THE COLOUR GROUP (GB)

PERCEPTION • MEASUREMENT • REPRODUCTION • ARTISTIC EXPRESSION

COLOUR VISION MEETING — WEDNESDAY 8 JANUARY 2025

10:00	***COFFEE and REGISTRATION***
10.20	***WELCOME***
10:30	***Receptoral and postreceptoral contributions to non-image-forming vision*** **Manuel Spitschan** Technical University of Munich
11.00	***Ancestral photoreceptor diversity as the basis of visual behaviour*** **Tom Baden** University of Sussex
11.30	***Mismatching surface colours in the wild*** **David Foster** University of Manchester
12.00	***Leveraging AI to model colour appearance in complex scenes*** **Arash Akbarinia** University of Giessen
12.30	***LUNCH***
14:00	***Heterochromatic brightness and luminance*** **Shuchen Guan** University of Giessen
14:30	***PALMER LECTURE: The robustness of material perception in rich environments*** **Hannah Smithson** University of Oxford
15:30	***HALSTEAD-GRANVILLE TEA***
16:00	***Associations between colour appearance and perceived food attributes across colour vision types*** **Ilgin Cebioglu** Newcastle University
16:30	***Colour matching functions for everyone*** **Andy Rider** University College London
17:00	***The role of colour in occupational scenarios*** **Gabi Jordan** Newcastle University
17:30	***FOOD and DRINK RECEPTION***

In person at **City St George's, University of London**

Receptoral and postreceptoral contributions to non-image-forming vision

Manuel Spitschan Technical University of Munich

Light influences human physiology, including circadian rhythms and melatonin suppression, through the retinohypothalamic pathway. This pathway is primarily driven by melanopsin-containing intrinsically photosensitive retinal ganglion cells (ipRGCs) but also receives inputs from cones and rods. I will discuss a series of studies that apply vision science techniques to investigate retinal contributions to non-visual processing in humans.

Ancestral photoreceptor diversity as the basis of visual behaviour

Tom Baden University of Sussex

Animal colour vision is based on comparing signals from different photoreceptors. It is generally assumed that processing different spectral types of photoreceptor mainly serves colour vision. Here I propose instead that photoreceptors are parallel feature channels that differentially support visual-motor programmes like motion vision behaviours, prey capture and predator evasion. Colour vision may have emerged as a secondary benefit of these circuits, which originally helped aquatic vertebrates to visually navigate and segment their underwater world. Specifically, I suggest that ancestral vertebrate vision was built around three main systems, including a high-resolution general purpose greyscale system based on ancestral red cones and rods to mediate visual body stabilization and navigation, a high-sensitivity specialized foreground system based on ancestral ultraviolet cones to mediate threat detection and prey capture, and a net-suppressive system based on ancestral green and blue cones for regulating red/rod and ultraviolet circuits. This ancestral strategy probably still underpins vision today, and different vertebrate lineages have since adapted their original photoreceptor circuits to suit their diverse visual ecologies.

Mismatching surface colours in the wild

David Foster University of Manchester

Coloured surfaces viewed in a scene may match at one moment but not at another, usually because of a change in viewing conditions. How often does such mismatching occur outdoors under natural, uncontrolled illumination changes, as distinct from the purely spectral changes in illuminant metamerism? Data were taken from hyperspectral radiance images acquired at intervals of 1 minute to more than 4 hours. For pairs of randomly chosen surfaces in a scene, the relative frequency of appearing initially the same and different later was around 0.01% to 0.1%, depending on the colour difference. But if they already appeared the same, the relative frequency was higher, around 6% to over 60%, much higher than for illuminant metamerism, suggesting that real-world lighting changes may well impair surface identification by colour alone.

Leveraging AI to model colour appearance in complex scenes

Arash Akbarinia University of Giessen

Our colour perception diverges from objective photometric measurements in several aspects, such as perceptually uniform colour space and categorical colour perception. Here, we study these two phenomena utilising deep neural networks. We train a linear classifier on top of frozen pretrained networks to perform an odd-one-out task oblivious to the studied phenomena. Next, we conduct two psychophysical tests to compare networks' internal representation to human colour responses. [i] The results of the colour discrimination experiment offer a novel framework to create a perceptually uniform colour space. The pattern of discrimination thresholds in networks highly resembles human sensitivity, including the known asymmetries in different parts of the colour space. [ii] The results of the colour categories experiment reconcile the longstanding debate between universalists and relativists: pure-vision models (e.g., ImageNet object recognition networks) explain 85% of human data, and the vision-language models (e.g., CLIP text-image matching networks) explain the remaining 15%. These results demonstrate that categorical colour perception is a free-from-language representation, yet linguistic colour terms influence its development. Overall, our findings suggest artificial neural networks are suitable candidates to model human colour perception beyond laboratory stimuli to ecological environments with all its inevitable complexities.

Heterochromatic brightness and luminance

Shuchen Guan University of Giessen

Co-authors: Ennis, R., Gegenfurtner, K.

Luminance has been the standard measure of light intensity for over 100 years. However, it has long been known as imperfect in predicting heterochromatic brightness. Compared to luminance, heterochromatic brightness judgments are non-additive, higher for saturated stimuli and short-wavelength (bluish) stimuli. Can we devise better models of heterochromatic brightness?

Our first goal was to measure heterochromatic brightness in a reliable manner. We obtained rankings from 44 observers in test and retest sessions in a raking task, using a set of 144 color patches covering 12 hues and 12 intensities. The high consistency of test-retest rankings indicated that this task reliably evaluated heterochromatic brightness. The rankings were best explained by a nonlinear model taking the maximum value of the three weighted monitor primaries. All other models, including luminance, radiance, CIELAB L* and CIECAM16 Q performed much worse.

We then obtained data from the same observers, running the experiment online using their computers at home. In an additional step, we calibrated these computers to determine the expected effects of using them in an uncalibrated manner. For our ranking task, these effects were modest and we obtained excellent agreement between both settings. This encouraged us to obtain an even bigger sample of 183 online-only observers via an online data collection service, which also agreed extremely well with the previous samples.

The non-linear weighted model also performed excellent with a different set of stimuli that included hue, intensity and chroma variations. The optimal weights were close to equal (0.29 R, 0.39 G, 0.32 B), giving credence to the wide use of the MaxRGB model in computer vision applications.

PALMER LECTURE: The robustness of material perception in rich environments

Hannah Smithson University of Oxford

Sensory data is incomplete, yet we are rarely fooled in our visual estimation of colour and material properties. Ten years on, audiences still talk about #TheDress – a photograph of a dress that went viral in 2015 because it split opinion on the colour of fabric in the photograph. The disagreement triggered by #TheDress is noteworthy because it runs counter to our dominant experience of visual judgements that are closely aligned to those of others, and to information from other senses, and to the physical world. Through a series of case studies of psychophysical experiments – using real, photographed and computer-generated stimuli; bespoke displays; lab-based and online testing; and a range of psychophysical methods and data modelling approaches – we highlight the benefits of stimulus richness for perceptual extraction of physical properties. The complexity of light-material interactions has necessitated compromises in empirical approaches to material perception – both in the generation and specification of stimuli and in the measurement of human responses to those stimuli. These compromises have sometimes emphasised the limitations of perception. However, a multitude of sensory signals carry robust information about the physical world, and perceptual decisions improve through active exploration of those signals. In daily life, visual perception is a dynamic process, quite unlike the static snapshot captured by #TheDress, and the tools available for studying such processes are evolving.

Associations between colour appearance and perceived food attributes across colour vision types

Ilgin Cebioglu Newcastle University

Trichromatic colour vision is considered an adaptive trait that enables efficient assessment of food properties and edibility, e.g. determining the ripeness of a banana as it transitions from green to yellow to brown. A recent study using near-metameric illumination changes to manipulate the colour appearance of 3D artificial fruits found significant correlations between fruit colour appearance and perceived sweetness, freshness, nutritive value, and appetisingness in participants with normal colour vision (NCV; Cebioglu et al., in revision). Building on this, the current study used near-metameric illumination changes to alter the colour appearance of real fruits, aiming to investigate whether similar associations hold for individuals with congenital colour vision deficiencies (CVD). Our findings suggest that while individuals with CVD and NCV exhibit broadly similar patterns in perceived fruit properties in response to changes in colour appearance, these associations are generally less pronounced in participants with CVD.

Colour matching functions for everyone

Andy Rider University College London

Human colour vision derives from the light-evoked responses of three cone types that preferentially respond to different regions of the visible spectrum. The probability that photons are absorbed in each cone type varies as a function of wavelength - the spectral sensitivity functions or cone fundamentals. These functions vary between cone types, between observers, across the retina and over the lifespan. Variability in the spectral sensitivities can lead to differences in colour vision and is crucial for colour critical tasks and psychophysical techniques such as silent substitution. Measuring a complete colour matching function is difficult, time-consuming and provides incomplete data about the cone fundamentals. I will

present a parametric model of the cone spectral sensitivities and describe some colour matching experiments that allow us to fit this model to an individual's colour vision.

The role of colour in occupational scenarios

Gabi Jordan Newcastle University

Co-authors: Dlay, H., Cebioglu, I., Hurlbert, A.

Colour plays an important role in everyday behaviours, from generic tasks common to everyone – such as choosing what to eat or wear - to specialised tasks specific to particular professions and occupations such as medical diagnoses, nursing, aviation, or policing. For reasons of health and safety colour vision standards are in place for some occupations but not others. However, questions still exist regarding the extent to which colour features in the day-to-day activities of employees. We here assess the perceived importance of colour in operational work and training in police officers.

We have surveyed 68 volunteers on their perceptions of colour in policing. We have also conducted semi-structured interviews with 11 volunteers to gain a richer data set about their daily operational tasks especially with regard to colour-critical scenarios.

We find large variability in the perceived importance of colour in daily policing activities. Our qualitative data demonstrate that there are challenges with colour regardless of colour vision status.