimulation of single foveal RGCs in the living macaque.

RGCs in an anesthetized female macaque were stimulated and imaged using adaptive optics scanning light ophthalmoscopy. Co-expression of ChrimsonR and GCaMP6s was achieved via intravitreal injection of a viral vector. On each trial, a targeted soma was exposed to four, 12.5 μm diameter flashes of 0.8 second duration. Targets were limited to those RGCs with at least a 20 μm separation from their nearest neighbors. The GCaMP responses to the flash of both targeted and nearby cells were imaged and the ΔF/F for each soma's response was averaged over the flashes. The ΔF/F values were used to calculate z-scores for each cell's response. Five cells were found to have responded significantly (z-score > 3.5) with no significant response from their neighbors.

We can directly activate single RGCs in the living eye and measure the resulting calcium signal, the first step toward a method to measure the sensations produced by individual RGCs in the awake behaving monkey.

Funding acknowledgements: R01 EY021166, P30 EY001319, Research to Prevent Blindness

P30

Explainable diagnosis based on retinal fundus images using deep learning

Ipek Oruc, *University of British Columbia*

Co-authors: Parsa Delavari, University of British Columbia; Gulcenur Ozturan, University of British Columbia; Ozgur Yilmaz, University of British Columbia

Deep learning techniques have seen tremendous interest in ophthalmology, particularly in the use of convolutional neural networks (CNNs) for automated detection of ocular diseases using fundus photography. Even traits and behaviours that were previously thought not to be present, or visible to the expert human eye, in fundus images, such as patient sex, can be detected via CNNs. Despite this success, lack of transparency due to the 'black box' nature of deep learning is a roadblock to their widespread adoption in medicine. Interpretations via posthoc explainability methods remain superficial and inadequate. We propose a novel methodology to overcome these limitations and translate what is learned by the model. We start out by training a CNN and use posthoc interpretation tools to visualize the model's decisions. Importantly, we use visualizations exclusively as "inspiration" and make "observations" leading to testable exploratory hypotheses. We then acquire an additional untouched dataset that we randomly separate into a small "sandbox" and a large "verification" partitions. We test all exploratory hypotheses in the sandbox to distill a select few to be tested on the verification partition. Finally, findings are translated into a training paradigm for ophthalmologists. I will present our proof-of-concept results for classifying patient sex in retina fundus images. This approach can be extended to a variety of other avenues of clinical as well as foundational importance.

Funding acknowledgements: Natural Sciences and Engineering Research Council of Canada Discovery Grant RGPIN-2019-05554 and an Accelerator Supplement RGPAS-2019-00026, and a Canada Foundation for Innovation, John R. Evans Leaders Fund. UBC Data Science Institute grant; UBC DMCBH Kickstart award.

P31

Extended Reality-based Minifying Lens Effects Decreases Dynamic Visual Acuity

Phani Paladugu, *Brigham and Women's Hospital, Harvard Medical School, Boston, MA and Sidney Kimmel Medical College, Thomas Jefferson University, Philadelphia, Pennsylvania, United States*

Co-authors: Ethan Waisberg, University College Dublin School of Medicine; Joshua Ong, Michigan Medicine, University of Michigan; Nasif Zaman, Human-Machine Perception Laboratory, Department of Computer Science and Engineering, University of Nevada, Reno; Sharif Amit Kamran, Human-Machine Perception Laboratory, Department of Computer Science and Engineering, University of Nevada, Reno; Andrew G. Lee, Department of Ophthalmology, Blanton Eye Institute, Houston Methodist Hospital + Center for Space Medicine, Baylor College of Medicine + The Houston Methodist Research Institute, Houston Methodist Hospital + Departments of Ophthalmology, Neurology, and Neurosurgery, Weill Cornell Medicine + Department of Ophthalmology, University of Texas Medical Branch + University of Texas MD Anderson Cancer Center + Texas A&M College of Medicine + Department of Ophthalmology, The University of Iowa Hospitals and Clinics; Alireza Tavakkoli, Human-Machine Perception Laboratory, Department of Computer Science and Engineering, University of Nevada, Reno

Dynamic visual acuity (DVA) refers to the ability to visualize objects in motion. Gravitational (G)-transitions can occur during spaceflight inducing rapid sensorimotor adaptation, impaired DVA, and gaze control as observed in astronauts upon their return to Earth {1}. Previous research has used 0.5x lenses to simulate the decreased DVA experienced by a returning astronaut {2}. Minifying lenses cause visual inputs to move less than normal, which creates visual-vestibular conflict and can impair DVA. Our study reports the novel development and use of head-mounted, extended reality to simulate decreased DVA from G-transitions. We developed and tested this minifying lens effect with 5 healthy subjects (best correctable visual acuity of 20/20). The level of minimization was decreased in a stepwise manner from: normal, 30% smaller, 50% smaller, 70% smaller, 80% smaller. Measured DVAs were 0.485; 0.525; 0.695; 0.655; 0.855 LogMAR respectively, showing a decreased DVA as the level of minimization increased. There are currently no DVA assessment techniques in microgravity, which is why DVA and vestibular adaptations in space are poorly understood. Our group aims to address this crucial knowledge gap by developing a head-mounted visual assessment system that can measure DVA and highlight the potential of using extended reality-based minifying lenses to study vestibular dysfunction in both space and terrestrial settings {3}.

Funding acknowledgements: NASA Grant [80NSSC20K183]: A Non-intrusive Ocular Monitoring Framework to Model Ocular Structure and Functional Changes due to Long-term Spaceflight.

P32

Reading with your tongue

Samuel Paré, *Université de Montréal*

Co-authors: Maxime Bleau, Université de Montréal; Ron Kupers, BRAINlab, University of Copenhagen, Copenhagen, Denmark;Institute of NeuroScience (IoNS), Université catholique de Louvain (UCLouvain), Belgium; Université de Montréal; Maurice Ptito, Université de Montréal; BRAINlab, University of Copenhagen, Copenhagen, Denmark

Despite being able to read in Braille or having tools like vocal synthesizer, there are still a lot of situations where blind persons depend on others to read. For these reasons, we tested the Tongue Display Unit (TDU), a vision-to-tactile sensory substitution device, as a potential reading aid for blind individuals. As of now, we recruited 7 late blind individuals (LB) and 7 sighted controls (SC) to perform letter recognition and word reading tasks with the TDU in two display mode. The letter task consisted of identifying eight letters: A, B, E, I, N, O, T, U and a non-letter form. In the word task, participants had to read five words and a non-word form. All letters and words were presented 4 times in a randomized order. Both tasks were done twice (once by display mode). In the display mode called active, participants controlled the camera. In the other called passive, participants had no control over the camera, but the letters scrolled from right to left. With less than 15 minutes of training with the TDU, LB and SC were able to read letters and words with an accuracy above 80%. However, LB were better than SC at reading words in the active mode with 94.7±22.5% of success over 81.3±39.1%. Both groups performed similarly in the passive mode (88.6±18.5% for LB, 81.3±11.8% for SC) and in both modes, the letters “B” and “E” were the hardest to discriminate. This study shows that with further experimentation and training, blind individuals could learn to read with the TDU

Funding acknowledgements: Canadian Institut of Health Research (CIHR), Fonds de recherche du Québec en Santé (FRQS)

P33

Towards Understanding Retinal Processing of Single-Cone Scale Stimulation

JT Pirog, *Herbert Wertheim School of Optometry & Vision Science, University of California, Berkeley, Berkeley, CA USA*.

Co-authors: William S. Tuten, Herbert Wertheim School of Optometry & Vision Science, University of California, Berkeley, Berkeley, CA USA.

The magnocellular (M) visual pathway can be distinguished from its finer-grained parvocellular (P) counterpart by its stronger response gain to contrasts near human detection threshold. This distinction is found when stimulus size is matched to the relatively large receptive field size of M cells, but it is less clear if preserved at smaller spatial scales. We examined foveal detection thresholds in tandem with a masking paradigm known to desensitize the M pathway. We used a custom DLP display in Maxwellian view to present either 3 or 23 arcmin spots for 100 ms against a uniform gray disk (1° VA) surrounded by a 0.5 cpd, 100% contrast, square wave grating flickered at 7 frequencies ranging from 0 to 30 Hz. Detection data were fit with psychometric functions to estimate threshold and thresholds were normalized to the static (0 Hz) condition. Relative sensitivity was fit with a modified impulse response function and compared to a constant model with ANOVA. With masking we found a significant reduction in sensitivity for large (23arcmin) increments (mean=0.39 log units; n=4; $p<0.01$) and decrements (0.31 log units; n=4; $p=0.02$) at 8.3Hz. By contrast, no significant masking effect was observed for small spot increments or decrements ($p>0.05$). These data suggest that the M pathway is not the primary determinant of small spot thresholds under the conditions studied. Further investigation with adaptive optics may be necessary to fully elaborate single-cone processing in the fovea.

Funding acknowledgements: Air Force Office of Scientific Research (FA9550-20-1-0195 and FA9550-21-1-0230), National Institutes of Health (R01EY023591), Alcon Research Institute, Hellman Fellows Fund

P34

Deep retinal laser lesions recruit resident microglia without involvement of labeled neutrophils

Derek Power, *University of Rochester, Center for Visual Science*

Co-authors: Jesse Schallek, University of Rochester, Center for Visual Science, Flaum Eye Institute

Adaptive Optics Scanning Light Ophthalmoscopy (AOSLO) has revealed the in-vivo behaviors of single immune cells (Joseph et al., 2020). Here, we study the cellular immune response to a laser lesion targeting the outer retina.
Using fluorescence AOSLO, we tracked microglia (Cx3CR1, GFP transgenic mice) and neutrophils (LY-6G-647 nm antibody). 1 hour, 24 hour and 72 hour time points were tracked in 5 mice. Lesions were induced by focusing light onto the photoreceptors for 3 minutes (488 nm, 1.12 mW, 24x1 μm). In response to light exposure, OCT images revealed focal brightening in the outer nuclear layer (ONL) through RPE within 30 minutes. Inner layers had no evidence of structural change. Motion contrast AOSLO showed capillary perfusion was maintained post-insult. Histology revealed loss of photoreceptor nuclei at lesion sites within 7 days post-lesion (n=1 mouse, 2 lesions). AOSLO showed Cx3CR1+ cells swarming the ONL as early as 24 hours with waning aggregation through 72 hours post-lesion. Despite microglia swarming, we did not find evidence for neutrophil arrival (n=2 mice, 2 lesions) up to 72 hours post-insult. This study shows resident immune cells aggregate into deeper layers with few labeled neutrophils suggesting the importance and lasting duration of resident microglia for efferocytosis in response to damage.

Funding acknowledgements: NIH Grant R01 EY028293, P30 EY001319, Career Development Award, Career Advancement Award (Schallek) and Unrestricted Grant to the University of Rochester Department of Ophthalmology from Research to Prevent Blindness, New York, New York, and a research collaboration grant from Genentech Inc.

P35

Fixational Eye Motion Measured with Tracking Scanning Laser Ophthalmoscopy in ABI/TBI and Control Subjects

Nicole M. Putnam, *Arizona College of Optometry, Midwestern University*

Co-authors: Caitlin Jomoc, Arizona College of Optometry, Midwestern University; Makayla Adams, Arizona College of Optometry, Midwestern University; Brandon Charbonneau, Arizona College of Optometry, Midwestern University; Thaddeus Davis, Arizona College of Optometry, Midwestern University; Angelique dela Victoria, Arizona College of Optometry, Midwestern University; Katheryn Engel, Arizona College of Optometry, Midwestern University; Albert Kemp, Arizona College of Optometry, Midwestern University; Chizoba H. Ogoke, Arizona College of Optometry, Midwestern University; Christina Esposito, Arizona College of Optometry, Midwestern University

This study compared fixational eye motion (FEM) in acquired/traumatic brain injury (ABI/TBI) subjects presenting with clinical symptoms (reading text, losing place while reading, words moving around the page, decreased reading comprehension) to control subjects as measured with Tracking Scanning Laser Ophthalmoscopy (TSLO). Six ABI/TBI subjects (4M, 2F) aged 29-62 and six control subjects (4M, 2F) aged 23-42 participated in the study. A 5°x5° square 840nm TSLO imaging raster was used to guide fixation in 3 conditions: upper right corner (UR), freely in the center (CF), and a dot in the center (DOT). At least three 10sec videos were collected for all subjects in both eyes for each condition. Offline, custom MATLAB software was used to stabilize the videos, extract eye motion at 480Hz, and extract FEM characteristics. Significant differences were seen between the ABI/TBI and control subjects with t-test analysis in all fixation conditions. Different Microsaccade and drift parameters of FEM were found to be significantly different for the different conditions with the number of Microsaccade reaching significance only for UR ($p<0.001$) and Microsaccade amplitude and peak velocity only for CF ($p<0.01$). These results demonstrate FEM measurements with TSLO in ABI/TBI subjects are different from control and are highly variable between fixation tasks. This warrants further exploration to determine the mechanisms behind oculomotor deficiency and to guide future clinical treatments.

Funding acknowledgements: This work was supported by a College of Optometrists in Vision Development (COVD) Research Grant awarded to Dr. Esposito.

P36

An Arduino-based Lightweight and Reliable Solution to Detect Relative Afferent Pupillary Defect

Prithul Sarker, *University of Nevada, Reno*

Co-authors: Alireza Tavakkoli, University of Nevada, Reno

Purpose: The swinging flashlight test (SFT) is widely used to diagnose any lesion in the afferent visual pathway which causes an asymmetric pupillary reaction in response to light, known as a relative afferent pupillary defect (RAPD). Due to the high subjectivity associated with traditional SFT, we propose an Arduino-based automated RAPD detection system.

Methods: We utilized the Pupil Core device from Pupil Labs for pupil diameter data. To control the duration and intensity of illumination properly, we developed an Arduino-based lighting system for each eye and experimented with 0.3 and 0.6 log unit reduced illumination in each eye to create an artificial asymmetric pupillary response. We evaluated the score for each illumination level based on the difference in the pupil diameter amplitude and used linear regression to obtain the final score. 18 controls and 7 optic nerve patients with a history of RAPD participated in this study.

Results: Our data analysis identifies the affected eye and the severity of RAPD, which is then converted to the Bells grading. Results from our experiments mirror the clinical records with 100% specificity and sensitivity. Our study suggests this approach has a precision level of less than 0.1 mm pupil diameter, which can considerably improve early detection.

Conclusion: In addition to no human interaction in stimulation and data collection, our solution weighs similar to any wearing glasses proving to be more practical, objective and reliable.

P37

Event-related Changes in Pupil Size in a Simulated Air Refueling Task

Eric Seemiller, *711th Human Performance Wing, United Stated Air Force*

Co-authors: Eleanor O'Keefe, KBR, inc.; Marc Winterbottom, 711th Human Performance Wing, United States Air Force; Steven Hadley, 711th Human Performance Wing, United States Air Force

There are many factors that influence the behavior of the pupil, but it is functionally an instrument of the visual system; its fundamental role is to balance light and image quality. Though it is common to use pupil size as a measure of other operator-state parameters such as cognitive workload or stress, its role in the visual system can complicate this. It may be more useful to assess dynamic, rapid changes in pupil size in response to workload or stress related events. Here, we measured pupil size velocity in 14 participants who were engaged in an aerial refueling simulation on a 3D display. Refueling collisions (when the fuel nozzle hits the receiver aircraft outside of the refueling receptacle) were recorded, and the pupil velocity at all time-points 10 seconds prior and 10 seconds post-collision were averaged to calculate the event-related change in pupil velocity. On average, there was a -0.49 mm/sec spike in pupil velocity that began 0.39 seconds after the collision and lasted 1.62 seconds before returning to stasis. This suggests that the collision caused a rapid pupil constriction, indicating a stress related change. Approximately 2 seconds post-collision, the pupil began to drift back toward its static state, showing a quick return to its role in promoting good image quality. These data represent a novel way of considering the pupil in the context of its many influences and suggests that rapid spikes in pupil size may indicate an increase in operator stress.

Funding acknowledgements: FA2396-22-F-0137 and FA8075-16-D-0010

P38

After up to a year of hyperglycemia Ins2Akita mice show minimal capillary change

Fei Shang, *University of Rochester, Center for Visual Science*

Co-authors: Jesse Schallek, University of Rochester, Center for Visual Science, Flaum Eye Institute

Diabetic retinopathy (DR) is a leading cause of blindness and is detected clinically via retinal vascular changes. Here we measure the impact of hyperglycemia in a mouse model to evaluate changes in retinal capillary density, path length and pericyte coverage. We crossbred mice with fluorescent pericytes (NG2DSRed) with hyperglycemic mice (Ins2Akita) to produce offspring with labeled pericytes and sustained hyperglycemia. Retinas from male mice (7 to 53 weeks) were fixed, flat mounted, then imaged with confocal microscopy (Nikon eclipse Ti2e). Pericytes and vessel path length were manually measured with ImageJ. Custom MATLAB code rendered path length as a function of depth. Two-tailed t-tests were used for statistics.

Regardless of hyperglycemic duration, Akita+ mice (n=7) had a pericyte density of 307.03 ± 69.09 cells/mm2 which was less than, but not statistically different from Akita- mice (n=5; 348.51 ± 29.78 cells/mm2; p=0.12). We did not find a difference in total path length in any of the trilaminar layers: superficial (p=0.08), intermediate (p=0.95) or deep (p=0.52).

Akita+ mice had increased blood glucose, decreased body weight, and polyuria. Despite a systemic phenotype, we saw no reduction in pericytes or vessel path length, even after ~1 year of hyperglycemic insult. These findings indicate that Ins2Akita vascular changes may be more subtle than previously reported and neural/behavioral deficits may not correlate with microvascular path length or pericyte density.

Funding acknowledgements: NIH Grant R01 EY028293, P30 EY001319, Career Development Award, Career Advancement Award (Schallek) and Unrestricted Grant to the University of Rochester Department of Ophthalmology from Research to Prevent Blindness, New York, New York, and a research collaboration grant from Genentech Inc.

P39

Perceptual scaling and natural image statistics

Idris Shareef, *Department of Psychology, University of Nevada, Reno, Reno NV 89557*

Co-authors: Mohana Kuppuswamy Parthasarathy, Department of Psychology, University of Nevada, Reno, Reno NV 89557; Zoey J Isherwood, Department of Psychology, University of Nevada, Reno, Reno NV 89557; Michael A Webster, Department of Psychology, University of Nevada, Reno, Reno NV 89557

Visual coding is thought to be matched to many of the properties of the natural visual environment, such as the characteristic amplitude spectra or fractal geometry of natural scenes. This match has been probed in a wide variety of ways. Here we used the paradigm of "maximum likelihood difference scaling" (MLDS, Maloney and Knoblauch Ann Rev Vis Sci 2020) to explore the perceptual representation of the spatial structure of images. The MLDS task involves presenting pairs of images drawn from different levels along a dimension and judging which pair has greater difference. In our case the stimulus dimension corresponded to the slope of the image amplitude spectrum. Grayscale noise images were filtered to form a range of slopes from 0 to -2 in steps of 0.2. Further image arrays were generated by first binarizing the image intensities and then extracting only the edges to isolate the fractal structure (corresponding to fractal dimension range from 1 to 2 in steps of 0.1). For each array the MLDS task was used to estimate the perceived differences. Scaling for fractal dimension did not differentially favor natural fractal values. However for the amplitude spectra, the derived perceptual scales tended to be steeper for intermediate levels of the array and shallower for both strongly blurred or sharpened levels, consistent with greater perceptual salience for image differences that have more naturalistic spectra.

Funding acknowledgements: EY-010834

P40

Achromatic increments and decrements are different: the relationship between scaling and discrimination

Yangyi Shi, *Northeastern University*

Co-authors: Rhea Eskew, Northeastern University

A basic problem in psychophysics is to relate the internal representation of a stimulus to its physical intensity. In this study, we measured perceptual scales for achromatic contrast with Maximum Likelihood Difference Scaling (MLDS), using squares against a mid-grey background. Observers compared two stimulus pairs and chose the more different pair. All four squares were either achromatic increments (A+), or achromatic decrements (A-). The MLDS result was then compared with 2AFC achromatic pedestal discrimination, with pedestals and tests that were all combinations of A+ and A-. The main result is not novel: A+ and A- obey different rules. A Naka-Rushton saturating function describes the A+ MLDS result well, and the derivative of that function is proportional to the A+ pedestal discrimination for some (but not all) observers. A- MLDS and discrimination results are more complicated and are reminiscent of the classic findings of Whittle (1986, 1992). The sensitivity of A- is a cubic polynomial function of pedestal contrast. These findings will be compared with a similar study of S-cone contrast (reported at VSS 2022), which found a different type of asymmetry between S+ and S-. Presumably these increment/decrement asymmetries are due to underlying differences between ON and OFF neural pathways. One implication is that using stimuli that include both contrast signs, such as gratings and flicker, may obscure important asymmetries in the processing of contrast.

Funding acknowledgements: NSF BCS-1921771

P41

Threshold versus intensity curves measured with a new high-brightness display system

Yesenia Taveras-Cruz, *Northeastern University, Boston, MA*

Co-*authors: Rhea T. Eskew, Jr., Northeastern University, Boston, MA*

Classical threshold vs. intensity (tvi) curves were measured using optical systems and were generally limited to increment test stimuli and relatively simple spatial patterns. Modern displays provide more flexibility in terms of stimuli spatial profiles but are usually dim enough that there may be rod intrusion when measuring cone responses. Here we describe a high-brightness display system and present tvi's for increment and decrement achromatic tests. The system consists of a PROPixx three-chip DLP LED color projector (VPixx Technologies, Saint-Bruno, Canada) controlled via a Datapixx display driver, with 12-bit digital to analog conversion per RGB channel. Light from the projector is collected in a large diameter lens and focused on high gain rear projection screen. Retinal illuminance of the background may be varied in three ways: (a) varying the mean current supplied to the LEDs from the controller (adjustable in software); (b) using calibrated neutral density filters mounted near the eye; and (c) changing the midpoint of the RGB channels in software (e.g., making the white background as R=G=B=0.1 instead of 0.5). Method (c) is made easier by the fact that the PROPixx "gamma curve" is linear, which also means that no RGB bits are lost to gamma correction. We will show thresholds for achromatic tests on a white background varying from 0.56 to 4.03 log trolands, with preliminary results suggesting differences in the tvi curves between the increment and decrement tests.

Funding acknowledgements: This work was supported by NSF BCS-1921771

P42

Experimental assessment of scleral anisotropy using multi-meridian air-coupled ultrasonic optical coherence elastography

Lupe Villegas, *"Daza de Valdes" Institute of Optics, The Spanish National Research Council - CSIC, Madrid, Spain*

Co-authors: Fernando Zvietcovich, "Daza de Valdes" Institute of Optics, The Spanish National Research Council - CSIC, Madrid, Spain; Alejandra Varea, "Daza de Valdes" Institute of Optics, The Spanish National Research Council - CSIC, Madrid, Spain; Andrea Curatolo, "Daza de Valdes" Institute of Optics, The Spanish National Research Council - CSIC, Madrid, Spain; Judith S. Birkenfeld, "Daza de Valdes" Institute of Optics, The Spanish National Research Council - CSIC, Madrid, Spain; Susana Marcos, The Center for Visual Science, University of Rochester, Rochester, New York, USA

Scleral biomechanics plays a key role in the understanding of myopia progression. In this study, we characterized the elastic properties of sclera using an air-coupled ultrasonic (ACUS) optical coherence elastography (OCE) system. New Zealand rabbit eyes (n=7) were measured (<24hr postmortem) in four scleral locations: superior/inferior temporal (ST, IT), and superior/inferior nasal (SN, IN) maintaining an intraocular pressure of 15 mmHg. Elastic waves were induced in the sclera, and wave propagation velocity and shear modulus were measured along two directions: circumferential (superior-inferior) and meridional (nasal-temporal). Wave velocity in scleral tissue ranged from 6 to 24 m/s and shear modulus from 11 to 150 kPa. Velocity was significantly higher ($p<.001$) in the circumferential vs. meridional directions in the following locations: ST:15.83±2.85 vs 9.43±1.68 m/s, IT:15.00±3.98 vs 8.93±1.53 m/s; SN:16.79±4.30 vs 9.27±1.47 m/s; and IN:13.92±3.85 vs 8.57±1.46 m/s. The average shear modulus in the circumferential was also significantly higher ($p<.001$) than in the meridional direction for all locations: 65.37±6.04 vs 22.55±1.36 kPa. These results show that the rabbit sclera is mechanically anisotropic with higher rigidity in the circumferential direction compared to the meridional direction. ACUS-OCE is a promising non-invasive method to quantify the biomechanical changes in scleral tissue for future studies involving myopia treatments.

Funding acknowledgements: Horizon 2020 Framework Programme European Project Imcustomeye (H2020-ICT-2017 Ref. 779960); European Research Council (2018-ADG-SILKEYE-833106); Spanish Government PID2020-115191RB-I00; NIH NIE P30EY 001319; Unrestricted Funds Research to Prevent Blindness, NY; Spanish Government10.13039/100014440 (CSIC JAE Intro Fellowship); L'Oréal-UNESCO "For Women in Science" Spain; Spanish Government Juan de la Cierva-Incorporation Fellowship (IJC2018-037508-I); Fundacja na rzecz Nauki Polskiej (MAB/2019/12); National Agency for Academic Exchange, Polish Government (NAWA ULAM/2020/1/00176)

P43

Optical coherence elastography for In situ measurement of stiffness increase in posterior sclera after crosslinking

Maria Vinas-Pena, *Wellman Center for Photomedicine and Harvard Medical School, Massachusetts General Hospital, Boston, MA, USA*.

Co-authors: Xu FENG, Wellman Center for Photomedicine and Harvard Medical School, Massachusetts General Hospital, Boston, MA, USA.; Guoyang Li, Wellman Center for Photomedicine and Harvard Medical School, Massachusetts General Hospital, Boston, MA, USA.; SEOK-HYUN Yun, Wellman Center for Photomedicine and Harvard Medical School, Massachusetts General Hospital, Boston, MA, USA.

During eye growth, scleral development critically determine eye size and thus the refractive status of the eye. Scleral remodeling in myopia includes scleral thinning, loss of scleral tissue, and weakening of the mechanical properties. Therefore, an intervention aiming at stiffening scleral tissues (crosslinking, SCXL) may provide a way to prevent or treat myopia. The development of SCXL requires tools to evaluate the effects of crosslinking on the mechanical properties of tissues, particularly in sclera where the mechanical properties are more spatially heterogeneous than in the cornea, anisotropic, and varying locally from the anterior to posterior regions.

Here, we apply the high-frequency OCE technique to measure the heterogeneous mechanical properties of posterior scleral tissues and, evaluate the changes in shear moduli after SCXL. As a model system, we use *ex vivo* in porcine eyes and riboflavin-assisted UV crosslinking. From measured elastic wave speeds (6-16kHz), the average out-of-plane shear modulus was 0.71±0.12MPa (n=20) for normal scleras. After treatment, the shear modulus increased to 1.50±0.39MPa. This 2-fold change was consistent with the increase of static Young's modulus from 5.5±.1 to 9.3±1.9MPa after crosslinking, using conventional uniaxial extensometry. OCE revealed regional stiffness differences across the temporal, nasal, and deeper posterior sclera, demonstrating its potential as a noninvasive tool to test the effect of scleral crosslinking.

Funding acknowledgements: This research has received funding from the European Union's Horizon 2020 Research and Innovation Program under the Marie Sklodowska-Curie grant agreement H2020-MSCA-IF-GF-2019-MYOMICRO-893557 to MV and grants from the U.S. National Institutes of Health (R01-EB027653 and R42-EY028820).

P44

Time resolved modulation of neuronal activity associated with attention to low-level visual features

Alex Wade, *University of York*

Co-authors: Thomas Maltby, QMUL; Kirstie Wailes-Newson, University of York

During eye growth, scleral development critically determine eye size and thus the refractive status of the eye. Scleral remodeling in myopia includes scleral thinning, loss of scleral tissue, and weakening of the mechanical properties. Therefore, an intervention aiming at stiffening scleral tissues (crosslinking, SCXL) may provide a way to prevent or treat myopia. The development of SCXL requires tools to evaluate the effects of crosslinking on the mechanical properties of tissues, particularly in sclera where the mechanical properties are more spatially heterogeneous than in the cornea, anisotropic, and varying locally from the anterior to posterior regions.

Here, we apply the high-frequency OCE technique to measure the heterogeneous mechanical properties of posterior scleral tissues and, evaluate the changes in shear moduli after SCXL. As a model system, we use *ex vivo* in porcine eyes and riboflavin-assisted UV crosslinking. From measured elastic wave speeds (6-16kHz), the average out-of-plane shear modulus was 0.71±0.12MPa (n=20) for normal scleras. After treatment, the shear modulus increased to 1.50±0.39MPa. This 2-fold change was consistent with the increase of static Young's modulus from 5.5±.1 to 9.3±1.9MPa after crosslinking, using conventional uniaxial extensometry. OCE revealed regional stiffness differences across the temporal, nasal, and deeper posterior sclera, demonstrating its potential as a noninvasive tool to test the effect of scleral crosslinking.

Funding acknowledgements: ESRC, BBSRC

P45

Comparison of brightness and vividness of colors with different background colors in PCCS

Tadayuki Wakata*, Waseda University*

The purpose of this study was to compare the brightness and vividness of color on different-colored backgrounds. The stimuli were 173 patches of colors lying within the Practical Color Co-ordinate System (PCCS). The backgrounds were three achromatic colors: white, mid-gray, and black. Each color patch was pasted on mounts colored each of the background colors, making 519 combinations. Participants evaluated the stimuli on scales of bright to dark (brightness) and vivid to dull (vividness) using the Visual Analog Scale app on an iPad. They viewed the stimuli in a D65 standard light source booth in a dark room. The brightness and vividness scores for the three background colors were compared using Bonferroni correction for multiple comparisons for each color. It was found that, for both brightness and vividness scores, there were considerably smaller differences between a white and a black background than between a black and a gray background or a white and a gray background. Color bias was shown, with significant differences arising compared to the PCCS tone. Brightness and vividness evaluations were correlated; thus, they were integrated using Principal Component Analysis. The loading of the first principal component was 0.826, and this new integrated dimension was termed "Brilliantness."

P46

Optoretinography-based frequency characterization of the retinal response to a chirped flickering light

Piotr Franciszek Wegrzyn, *ICTER – International Centre For Translational Eye Research*

In this contribution, we present experimental results of *in vivo* characterization of the photoreceptor's response to a chirped flickering white light stimulating the retina. We acquire the ORG signal with Spatio-Temporal Optical Coherence Tomography (STOC-T) setup, which combines both temporal and coherence gating to overcome limitations present in Full Field Fourier Domain Optical Coherence Tomography. From the acquired volumes, we extract the changes in optical path length (OPL) between the inner and outer photoreceptor junction (ISOS) and the cone outer segment tips (COST). We perform the measurements for frequencies ranging from 5 Hz to 50 Hz. The chirped flickering facilitates significantly shorter data acquisition time. We present results of *in vivo* measurement from three volunteers. Our results show that we can measure OPL changes between ISOS and COST occurring in response to a chirped flickering stimulation in a reproducible manner and resolve the amplitude of the response in the function of flicker frequency.

Funding acknowledgements: Foundation for Polish Science (MAB/2019/12): The International Centre for Translational Eye Research (MAB/2019/12) project is carried out within the International Research Agendas Programme of the Foundation for Polish Science, co-financed by the European Union under the European Regional Development Fund. National Science Center: 2016/22/A/ST2/00313 and 2020/38/L/ST2/00556

P47

Investigating temporal evolutions of perceptual choice within biological and artificial neural networks

Yunlong Xu, *University of Rochester*

Co-authors: Oh-Sang Kwon, Ulsan National Institute of Science and Technology; Ruyuan Zhang, Shanghai Jiao Tong University; Duje Tadin, University of Rochester

Perceptual decisions involve a process that evolves over time until it reaches a decision boundary. It's important to understand how this process unfolds. Recent psychophysical data indicates that the visual system extracts motion axis information faster than motion direction information (Kwon et al., 2015, J Vision). To understand the underlying mechanisms, we developed a biophysically realistic cortical network model of decision making. We generalized the two-variable reduced spiking neural network (Wong et al., 2006, J Neuroscience) to four-variable. The network input is based on motion energy (Adelson et al., 1985, Josa a) and the temporal profile of surround influence (Tadin et al., 2006, J Neuroscience). The model reproduces the prior experimental findings, showing the motion axis extraction before direction extraction. It reveals a stronger axis-wise inhibitory connection between the selective neural populations than the direction-wise inhibitory connection. We further designed a recurrent deep neural network to validate the neural population connectivity pattern. Our model provides a quantitative explanation for the temporal evolution of motion direction judgments. The results show that the spatiotemporal filtering for visual motion integration, the center-surround antagonism, and stronger axis-wise inhibitory connection between the selective neural populations can explain how the visual system can extract motion axis orientation before detecting motion direction.

P48

A Simple Method for the Measurement of the Color Matching Functions

Yasuki Yamauchi, *Yamagata University*

Co-authors: Yuki Kamimura, Yamagata University; Ruiyan Liu, Yamagata University

It is well known that colorimetric matching of colors on different media does not ensure that their appearance is the same for everyone. One of the reasons is that there are variations in the color matching functions (CMFs) between observers, and that individual CMFs are different from that of the standard observer defined in CIE. If CMFs can be measured easily for each observer, customized color management will be possible. Traditional methods require the adjustment of the intensities of three primary lamps (R, G, B) which is not easy for naïve observers.

A simple method is proposed in this research, in which observers select the closest color from multiple candidates to a reference. The candidate colors are composed of 5 x 5 x 5 lattice, whose center is the expected matching color.

The average and standard deviation of the CMFs were calculated based on the CMFs of 11 observers. For each CMF, 5 candidate values were produced: average, average +/- 1/2 SD, average +/- SD. In the experiment, the observers were allowed to choose one for each CMF of RGB among 5 candidates to make a best match. Five observers whose CMFs were measured with the adjustment method participated in the experiment. The results of two methods showed good consistencies for the G and R CMFs, while some discrepancies were observed for the B CMFs. The total time of the experiment was reduced to 1/4 to 1/3, and it was also easy for the naïve subjects, which indicate that our method is an effective one.

Funding acknowledgements: This work was partially supported by JSPS KAKENHI (C) Grant Number 20K12017

P49

The impact of retinal excitotoxic lesions on parallel visual streams in the ferret dorsal lateral geniculate nucleus

Jingyi Yang, *University of Rochester*

Co-authors: Krystel Huxlin, University of Rochester; Farran Briggs, University of Rochester

Attesting to the relative strength of retinal inputs to the dorsal lateral geniculate nucleus (LGN) of the thalamus, in cats, acute retinal lesions erase responses of LGN neurons whose receptive fields fall within the retinal lesion projection zone (LPZ). Yet, thirty days later, these receptive fields appear to shift their representation to the immediate surround of the LPZ. However, little is known about whether LGN neurons in parallel streams are equally affected following retinal damage. Here, we asked whether changes in response properties of surviving LGN neurons depend on (1) their identity as either X/Y or ON/OFF cells, or (2) their receptive fields' positions relative to the LPZ. To test these hypotheses, we made retinal lesions by injecting kainic acid (KA) into one eye of ferrets and recorded from LGN neurons bilaterally in response to visual stimuli 7 days post-lesion. Area and eccentricities of retinal ganglion cell (RGC) loss in the retina were measured by RBPMS immunostaining. Relative eccentricities of recorded LGN neurons were based on electrode tracts. Our preliminary data suggest that RGC with large cell bodies are preserved in the lesioned eye. Additionally, we observed normal transient responses but altered sustained responses to flashing stimuli among contralateral responsive OFF LGN neurons. Together, these findings support the notion that acute KA lesions may differentially impact visual parallel processing streams at the surround of the LPZ in the LGN.

Funding acknowledgements: EY031520

P50

Comparison of Dynamic Visual Acuity Assessments in Head-Mounted Technology and Traditional Laptop-based Method

Nasif Zaman, *Human-Machine Perception Laboratory, Department of Computer Science and Engineering, University of Nevada, Reno, Reno, Nevada, United States*

Co-authors: Ethan Waisberg, University College Dublin School of Medicine; Joshua Ong, Michigan Medicine, University of Michigan; Phani Paladugu, Brigham and Women's Hospital, Harvard Medical School; Sharif Amit Kamran, Human-Machine Perception Laboratory, Department of Computer Science and Engineering, University of Nevada, Reno; Andrew G. Lee, Department of Ophthalmology, Blanton Eye Institute, Houston Methodist Hospital, The Houston Methodist Research Institute, Houston Methodist Hospital, Departments of Ophthalmology, Neurology, and Neurosurgery, Weill Cornell Medicine, Department of Ophthalmology, University of Texas Medical Branch, University of Texas MD Anderson Cancer Center, Texas A&M College of Medicine, Department of Ophthalmology, The University of Iowa Hospitals and Clinics; Alireza Tavakkoli, Human-Machine Perception Laboratory, Department of Computer Science and Engineering, University of Nevada, Reno

An impairment in dynamic visual acuity (DVA) has been observed in astronauts shortly after they return to Earth.1 These transitional effects may lead to safety risks during interplanetary spaceflight. At this time, functional vision assessments are performed via laptop onboard the International Space Station. However, DVA is not performed as a standard assessment, and optimization of traditional assessments may aid in more efficient and frequent testing. As part of our group's NASA-funded head-mounted visual assessment system to detect subtle vision changes in long-duration spaceflight2, we present a method to measure DVA in virtual reality. An early validation study was conducted with 5 subjects comparing our novel assessment with a traditional laptop-based test. All participants had a best correctable visual acuity of 20/20, had no past ocular history, balancing disorders, or neurological history. Our DVA assessment framework was built in UnrealEngine 4. The early validation study confirmed that our VR-based DVA assessment performed similarly to traditional laptop-based test (0.485 and 0.525 LogMar respectively, Pearson Correlation = 0.911). A Bland-Altman plot and analysis demonstrated that our DVA assessment data fell within the upper and lower limits of agreement. Future studies are required to further validate this technology; however, these early results showcase VR-based DVA assessment as a promising alternative to laptop-based methods.

Funding acknowledgements: NASA Grant [80NSSC20K183]: A Non-intrusive Ocular Monitoring Framework to Model Ocular Structure and Functional Changes due to Long-term Spaceflight.

P51

Deep Active Learning Using Retinal Image Embedding Vectors to Optimize Training Data Selections

Yifan Zhang, *C. Light Technologies, Inc.; Department of Computer Science, University of California, Berkeley; Department of Statistics, University of California, Berkeley*

Co-authors: Christy Sheehy, C. Light Technologies, Inc.; Min Zhang, Department of Ophthalmology, University of Pittsburgh School of Medicine; Ethan Rossi, Department of Ophthalmology, University of Pittsburgh School of Medicine; Ari Green, Department of Neurology, University of California, San Francisco; Department of Ophthalmology, University of California, San Francisco; Joe Xing, C. Light Technologies, Inc

In recent years, deep learning (DL) has made breakthroughs in many fields. However, the success of DL requires constant re-training with large amounts of data, which is often costly, causing data paucity problems in the medical space. Active learning (AL), on the other hand, aims to reduce the amount of training data while still retaining similar performance through the exploration of the added value of data.

In this study, we designed an AL system for training Artificial Intelligence (AI) models to explore faster learning curves while minimizing the need for new data. The model was designed for vessel object detection, using a Deep Neural Network (DNN), for scanning laser ophthalmoscopy (SLO) retinal images. Image embedding vectors were used to proactively select the most informative data. We established a baseline of k-fold cross validation frameworks to measure model performance, where 809 annotated images were randomly selected from our database and divided into multiple regions of interest with minimal selection bias. Using this validation framework, we observed the detection model for vessel junctions could achieve a mean average precision (mAP) of 0.648, precision of 0.645, and recall of 0.703; tested on 135 images. We then tested our active learning system by dividing the dataset into two clusters using image embedding vectors and machine learning clustering algorithms. We observed one cluster converged faster to the desired mAP performance than the other by 2.3x.

Funding acknowledgements: This research was supported by grants from the National Institutes of Health TL1 TR 001871 (C.K.S.) and R41 NS100222-01A1 (A.J.G. and C.K.S.), and That Man May See (A.J.G. and C.K.S.).

P52

Dynamic optomechanical eye model for the validation of peripheral aberration measurement

Yanbo Zhao, *Centre of Micro/Nano Manufacturing Technology (MNMT-Dublin), University College Dublin, Dublin 4, Ireland*

Co-authors: Fengzhou Fang, Centre of Micro/Nano Manufacturing Technology (MNMT-Dublin), University College Dublin, Dublin 4, Ireland and State Key Laboratory of Precision Measuring Technology and Instruments, Centre of Micro/Nano Manufacturing Technology (MNMT), Tianjin University, Tianjin 300072, China

Many myopia control products based on the peripheral defocus theory have emerged on the market in the past five years. However, efficient measurement of peripheral aberrations is still not a well-addressed problem. To validate the aberrometer for peripheral aberration measurement, a dynamic wide field optomechanical eye model is designed and fabricated. This model consists of a plano-convex lens representing cornea (f'=30mm), a double-convex lens representing crystalline lens (f'=100mm), and a spherical retinal screen with a 12mm radius. To optimize the quality of spot-field images get from the Hartman-Shack sensor, the materials and surface treatment for the retina are studied. The model has a movable retina to achieve Zernike 4th item (Z4 focus) ranging from -6.28-+6.84 μm. As for M (Mean sphere equivalent), it can achieve -11.85D-+10.88D at 0° visual field and -6.97D-+5.88D at 30° visual field with a 4mm pupil size. To allow a changing pupil size, a slot at the back of the cornea mount and a series of thin metal sheets with 2, 3, 4, and 6 mm holes are manufactured. Both on-axis aberrations and peripheral aberrations of the eye model are verified by commercial aberrometer VX130 (Luneau Technology, France) and the feasibility of the eye model to mimic a human eye in a peripheral aberration measuring system is illustrated.

Funding acknowledgements: Science Foundation Ireland (SFI) (No. 15/RP/B3208) and Enterprise Ireland (EI) (CF20221894)

P53

Peripheral blur may provide the eye with a cue for the sign of defocus

Len Zheleznyak, *Clerio Vision, Inc.*

The sign of defocus is used by the retina to guide emmetropization. However, the means by which the eye determines whether light is focused in front of, or behind the retina, remains elusive. In the current study, we propose a new cue for the sign of defocus: the orientation of the anisotropic peripheral blur. Previously published [1] population averages of wavefront aberrations across the horizontal visual field in hyperopes, emmetropes and myopes were used to assess peripheral optical quality and blur orientation. Due to the large magnitudes of off-axis astigmatism and coma, the peripheral retinal image quality was dominated by anisotropic blur, whose direction was also correlated with refractive error (vertically elongated peripheral blur in myopic eyes and horizontally elongated peripheral blur in emmetropic and hyperopic eyes). The differences in groups may be due to the interaction between peripheral wavefront aberrations and globe shape (i.e. peripheral axial length). We also found an interaction between longitudinal chromatic aberration and off-axis astigmatism, wherein peripheral blur orientation is wavelength dependent, raising additional questions pertaining to the nature of chromatic cues. The orientation of peripheral blur may provide the retina with an optical cue for the sign of defocus, potentially playing an important role in emmetropization.

[1] Romashchenko et al., "Peripheral refraction and higher order aberrations." Clin Exp Optom 103.1 (2020): 86-94.

Funding acknowledgements: NSF STTR Phase I: NSF/IIP 1549700; NSF STTR Phase II: NSF/IIP 1738506

P54

Neural Correlates of the Visual Expectation of Active and Passive Touch

Emily Isenstein, *Brain & Cognitive Sciences, University of Rochester*

Co-authors: Grace Rico, Ed Freedman, Duje Tadin, John Foxe

The sense of touch is frequently paired with a visual stimulus that provides information on how the sensation will be experienced. This is true for both active touch—when a person moves to touch an object—and passive touch—when an object moves to touch a person. However, limited research has been conducted on how active and passive touch are processed by the cortex, as well as how prediction of the sensory experience influences that processing. Here, we use electroencephalography (EEG) to measure cortical activity while virtual reality creates the visual expectation of touching an object that is paired with vibrotactile feedback. In the active condition, the participant will reach toward and receive tactile input from the virtual object. In the passive condition, the virtual object will move toward and provide tactile input to the participant. This experiment will measure an electrophysiological phenomenon called the mismatch negativity (MMN), a distinct deflection in the EEG waveform shown to index a deviation from an established pattern in sensory stimuli. To elicit an MMN, we will manipulate the duration of the vibrotactile stimuli, with 80% being 100 ms long and 20% being 160 ms long. Our experiment is the first to assess the MMN in an active tactile context. Preliminary data (n=4) show a robust N1 component and MMN in response to active and passive touch. Further data collection is ongoing.