TC1-47: Hue and Lightness Correction to Industrial Colour-Difference Evaluation

During the TC meeting, there were several presentations. (1) Work by Dr. Nobbs and his students at Leeds University has led to a better SL formula than what is currently suggested in the CIE94 color-difference formula. This is only applicable to the 1964 10° CIE Standard Observer. In order to use it, you must also specify the luminance of the background. (2) Next, Dr. Luo showed that, in the blue region of the $a^* b^*$ diagram, the color-difference ellipses do not point towards neutral. It was proposed to use an S_r rotation term based on some new color-difference data gathered in the blue region. (3) Dr. Berns sent some data on hue dependency. He has shown that the hue weighting changes as a function of hue angle. This can and will be used to correct the S_H term. Once all these new findings are incorporated, CIE94 will be superseded by a new formula that should be better than CIELAB, CMC, and CIE94.

TC1-55: A Uniform Colour Space for Industrial Difference Evaluation

Jim Nobbs chairs this new TC, which held its first meeting in Warsaw immediately after being formed. The TC1-47 members will be invited to join, as well as Rolf Kuehni and Françoise Viénot. It will develop an industrial color-difference equation for fixed reference conditions. They would like to start the work by using cone fundamentals. Color-appearance model parameters should be applied to the color-difference equation derivation. They will also need to identify datasets again. Because this will represent a color-appearance space with an associated color difference equation, ΔE values larger than 10 should be considered, and not many datasets around fit that criterion. First they will look at existing data on small ΔE values to derive equations. Then they will apply those equations to large ΔE values to see how well they work.

CONCLUSION

This report would be remiss if no mention were made of the outstanding social events that were featured throughout the 6-day CIE Quadrennial Meeting. The two most memorable events were the Russian Ballet and the official banquet. First, the Russian Ballet debuted in Warsaw the night we attended the performance, and it was a smashing hit. We even had the pleasure of meeting its Russian creator after the performance. We were then treated to an incredibly delectable feast to cap off the evening. The official banquet was on the last evening, June 29th. It was shear delight as we were entertained by Polish college students in traditional garb dancing to traditional Polish music. The garb and music changed with each course. The evening was so lively that the distinguished CIE President felt compelled to join in a dance with one of the students. The National Polish CIE Committee is to be commended for putting on a memorable technical and social meeting for the 24th CIE Quadrennial session.

PAULA J. ALESSI
Eastman Kodak Company

The Rank Prize Funds Symposium, 1999

In April 1999, invited delegates convened at Grasmere in the English Lake District for the Rank Prize Funds Symposium on Colour Vision and its Variation. The Rank Prize Funds are a memorial to the charitable interests of the late Lord Rank and support investigations into the food industry and opto-electronics: two areas of science that underlay Lord Rank's business career. The symposium was intended to support younger scientists by encouraging them to develop their skills and make contacts. Ten leading colour vision scientists were invited to meet with 20 younger researchers and, in a relaxed and informal atmosphere, all delegates were required to give a presentation of their work.

Horace Barlow welcomed the conference attendees on Tuesday morning and John Mollon set the scene with an introductory review. Mollon highlighted the fact that we can look to inherited differences, for example in photopigments or macular pigment, to explain the variation in colour vision, and argued that it is perhaps the properties of the natural world that have been instrumental in shaping our colour vision. His discussion encompassed the variety of methodological approaches drawn together in this meeting: psychophysical, physiological, genetic, and ecological.

ECOLOGICAL STUDIES

Petroc Sumner built on the suggestion that the evolution of trichromacy, common to all Old World primates, may have been driven by an advantage in detecting food items against a foliage background. Sumner presented data from field work in Uganda and concluded that the selective advantage could have been in either frugivory or folivory, and that the properties of mature leaves, not particular diet items, determined the spectral tuning of primate photoreceptors. The evolution of the opsin gene array was discussed by David Hunt, and Matthew Wright presented information on the cone visual pigment of paleognathous birds, which are believed to provide an important link between the visual system of reptiles and that of neognathous birds. Sarah Hunt argued for the importance of obtaining objective measures of colour that are independent of human colour vision when studying bird-selected colour patterns or visually mediated avian behaviors. She presented her work on blue-tit plumage, avian foraging, and protective coloration of lepidopteran larvae.

GENOTYPE AND PHENOTYPE

Samir Deeb reviewed the genes encoding the L and M pigments. These genes are arranged on the X-chromosome

in a head-to-tail tandem array. Genotypic polymorphisms comprise variations in base-pair sequence, variation in number and position of M genes and L/M hybrid genes, and possibly variation in retinal expression. L/M hybrid genes have been implicated in protan and deutan colour vision defects, but are also found in about 6% of individuals with normal colour vision. Deeb unravels this paradox by suggesting that only the first of two genes of a visual pigment array are expressed sufficiently to influence colour vision.

Contrary to Deeb, Jay Neitz suggests that more than two pigment genes from one X-chromosome array can be expressed and can cause variation in colour vision. Pamela Kainz reported that men with normal colour vision can express high levels of more than one L pigment gene in addition to M pigment genes. She found that the first gene in the array was always expressed in cadaver eyes at a higher level than the downstream genes, and that each individual cone expressed one pigment gene and most expressed the first gene in the array. Stacy Sjoberg reported large variation among expressed cone pigment cDNA sequences: she found 9 normal variants of the M pigment sequence among 89 expressed sequences, and 19 normal variants of the L pigment sequence among 93 expressed sequences. The idea of stereotypical L and M pigment genes seems no longer tenable.

L:M CONE RATIOS

Characterization of the retinal distribution of the morphologically indistinguishable L and M cones was an important thread in the meeting. Herbert Jaegle presented his studies of variations in L:M ratios in colour normals. He crystallized two as yet unanswered questions: which genetic factors influence L/M cone ratio; and how reliable are psychophysical estimates of it? Janice Nerger, a proponent of the view that the wavelength of unique yellow depends on the relative proportions of the L and M cones in the retina, measured unique blue in the fovea and at various peripheral locations and concluded that unique blue is determined by the number of S-cone inputs. Gabriele Jordan suggested that the phenomenologically observed unique hues are not determined by internal factors (e.g., L:M ratios) but have been defined by properties of the natural world. Sheila Imhoff introduced yet another complication in determining L and M contributions to hue discrimination: recent models of the interaction between rods and cones suggest that rods contribute to hue perception by affecting the M and/or the L cone signals. Imhoff found that the Bezold–Brücke hue shift was affected by the number of rods in the test area and the varying intensity falling on these rods.

Psychophysical estimates of L:M cone ratios remain controversial and may have to be resolved by other methods. Stephanie Hagstrom examined L:M cone ratios by measuring the ratio of L:M cone pigment mRNA. She evaluated this technique by also collecting individual cones and analyzing the pigment gene expressed. Hagstrom found large variations in L:M cone ratios at different eccentricities and for different eyes, and the single cone analysis also showed that individuals can have more than three types of cones in their retina. Lisa Diller employed a physiological method to view the primate L:M cone ratio. She found large variability in the relative strength of L to M cone signals in H1 horizontal cells and parasol and midget ganglion cells, yet at a given location, the chromatic properties of these three cell types in peripheral retina are nearly identical. Diller suggested that the simplest explanation for her results is that the variable cone mosaic dictates the relative strength of L and M cone signals in these cell types. A more direct approach to studying L:M cone distributions has been developed at the University of Rochester: high-resolution images of living retinae are obtained using adaptive optics such that spatially localized retinal densitometry can be used to identify the L, M, and S cones in living retinae. Austin Roorda studied two human trichromats and one macaque. Human L:M cone ratios were 3.79 and 1.14, but both observers chose a unique yellow within the normal range. Roorda found no evidence for a regular packing arrangement of L and M cones and only the macaque had a regular S-cone mosaic.

COLOUR VISION DEFECTS

Lindsay Sharpe considered subjects with genetic mutations that caused severely abnormal retinal development, and argued that disruption at this very low level should have ramifications higher in the visual system. He reported drastic consequences on the retinal mosaics of rod monochromats, and fMRI studies showed how the topography of the visual cortical maps of these patients has been changed to compensate for their missing foveal input. Benedict Regan continued with the topic of abnormal colour vision and asked “Can daltonism be cured?” By modeling the effects of a range of filters on the chromaticity distributions of natural objects viewed by daltonians, Regan found that certain filters may help the daltonian discriminate the reflectance spectra of real-world objects.

PSYCHOPHYSICS

Joel Pokorny reviewed the several biological variables that control metameric matching. Colour matches depend only on the shapes of the photoreceptor spectral sensitivity functions, which are governed by the photopigment extinction spectrum and the photopigment optical density, and on any modification of the spectral composition of the light reaching these due to spectrally selective prereceptoral filters, e.g., the lens and macular pigment. The topic was continued by José Diaz, who explained how individual variations in metameric matches could be successfully modeled using psychophysical estimations of the lens density and macular pigment density and in some cases by shifting the L-cone fundamental to shorter wavelengths.

Higher-order tasks requiring colour vision were also well represented in this meeting with contributions from Marina Bloj, who used a modified colour-matching task to show that surface colour perception depends on shape perception;

Anya Hurlbert, who studied individual differences in learning a colour discrimination task; and James Kraft, who investigated the relationship between hue discrimination and chromatic scaling as methods of assessing saturation. Hannah Smithson studied the variation in chromatic thresholds that can be produced by a chromatic masking stimulus presented within 100 ms of the target. By manipulating stimulus onset asynchrony, she found no latency differences between the S-cone and L-/M-cone subsystems mediating our colour perception.

CULTURAL DIFFERENCES

The last two papers in the symposium concerned cultural differences in colour perception. After describing experiments on whether perceptual learning could, in principle, cause individual differences in colour perception and by looking for perceptual-cognitive differences associated with differences in colour language, Ian Davies concluded that colour perception is largely universal, but may be tuned by personal or cultural history. Debbie Roberson investigated Rosch Heider's classical work, which has been taken as evidence for universality of colour categories. She found that colour language did affect test performance and that the only universal constraints on colour categorization may be that all languages group colours by similarity and that no language has yet been found that groups together disparate areas of the spectrum while leaving out the intermediate portion.

LOCAL COLOUR

The local history around Grasmere provided a particularly suitable backdrop for this meeting. William Wordsworth resided for much of his life at Dove Cottage in Grasmere. In his "Lines composed upon an evening of extraordinary splendour and beauty", Wordsworth elaborates on his theory of infant colour vision and his hypothesis that the vividness of our colour sensations declines with age. John Dalton, who was born at the nearby town of Cockermouth just four years before Wordsworth, is celebrated for his description of his own dichromacy. Dalton combined the physical pleasure of hill walking with a scientific interest in the relationship between barometric pressure and altitude. He visited the Lake District for relaxation and remarks that he "spent the time in breathing the salubrious air of the mountains and lakes," and it was "an additional gratification to be enabled to unite instruction with amusement."[1] As one of the younger researchers present at this meeting, I would like to thank the Rank Prize Funds and all the delegates, both the well-established researchers and those just starting out, for providing such a successful and supportive meeting.

1. Dalton J. Observations in meteorology, particularly with regard to the dew-point, or quantity of vapour in the atmosphere; made on the mountains in the north of England from 1803 to 1820. Memoirs of the Literary and Philosophical Society of Manchester. 1824;4:104–124, esp. 106–107.

H. E. SMITHSON
Department of
Experimental Psychology
University of Cambridge
Downing Street
Cambridge, CB2 3EB
United Kingdom

CIE Symposium '99 "75 Years of CIE Photometry"

CIE is an organization that will soon celebrate the 100th anniversary of its establishment. During all these years CIE has produced many reports, measurement and design guidelines for all lighting situations. From among all the advice there are two groups of recommendations of especially great importance. These are those that dealt with the fundamentals of light and colour measurement. The first of these recommendations established modern photometry. It codified the visibility (now spectral luminous efficiency) function and laid down the terms and definitions of the fundamental photometric quantities. This happened 75 years ago at the Geneva meeting of the CIE. The 1999 Symposium of the CIE celebrated this 75th anniversary of the CIE photometric system. The symposium was held at the Hungarian Academy of Sciences, Budapest, between 30 September and 2 October 1999. Nine Invited Papers summarized the pre-1924 situation of photometry, dealt with establishment of the present photometric system, discussed its shortcomings and possible extensions. Further 16 Contributed Papers and four Poster Presentations elaborated on the subject. It is remarkable that a technical quantity, based on psychophysical investigations survives 75 years without a major change. In 1924 very little was known about the light sensation mechanism of the human visual system, thus it is understandable that several extensions were proposed during all these years. But the fundamentals stayed unchanged, the $V(\lambda)$ function has been used practically in its original form ever since 1924.

There are two international organizations that share responsibility regarding photometric measurements. CIE is responsible for the quantities, their definitions and the preparation of guidelines for photometry, and the Metre Convention defines and maintains the "light unit". Also at the symposium experts discussed these two aspects of photometry, how far CIE photometry is relevant in the different illuminating engineering tasks, and how can the stability of the photometric system be maintained. Fifty-eight experts of the two interested international bodies (CIE and CIPM with its consultative body: CCPR, Consultative Committee on Photometry and Radiometry) and of further 15 countries participated in the discussions. The presented papers and discussions made it clear that the 75 year old photometric system is still the internationally accepted basis for all visually significant light measurements. It defines one of the base units of the SI system, the candela, and as such it should have a permanent status also in the future. Contri-