TUNING LIGHT TO SEE AND FEEL BETTER: THE HUMAN VISUAL AND NON-VISUAL RESPONSES TO SPECTRAL VARIATIONS IN LIGHT

Hurlbert, A.C.[1], Pearce, B.M., Aston, S.
[1] Institute of Neuroscience, Newcastle University, Newcastle upon Tyne, UNITED KINGDOM
Anya.hurlbert@ncl.ac.uk

Abstract

The advent of tuneable, multi-channel LED light source technology enables vision scientists to probe better the human response to light, yielding greater understanding of how human physiology has adapted to natural environmental illuminations. At the same time, novel lighting technology allows designers to tune lighting to shape human behaviour in different environments. In this talk, I will discuss the effects of spectral tuning of light in terms of both the visual and non-visual systems, and their possible interactions.

For example, I will describe the effects of dynamic changes in the spectral content of light on object colour perception, in the context of the basic phenomenon of human colour constancy. Colour constancy is the perceptual phenomenon by which object colour remains constant despite changes in the illumination spectrum – a yellow banana appears yellow to whether illuminated by tungsten light or morning daylight. Colour constancy depends on multiple mechanisms in the human visual system, and, although a textbook example of a perceptual constancy, it is not universally perfect for all surfaces and all illuminations – a fact captured by colour appearance models. To examine the dependence of colour constancy on illumination, we have developed an illumination discrimination task which measures colour constancy by determining discrimination thresholds for illumination changes in particular chromatic directions (parametrised by unit distances in a perceptually uniform space (Lu*v*)). Using tuneable multi-channel LED light sources to generate changing illuminations in real time, we find that thresholds for discriminating illumination changes are highest – i.e. colour constancy is best - for "blue-ish" daylight illuminations. Conversely, colour constancy is worst for atypical illuminations. These results suggest that colour constancy is optimised for naturally encountered illuminations, and that stability of object colour may be achieved even under changing illuminations, provided these changes occur for cooler temperatures along the daylight locus. This "blue bias" in colour constancy also holds for adaptation points biased away from a neutral chromaticity point.

I will also describe another sort of "blue bias", with respect to the non-visual pathway, probed with multi-channel LED light source technology. In a series of laboratory experiments, we are examining the effects of varying light spectra and overall irradiance levels on mood, sleepiness, attention, cognitive performance, and melatonin production, putatively mediated by the pathway originating in melanopsin-containing, intrinsically photosensitive retinal ganglion cells (ipRGCs), whose spectral sensitivity peaks in the short-wavelength ("blue") region. In each testing session, which commences approximately 12 hours after daily wake-up, the participants are first exposed to dim light for 2 hours, followed by 2 hours of the experimental light condition. The experimental light conditions vary either the melanopsin-stimulating content of the light (the "melanopic irradiance") or the photopic irradiance (lux), with the other held constant. Preliminary results suggest that there is an interaction between the visual and non-visual pathways; the effectiveness of a particular melanopic irradiance depends on the light's lux. Thus, it is possible that the "blue" content of light is not sufficient to determine the non-visual effects of light on human behaviour.

These visual and non-visual responses to spectral variations in light may also be considered in the context of lighting for museum paintings. To assess colour constancy outside of the laboratory in a gallery setting, using real artworks, we performed a series of mass experiments as part of a multi-media installation in the 2014 "Making Colour" exhibition at the National Gallery, London. The installation was designed to educate and engage the public while enabling data to be collected from individual wireless response pads. The experiment used tuneable, multi-channel LED lighting technology (developed in the EU FP7 HI-LED project) to produce controlled changes in illumination spectra in real time. The perceptual experiments included two assessments of colour constancy – (1) Colour naming under near-

metameric illumination changes and (2) global illumination discrimination – and one assessment of illumination preference, for a particular pair of artworks. Over 10 000 people took part in the experiments; of these, approximately 1 800 provided complete data sets which enabled us to assess the effect of individual factors (age, sex, and putative colour vision deficiency) on colour constancy and illumination preference. We found for that (1) even when the illumination change was constrained to be near-metameric, i.e. preserving both CCT and lux of the illumination spectra, colour constancy was not preserved, as measured by colour naming and (2) colour constancy was enhanced for illumination changes in the "blueish" daylight direction, replicating the results from the small-scale laboratory studies. The illumination preference experiment found an overwhelming preference for daylight illumination (6 500 K), in comparison to three illuminations of lower colour temperatures, simulating candlelight, tungsten light and cool white fluorescent light.

The results of these and other experiments suggest, overall, that the human visual system is tuned to the natural illuminations under which it has evolved, and that lighting design should take account of both visual and non-visual responses to spectral variations in illumination.