Colour in Health and Employment

18 JULY 2019
ROOM B200, CITY, UNIVERSITY OF LONDON
WELCOME!

A warm welcome to our specialised symposium on ‘Colour in Health and Employment’. We hope you all enjoy the presentations, posters and the insightful discussions that are sure to follow.

The symposium dinner will be held at The Peasant restaurant in St John’s Street. Its location is as indicated on the last page of this booklet.

We would like to acknowledge our sponsors below for their generous support. We hope that you all enjoy the symposium and your stay in London.

Marisa Rodriguez-Carmona
John Barbur

City, University of London

THE COLOUR GROUP (GB)
<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:30 - 09:55</td>
<td><strong>Coffee / Registration</strong></td>
</tr>
<tr>
<td>09:55</td>
<td>Welcome (Professor Chris Hull, Associate Dean for Research and Enterprise)</td>
</tr>
<tr>
<td>10:00</td>
<td>John Parkes - The real-life complexities of occupational colour vision standard setting – Antipodean perspectives</td>
</tr>
<tr>
<td>10:30</td>
<td>Kathryn Albary-Ward - The importance of early colour vision screening of school children</td>
</tr>
<tr>
<td>10:50</td>
<td>Jenny Bosten - Colourspot: a new tablet-based app for assessing colour vision in young children</td>
</tr>
<tr>
<td></td>
<td><strong>Discussion (5 mins)</strong></td>
</tr>
<tr>
<td>11:15 - 11:45</td>
<td><strong>Coffee break</strong></td>
</tr>
<tr>
<td></td>
<td>Colour assessment outcomes - new protocols (Chair Marisa Rodriguez-Carmona)</td>
</tr>
<tr>
<td>11:45</td>
<td>Benjamin Evans - A series of case studies: Occupational colour vision protocols and the Farnsworth D-15</td>
</tr>
<tr>
<td>12:05</td>
<td>Sergejs Fomins - Model to predict Farnsworth D-15 performance under fluorescent and daylight illumination</td>
</tr>
<tr>
<td>12:25</td>
<td>John Barbur - Accurate and efficient colour assessment protocols for visually demanding occupations</td>
</tr>
<tr>
<td></td>
<td><strong>Discussion (5 mins)</strong></td>
</tr>
<tr>
<td>13:00 - 14:15</td>
<td><strong>Lunch and posters</strong></td>
</tr>
<tr>
<td>14:15</td>
<td>Effects of pre-receptoral filters on visual performance and the outcome of colour assessment tests (Chair Jenny Bosten)</td>
</tr>
<tr>
<td>14:15</td>
<td>Stephen Dain - Occupational colour vision standards: the Australian experience</td>
</tr>
<tr>
<td>14:45</td>
<td>Alessandro Farini - Spectrophotometric Characteristics of Blue Blocker lenses and their effect on circadian rhythm and colour perception</td>
</tr>
<tr>
<td>15:05 - 15:35</td>
<td><strong>Coffee break</strong></td>
</tr>
<tr>
<td>15:35</td>
<td>Cat Pattie - Do the EnChroma glasses help colour blind individuals to discriminate between more colours?</td>
</tr>
<tr>
<td>15:55</td>
<td>Ken Knoblauch - Fast estimates of contrast response functions in normal and anomalous observers and some effects of long-term filter use</td>
</tr>
<tr>
<td></td>
<td><strong>Discussion (5 mins)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Colour Research Laboratory Tour</strong></td>
</tr>
<tr>
<td>16:30</td>
<td>Lab tour and demonstrations</td>
</tr>
</tbody>
</table>
The real-life complexities of occupational colour vision standard setting – Antipodean perspectives

Dr John Parkes
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The basis for the setting of occupational medical standards varies from highly scientific to ad hoc with everything in between. The setting of occupational colour vision standards exemplifies this extreme variety more than in almost any other area of occupational medical standards. The situation is compounded because of the high prevalence of colour vision deficiencies in the population, but the low incidence of proven colour vision related fatalities, accidents and adverse outcomes. Other factors affecting the setting of occupational colour vision standards include: the will and funding for the underpinning scientific research, public perception, lobby groups, political will, the lack of otherwise suitable recruits for “important” jobs involving colour vision, and the occurrence of colour vision deficiencies in key decision makers in organisations (or their children).

In order to understand some of the complexities of the setting of colour visions standards in employment, and the compromises that are almost always necessary, the main categories for the basis of occupational colour vision standard setting are examined, with examples given of current and past occupational colour vision standards, taken largely from Australia and New Zealand. The categories are:

- Accident analysis;
- Risk assessment with scientific validation;
- Risk assessment without scientific validation;
- Classification into normal, colour defective safe and colour defective unsafe;
- Exclusion of all colour defectives;
- Exclusion of colour defectives who perform worse that the least able normal trichromats;
- Extension from a standard in another area;
- Matching the performance of an older standard with performance on newer colour vision tests;
- Practical testing;
- Genetic testing;
- Yielding to public pressure or lobby groups;
- Obeying directives from ombudsmen (particularly anti-discrimination), tribunals, courts or government;
- Ad hoc basis; and
- No standard.
Kathryn Albany-Ward founded Colour Blind Awareness in 2010 having discovered by chance that her then 7 year old was severely colour blind. As her son is now 17, approaching A Level exams and decisions about his future studying and career options, the symposium offers a timely opportunity to review the current situation facing colour blind children in UK schools. Kathryn’s presentation will consider the implications of the removal of school screening from the Healthy Child Screening Programme in 2009, discuss how many children are actually being screened and by whom, then move on to consider, in practical terms, the potential effects of a lack of diagnosis upon education and future careers.

Reference will be made to the very limited research which has been undertaken to date, investigating the actual effects of a highly colour-coded classroom environment upon the potential achievement of modern school children with CVD. The conclusions will cover how schools and optometric practice can improve the current situation.
ColourSpot: a new tablet-based app for assessing colour vision in young children

Dr Jenny Bosten
Teresa Tang, Leticia Alvaro, James Alvarez, Brenda Meyer, John Maule and Anna Franklin
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We have developed a child-friendly gamified calibrated tablet-based app intended for use as a screening tool for colour vision deficiency in children. The app does not require language or reading skills and has an attractive interface designed to maximise task engagement. On each trial, children are shown 12 discs (spots) which are a deutan, a protan, a tritan target and 8 distractors, containing marking titan and luminance noise. Children are asked to find and tap a “coloured” spot. If a target is tapped, a reward is presented. Depending on whether a target or a distractor is tapped, the saturation of the targets are altered along the three confusions lines according to a Bayesian staircase procedure.

We have conducted a study to validate the new app against the Ishihara for the Unlettered test as the current gold standard test for our target age range of 4-7 years. We first tested a “discovery” cohort of 236 boys, who all completed the Ishihara for the Unlettered test and the Neitz test, and a subsample of 17 boys diagnosed as CVD on the Ishihara for the Unlettered test and 74 controls were tested on ColourSpot. We fit psychometric functions to the staircase results for each of the three target types and generated an optimal algorithm to classify CVD versus normal colour vision, which resulted in complete agreement with the Ishihara for the Unlettered test. Our validation cohort had 532 boys, of which 175 were tested on ColourSpot. Applying the same classification algorithm as developed for the discovery cohort ColourSpot again achieved excellent agreement with the Ishihara for the Unlettered test.

ColourSpot is a sensitive test for CVD in young children that could be used as a screening tool. We next plan to validate it against the anomaloscope in an older age group in order to assess its potential for categorising protan versus deutan deficiency, and its ability to detect mild anomalous trichromacy that might be missed by Ishihara for the Unlettered test.
A series of case studies: Occupational colour vision protocols and the Farnsworth D-15

Benjamin Evans
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The concept behind the majority of occupational colour vision requirements is remarkably simple, yet the methods employed, and outcome achieved can vary considerably. The majority of occupational protocols involve two stages of testing; initial screening and secondary testing. Initial screening aims to swiftly and accurately identify applicants with a colour vision deficiency. Secondary testing aims to separate applicants into those with mild to moderate colour vision deficiency and those with moderate to severe colour vision deficiency.

The Farnsworth D-15 test is commonly used, as a secondary test, to determine whether an individual meets the colour vision (CV) requirements for employment in a given occupation. The 15 caps are illuminated with daylight (D65) and the subject is required to place the caps in order so as to minimise perceived differences between adjacent caps. Monochromats, dichromats and subjects with severe anomalous trichromacy are expected to fail whilst subjects with normal CV or a mild colour vision deficiency (CVD) are expected to pass.

RG and YB thresholds were measured in 590 subjects at the City Sight Clinic (325 deutans, 170 protans and 95 normals) using the Colour Assessment & Diagnosis (CAD) test. Each subject also completed the D-15 test and the Nagel Anomaloscope. A rod monochromat, a tritanope and several protanopes and deuteranopes were also tested using the D-15 test under two protocols. Initially the D-15 was completed using the standard protocol before the caps were separated into two groups (from caps P-8 and caps 9-15) and subjects were asked to repeat the task. The spectral radiance data measured for each of the 15 caps under D65 illumination were used to estimate differences in photoreceptor excitation and to model the colour signals involved for each class of CVD.

The results of this study, the Farnsworth D-15’s agreement with other colour vision tests and its suitability for modern vocational guidance will be discussed. This presentation is likely to be of interest to occupational health professionals, researchers with an interest in colour vision assessment and those involved with the creation and implementation of occupational health protocols.
Model to predict Farnsworth D-15 performance under fluorescent and daylight illumination

Dr Sergejs Fomins
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The red-green anomalous colour deficiency is possible to model including the impact of the optical density of visual pigments. Previously, we have proposed the model for pseudo-isochromatic (PIC) test performance (Fomins et al., ICVS 2017). In our approach we assume the task of the proposed colour vision testing to be modelled according to the perceptual demand as also the possible violation of illumination restrictions.

In case of PIC tests the task is to segregate the object from the background solely on colour signal. However, in arrangement tests, as Farnsworth D-15 the perceptual task is to provide the right order of caps based on the mechanism available for perceptual decision. Blue-yellow mechanism plays a substantial role in pass rates of D-15 as identified in the aging population (Schneck et al, 2014). Spectral data of D-15 caps acquired under popular luminescent illuminations was transformed into cone excitations and to DKL colour space, to be able to estimate the impact of background.

Model allows to provide the D-15 characteristic patterns for different severities of red-green colour vision deficiencies. This approach indicates pronounced role of blue-yellow signal on D-15 cap arrangements, at the same time showing the luminance data to be less productive to predict cap arrangements. The model performance is compared to subjects data coming from two data sets acquired on young population.
Accurate and efficient colour assessment protocols for visually demanding occupations

Prof John Barbur
Benjamin Evans and Marisa Rodriguez-Carmona
Centre for Applied Vision Research, School of Health Sciences, City, University of London, United Kingdom
J.L.Barbur@city.ac.uk

Current colour assessment protocols based on either single or multiple conventional colour tests (such as Ishihara, D-15, City University and Lantern tests) fail to achieve both high sensitivity and specificity. These tests also fail to quantify accurately the severity of colour vision loss. As a result, on many current tests and protocols, some normal trichromats fail and colour deficient applicants pass, without any reliable indication of severity. Some of those colour deficient applicants who pass can have severe loss of colour vision [1].

We propose an efficient, two-step protocol as a solution to these problems. This protocol relies on the use of a new CAD Vision Screener as the first step. The screener tests for normal red / green (RG) and yellow / blue (YB) colour vision, takes ~ 2.5 mins to complete and has both high sensitivity and specificity.

All normal trichromats pass, all protans fail and all, but a small percentage of the least affected deutans also fail. Those who fail (i.e., subjects with congenital colour deficiency (~ 8% of male and ~ 0.5% of female applicants) and some with acquired loss of colour vision) are required to have full colour assessment using threshold tests such as CAD. The latter takes between 12 and 15 minutes to complete and classifies accurately the applicant’s class of colour vision (i.e., normal trichromacy, congenital RG or YB colour deficiency, acquired deficiency or acquired loss in subjects with congenital deficiency). The new, more efficient, two-step protocol ensures that fewer subjects require full assessment.

In addition to classification, the CAD test measures RG and YB thresholds to quantify the loss of chromatic sensitivity. These thresholds can be used to categorise the severity of colour vision loss [1] and to set minimum colour vision requirements (that can be enforced) in visually demanding occupations. The remaining task is to establish ‘Pass / Fail’ limits that can be justified as safe and fair within a given occupation. The colour signal strengths needed to carry out the most demanding, suprathreshold, safety critical tasks with the same accuracy as normal trichromats, can be derived experimentally (as has been done for pilots, air traffic controllers and TfL train drivers). This approach is arguably the most justified, but it requires detailed visual task analysis, replication of the most safety-critical, colour-related tasks in the laboratory and experiments with many participants to establish thresholds limits above which subjects with colour deficiency can no longer perform as well as normal trichromats.

An ‘intermediate’, alternative approach is to estimate appropriate ‘Pass / Fail’ limits based on existing data. ‘Equivalent’ CAD thresholds can be computed to pass the same percentage of
deutan and protan applicants as many of the exiting current protocols. Although the number of deutan and protan applicants who pass remains unchanged, the spread in deficiency in those who pass is much reduced. As a result, applicants with less severe deficiency pass and those with more severe loss of colour vision fail. This approach yields a safer, more efficient and fairer protocol, even in the absence of a detailed experimental study.

In Australia, occupational employment practices setting in vision standards are driven substantially by the decisions of tribunal hearings or by the concern to avoid such hearings. The situation is complicated by the fact that both federal and state laws. These tribunals operate at both levels. Federal law deals with, for instance, the Australian Federal Police, the military and aviation safety. State law includes state police, ambulance services, fire brigades, railways and driving licences. At the federal level, tribunals have dealt with the aviation standards (Administrative Appeals Tribunal) and at the New South Wales level they have dealt with the police service (NSW Anti-Discrimination Tribunal, Human Rights and Equal Opportunity Tribunal {a federal body}), the ambulance service, the fire brigades (both NSW Administrative Decisions Tribunal [Anti-Discrimination Division]) and the railways (Australian Industrial Relations Commission {a federal body}) also in Queensland Anti-Discrimination Tribunal). The decisions of these tribunals are very mixed and, in some cases, impractical or, possibly, just as inequitable as some standards themselves. These decisions may arise from principles that are actually unrelated to colour vision. In NSW, the anti-discrimination legislation and the privacy legislation both take precedence over the work health and safety legislation. In this presentation we will trace the evolution of colour vision standards in these areas, examine the decisions of the tribunals and how they influenced standards setting and detail the present standards.
Accurate and efficient colour assessment protocols for visually demanding occupations

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Modern light sources emit short-wavelength light. Blue light plays a role in the control of circadian rhythms and pupil responses as well as being the potential cause for visual discomfort, eye-strain and disruptive sleep patterns. Blue-light blocking spectacle lenses have been designed to reduce the amount of short-wavelength light that enters the eye and absorb small amounts of short-wavelength light over a limited spectral range with significant absorption only below 460nm. These lenses may affect yellow / blue (YB) color vision since S-cone signals are most affected. We want to study red/green (RG) and YB colour thresholds under conditions of chromatic adaptation that correspond to daylight (D65), simulated D65 on visual displays viewed either directly or through typical, blue-blocking lenses, as well as backgrounds that are equivalent in chromaticity to D65 when filtered with each of the blue-blocking lenses investigated.

Spectral transmittance was measured for lenses and then used to compute the change in the CIE1931 chromaticity of D65 light as well as the change in the scotopic to photopic efficiency of the light. Three background chromaticities were selected to correspond to D65, D65 + Hoya Blue Control and D65 + Crizal Orma lens. RG and YB color thresholds were measured in three subjects for each of the three background chromaticities. One further experiment was carried out which required the subjects to view the D65 background through one lens.

These experiments were performed using the CAD-test which isolates fully the use of RG and YB color signals for a specified background chromaticity. There are no significant changes in either RG or YB colour detection thresholds for any subject and any of the filters investigated. The blue-light blocking lenses investigated do not cause any significant reduction in either RG or YB chromatic discrimination. Blue-light blocking lenses do not affect significantly colour vision and are also not likely to affect circadian rhythms. It is of interest to question the purpose of such lenses and to establish the wavelength range and the amount of blue light one can continue to absorb without causing unacceptable changes in visual and non-visual functions.
Do the EnChroma glasses help colour blind individuals to discriminate between more colours?

Cat Pattie
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Hereditary red-green colour blindness (CVD) is very common, affecting 8% of men. There has been much endeavour to create commercially available visual aids to help those with CVD. Although customer testimonials and media reports about these are compelling, there is little empirical evidence supporting the efficacy of such aids to improve CVD individuals’ abilities to discriminate between colours. In particular, there is little research investigating the EnChroma glasses, currently the most popular aid. This talk will outline a study carried out at Newcastle University to provide an actual evaluation of the efficacy of these glasses. Detailed analysis of their effects on different CVD subtypes was performed. Methods and results of the study will be outlined, as well as an explanation as to why it was not possible to conclude that the EnChroma glasses reliably improve colour discrimination for any subset of CVD individuals.
Fast estimates of contrast response functions in normal and anomalous observers and some effects of long-term filter use.

Prof Kenneth Knoblauch
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Historically, the great majority of rigorous psychophysical results, color vision testing being no exception, are based on measuring discrimination thresholds, reaction times and equivalency by matching and focus on assessing the limits of sensation rather than appearance. We have recently been exploiting relatively novel techniques for assessing vision beyond the threshold regime by asking subjects to compare perceptual intervals between pairs of stimuli. The task, called difference scaling, is relatively easy for subjects and usually rapid, at least compared to classic psychophysical methods. The data constitute a set of choices from the observer for each trial on which of a pair of intervals between pairs of stimuli is perceived to be greater. Based on a decision rule and the assumption that the judgments are perturbed by random judgment noise on each trial, a psychological response function can be estimated by maximizing the likelihood over the set of observer choices in the experiment, leading to Maximum Likelihood Difference Scaling (MLDS). The estimated scales have the property that equal differences in response should appear perceptually equal. We have exploited MLDS to estimate contrast response scales for normal and anomalous trichromats for low frequency Gabor stimuli with contrasts varying in luminance (Lum) or along an axis that corresponds to the difference in L and M cone signals (LM). All of the data are well described by a Michaelis-Menten (or Naka-Rushton) function that is determined by two parameters, the response gain, Rm, and the semi-saturation constant, σ, whose inverse can be considered a measure of contrast gain. Response gains cannot be distinguished between normal and anomalous observers along the Lum direction, but the anomalous observers show reduced response gain along the LM axis, as expected from the chromatic signal loss at the input due to the reduced separation between their long-wavelength cone photopigments. On the other hand, anomalous observers display greater contrast gain than normal observers along both the LM and Lum axes, suggesting a mechanism to boost perceptual responses in compensation for the signal loss at the input. In a second series of measurements, we evaluated the contrast responses of anomalous observers over an extended period during which they wore glasses designed to enhance the chromatic input signal. Surprisingly, the observers showed no changes in contrast gain but systematic increases in response gain along the LM axis relative to the Lum axis, suggesting that the response gain is not simply limited by the reduced separation of the cone spectra. The method is relatively rapid and reliable but could be optimized for use in the clinic to better understand not just what observers detect but what they see.
Posters on display

Thursday 18th July

Time: 13:00-14:15

#1 Loss of color and flicker sensitivity in subjects at risk of developing diabetes
Marisa Rodriguez-Carmona, Qais Bastaki, John Barbur

#2 New screener for congenital and acquired colour deficiencies
John Barbur, Benjamin Evans, Marisa Rodriguez-Carmona

#3 Analysis of the residual signals colour deficient can use to pass the D-15 test
Benjamin Evans, Marisa Rodriguez-Carmona, John Barbur

#4 Colour vision in diabetes in the absence of proliferative retinopathy
John L Barbur, Imran Ansari, Chris Canning
The Peasant @6.30pm Thursday 18th July

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