THE COLOUR GROUP (GB)

PERCEPTION • MEASUREMENT • REPRODUCTION • ARTISTIC EXPRESSION

JANUARY VISION MEETING WEDNESDAY 6 JANUARY 2021

14:00	***Hue selectivity of SSVEP response: properties of its grand mean and underlying factors.*** **Ichiro Kuriki,** *Tohoku University*
14.30	***Effect of ageing of optical elements of the human visual system on its contrast sensitivity.*** **Maliha Ashraf,** *University of Liverpool*
15.00	***Sensing Changes in Illumination Spectra over Time.*** **Anya Hurlbert & Ruben Pastilha,** *University of Newcastle*
15.30	**GRANVILLE TEA (brew your own)**
16:00	***Modelling Individual Variations in Equiluminance Settings.*** **Jingyi He,** *Northeastern University*
16.30	***Color constancy: priors, cues, and development.*** **Maria Olkkonen,** *University of Durham*
17:00	**Palmer Lecture:** ***Compensation for Color Deficiencies.*** **Michael A. Webster,** *University of Nevada, Reno*
17:45	**Cutting-edge advances in vision research:** ***Toward a High-fidelity Artificial Retina.*** **E.J. Chichilnisky,** *Stanford University*
18:30	**"GRANVILLE GATHER" social event (bring a bottle)**

ONLINE

COLOUR GROUP JANUARY MEETING ABSTRACTS

Title: Hue selectivity of SSVEP response: properties of its grand mean and underlying factors

Authors: Ichiro Kuriki, Sae Kaneko, Saki Otomo (Tohoku University, Japan), Søren K. Andersen (University of Aberdeen, U.K.), David H. Peterzell (Fielding Graduate University, U.S.A.)

Neural representation of colour in early visual cortex is an unsolved issue in human vision. Cortical responses reflect properties of various colour-sensitive systems. We explored the hue selective responses in early visual cortex using recordings of steady-state visual evoked potentials (SSVEPs), elicited by a flickering checkerboard whose colour swept around a hue circle defined in cone-opponent colour space. The stimulus was similar to those used in our previous study by fMRI (Kuriki et al., 2015). Insights into the properties of hue selective mechanisms were obtained by examining 1) grand mean responses, 2) systematic individual differences, and 3) responses from a chromatic masking paradigm.
Grand means: Various sweeps yielded SSVEP amplitudes with hue-selective profiles that (1) increased in amplitude with colour contrast, and (2) were non-isotropic when the colour of the flickering stimulus swept along a circle the cone-opponent plane. Despite individual differences, the shape of grand mean SSVEP amplitude across the hue was beautifully point symmetric. The overall elliptic amplitude profile was significantly tilted away from the cardinal axes to have the highest amplitudes in the 'lime-magenta' direction, indicating that hue representation is not dominated by cone-opponency. It was fit nicely by the combination of waveforms predicted from cone-opponent responses (40%) and Munsell iso-Chroma locus (60%). This grand-mean property suggests that early visual cortex partially reflects perceptual colour responses (Kaneko et al., 2020). *Individual differences:* Correlational and factor analyses showed at least 5-8 chromatic mechanisms that are consistent with a multi-channel model. *Masking:* The SSVEP sweeps described above were conducted in the presence of a non-sweeping chromatic mask of a different temporal frequency. The bandwidth of the masking effect revealed by this frequency-tagging technique was also consistent with the multi-channel model with 5-8 hue-selective mechanisms.

Effect of ageing of optical elements of the human visual system on its contrast sensitivity

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Contrast sensitivity of human visual system declines as it ages even in the absence of any optical pathology. This decline in contrast sensitivity results from various physiological changes that happen as humans age. The lens becomes yellower and denser, the pupil become smaller and becomes less flexible, interocular light scattering increases, etc. To test this, we collected spatio-chromatic contrast sensitivity data from both younger (mean age: 33, n = 20) and older (mean age: 65, n = 20) colour-normal observers across three colour directions (achromatic, red-green, yellowish-violet), and six luminance levels from 0.02 to 2000 cd/m^2.

We found that the sensitivity of the younger age group is higher than that for the older age group by 0.3 log units on average. The cut-off frequency of the contrast sensitivity functions decreases with age for all colour directions and the rate of this decline is dependent on the mean luminance level. The rate of change of cut-off frequency with respect to age increases with increasing mean luminance level.

We modelled these findings as functions of age-related changes in optical properties of the human visual system. We found that the decline in yellow-violet contrast sensitivity is completely explained by the yellowing of the lens. In case of achromatic and red-green contrast sensitivity functions, reduction in retinal illumination due to changes in both lens transmission and pupil size explained some reduction in contrast sensitivity. Interocular scattering did not sufficiently explained the decrease in contrast sensitivity in older adults.

Sensing Changes in Illumination Spectra over Time.

Anya Hurlbert & Ruben Pastilha, University of Newcastle

Natural light is dynamic, changing in spectral shape and overall irradiance over both short- and long-time scales. Despite the consequent ever-changing retinal signal, the human visual system perceives constant object colours, effectively extracting the stability of intrinsic object materials. Yet the information conveyed by temporal variations in the extrinsic light spectra is not wholly discarded, and may be used to guide behaviour, both non-visual and visual. To what extent does the human visual system directly perceive changes in the illumination? Do dynamic changes in illumination influence non-visual behaviour? Here we describe results of two studies that address these questions. In an immersive laboratory environment, we measured speed detection thresholds of smooth changes in daylight metamers and showed that discrimination of chromaticity changes depends on the correlated color temperature (CCT) of the base illumination: cool-changes become less noticeable for progressively warmer base lights and vice-versa (Pastilha et al., 2020). These thresholds are generally larger than the typical speed of chromaticity changes in daylight, suggesting that natural CCT changes are too slow to be visually detected. In a real-world office setting, we assessed subjective and objective non-visual responses to distinct lighting conditions, including a real-time recording-and-replaying of outdoor illumination, and found significant preferences for dynamic over static illumination (Llenas et al., 2019). The human visual system is better able to detect large changes in illumination chromaticity away from neutral, as occur at dawn and dusk, yet smaller changes in illumination spectra may influence behaviour even when invisible.

Modelling Individual Variations in Equiluminance Settings

Jingyi He, Yesenia Taveras Cruz, Rhea T. Eskew, Jr

Recently we reported measurements of heterochromatic flicker photometry (HFP) in 22 young observers, with stimuli that (nominally) modulated only L- and M-cones, and were kept at (approximately) a constant multiple of detection threshold (He, Taveras Cruz, & Eskew, 2020). These equiluminant settings were represented as the angle in the (L,M) cone contrast plane, with the 'greenish' peak of the flicker in quadrant II and the 'reddish' peak in quadrant IV; equiluminant settings were reported as the 'greenish' angle. The mean equiluminant angle was 116.3° (a M/L cone contrast ratio of -2 at equiluminance), but individual differences in the settings were substantial, with the variation across individuals almost five times larger than the within-subject precision in the settings. In the present study we sought to determine the degree to which we could account for our observers' HFP settings by plausible variations in the density of macular pigment (MPOD), the L- and M-cone photopigment optical densities (PPOD), and serine/alanine polymorphism in L-cone opsin (λ_{max}). Most of the range of our measured equiluminant angles could be accounted for by these factors, although the largest angles (smallest $|\Delta M/M: \Delta L/L|$ ratio at equiluminance) could not. Individual differences in HFP have sometimes been taken to indicate variations in the ratio of L:M cone number (e.g. Gunther & Dobkins, 2002; Kremers et al., 2000; Rushton & Baker, 1964); our results suggest that most of the individual differences in HFP might be equally-well ascribed to physiological factors other than cone number.

References:

Gunther, K. L., & Dobkins, K. R. (2002). Individual differences in chromatic (red/green) contrast sensitivity are constrained by the relative number of L-versus M-cones in the eye. *Vision Research, 42*(11), 1367-1378. doi:10.1016/S0042-6989(02)00043-3

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Kremers, J., Scholl, H. P., Knau, H., Berendschot, T. T., Usui, T., & Sharpe, L. T. (2000). L/M cone ratios in human trichromats assessed by psychophysics, electroretinography, and retinal densitometry. *Journal of the Optical Society of America A, 17*(3), 517-526. doi:10.1364/JOSAA.17.000517

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Color constancy: priors, cues, and development

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Color constancy is the ability to identify surface color across changes in illumination and viewing context. Although requiring no conscious effort, inferring surface color from ambiguous sensory signals is a hard computational problem. In order to solve this task, the visual system may use information about statistical regularities in the environment such as a daylight prior, as well as cues to the illumination in the visual scene itself. Across several experiments, we tested whether adult observers can use highlights as a cue to the illumination; whether adult and child observers have a daylight prior when estimating surface color across simulated illuminant changes; and what is the developmental trajectory of color constancy from 6-year old children to adults. Across these experiments, we used both achromatic matching and a child-friendly block-selection task. We found that observers were able to use a highlight cue when other cues were weakened; that the pattern of color constancy across illuminants and surface reflectances was remarkably similar for children and adults; and that color constancy for both children and adults was best for bluish illuminations, consistent with a blue-biased daylight prior. Surprisingly, color constancy was overall slightly better in children than adults across all experiments, suggesting that adults may use cognitive strategies to "override" low-level color constancy in a block-selection task.

Palmer Lecture: Compensation for Color Deficiencies.

Michael A. Webster, University of Nevada, Reno

Common inherited color deficiencies arise at the first stages of vision – when light is absorbed by the cones – and reflect highly stable changes to which the observer has a lifetime to adapt. They thus provide an ideal natural experiment for probing the capacities and limits of visual plasticity. The nature of these adjustments can also help to address fundamental questions about the properties of color coding and color experience. A number of studies have found that the reported color percepts of anomalous trichromats are stronger than predicted by the reduced spectral separation of their longer-wave cone sensitivities. These results suggest that responses at subsequent stages are compensated to discount the sensitivity losses. I will discuss the advantages of probing these compensations at different levels of visual coding and with different tasks, as well as potential mechanisms and limits to these adjustments.

Toward a High-fidelity Artificial Retina

E.J. Chichilnisky, Stanford University

Abstract: Electronic interfaces to the retina represent an exciting development in science, engineering, and medicine – an opportunity to exploit our knowledge of neural circuitry and function to restore or even enhance vision. However, although existing devices demonstrate proof of principle in treating blindness, they produce limited visual function. Some of the reasons for this can be understood based on the precise and specific neural circuitry that

mediates visual signaling in the retina. Consideration of this circuitry suggests that future devices may need to operate at single-cell, single-spike resolution in order to subserve naturalistic visual function. I will show large-scale multi-electrode recording and stimulation data from the macaque and human retina indicating that, in some cases, such resolution is possible. I will also discuss cases in which it fails, and propose that we can improve artificial vision in such conditions by incorporating our knowledge of the visual system in bi-directional devices that adapt to the host neural circuitry. Finally, I will introduce the Stanford Artificial Retina Project, aimed at developing a retinal implant that more faithfully reproduces the neural code of the retina, and briefly discuss the implications for scientific investigation and for other neural interfaces of the future.

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