

Opinion

# The Implication of Vision and Colour in Cultural Heritage

Ricardo Bernárdez-Vilaboa 

Professor in Optometría y Visión Department, Univeridad Complutense de Madrid, 28044 Madrid, Spain; ricardob@ucm.es; Tel.: +34-649-172-142

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**Abstract:** Colour is important in art, particularly in pictures. The eyes receive images with a particular condition after traversing the cornea, other surfaces and interior liquid of orbit. It is possible for changes in colour to be perceived when pictures are viewed by one eye that has defects in any surface. Cone defects are directly related to colour failure. Can the original colour be recovered by modifying the visual function? There are multiple colour tests, but there is no consensus on which colour test is best. After detecting a problem with colour, we found several techniques to enhance colour contrast for dichromats. Treatments considered were reversible and innocuous and combined with melanopsin-based blue light sensitivity for melatonin suppression, allowing visual acceptance and luminous perception. A light source of 4000 K with a Duv value of zero, a good observer and adequate illumination were necessary. Subjective assessment may be affected by visual functions such as accommodation, binocular vision and quality of the eye.

**Keywords:** colour; art; visual; accommodation; binocular vision

## 1. Introduction

The human eye detects light at wavelengths between 400 and 700 nm, the visible band. There are three kinds of colour-sensitive pigments for absorbing energy in this range, which allow the eyes to see [1]. There are different tests to evaluate colour fidelity indices (CIE-Ra, CQS-Qf, CRI2012, CRI-CAM02UCS, and IES-Rf). Prediction is better with CIE-Rf than with CIE-RaFew [2].

In this paper, the appearance of objects in a museum situation with different spectral power distributions was investigated [3,4]. Other studies have analysed relative attractiveness, naturalness and preference for exhibits in correlation with colourfulness. All differences were compared based on the realisation of different targets for light emitting diode (LED) blending and standard light sources [5–7].

It is easy to find different evaluations of perceptions of LED-based white-light sources in persons of different ethnicity with different objects (fresh food, packaging material or skin tone) [8–11]. The colour perception of an object is little influenced by the neutral interior of a light booth [12]. This usually involves judging brightness, colourfulness and pleasantness when lit with pre-set spectra with correlated colour temperatures (CCTs) via LED and fluorescent lights, in approximately 500 lx. The lighting choices did not differ based on individuals' selections, ranging (2850 to 14,000 K) and lying slightly below the blackbody curve [7,13]. Other attributes did, however, have an impact on perception: attraction, vividness and warmth [14].

The spectral region around 570–580 nm is deleterious to the perception of colour and brightness [15]. High-quality LEDs can improve observers' perceptions and can make the colour appearance more vivid and saturated [16]. With colour LEDs, the hue and the saturation of a target colour can be modified according to preference [17].

Smartphone and tablet use are associated with visual and ocular discomfort such as headaches, eyestrain and other symptoms; this is also reported with desktop computer use. Smartphones, tablets and similar devices differ from desktop computers in position and distance, screen size and luminance. It is important to know that accommodations decrease with handheld device use, lag increases and it induces changes in convergence [18,19]. These changes in accommodation and convergence for near items in inadequate lighting conditions are implicated in the evolution of myopia. There is greater accommodative lag in myopes than in emmetropes and in schoolchildren than in adults [20]. Longitudinal chromatic aberration is related to this accommodation and changes in the emmetropisation process and the change of the depth of field (DOFi). This state causes a dioptric change in the monochromatic accommodation response [21]

Intraocular lenses (IOLs) with more diopters are problematic in that their central thickness and aberrations reduce image quality [22]. In measuring the quality of a polychromatic image using IOLs, a model eye was constructed with diffractive optical elements. Image quality was evaluated for vergences, lengths and pupil modulation transfer functions and image quality. There was a significant modification in the near-distance balance [23].

It is possible that changes in colour are observed when pictures are viewed by one eye with any surface defects? These aberrations could be caused by opacity or trauma in any of the elements in front of the retina, although it can also be produced in the retina itself. Cone defects are directly related to colour failure. Can original colour be recovered by modifying the picture viewed by that eye? With another functional eye problem, would it be possible to visualise the original colour with adequate irradiation?

## 2. Materials and Methods

All of the observers had normal colour vision. A refractive correction lens was evaluated [3,24]. Currently, there is no consensus on which colour test is the most complete. It is recommended to use at least 2 tests to uncover more information about visual perception [25]; possible tests include Ishihara, Color Vision Testing Made Easy (CVTME), Farnsworth–Munsell 100-Hue and other similar tests [25]. In many experiments, multiple light sources were used, with a CCT different in K value at different Duv values. These represent the most common light sources used, for example, in Chinese museums [3]. The application of memory and preferred colours to colour rendition evaluation of white light sources is reviewed with Sanders, Judd's flattery index, Thornton's colour preference index and Smet's memory colour rendition index. Here, we evaluated the agreement of data on visual appreciation and perception of naturalness [26]. Referenced patient studies comply with the Helsinki statement.

The participants evaluated a room with objects chosen to cover a range of hue, saturation and lightness values to evaluate the subjective impressions of a light source's colour quality [27]. The interpretation of lighting conditions included naturalness, vividness or preference in two scenes illuminated with different SPDs (spectral power distributions) [28].

With any transformation, colours varied in many directions and there was with no guarantee that colours fell within in the desired range [29]. In other experiments, the observer matched the left eye standard square with the luminance and chromaticity of the right eye modified by a control after being previously dark adapted [30]. The values were noted after the observer expressed that they were satisfied with the match by pressing a key [31]. The CVTME test consists of 10 plates for demonstration containing a circle, star and square, visible to all colour-deficient and colour-normal subjects and other plates designed for young children and those with learning difficulties [32,33].

Accommodation and vergence, in conjunction with ocular surface and blink, were evaluated while the participants were reading a text on a smartphone for a large time and were measured during reading. Eye fatigue and other symptoms, fixation disparity and binocular accommodation were assessed, and the frequency and amplitude of the blink and viewing distance were measured [19].

Accommodative lag and accommodative fluctuations were evaluated with the Grand Seiko WAM-5500 open-field auto-refractor [20]. Subjective DOFi was measured using a motorised Badal system. The subject's eye was paralysed and different, previously measured accommodative states were simulated with a deformable mirror. Different colour conditions were tested [21]. Spherical IOLs with different diopters were implanted in a IOL eye model and measured with a modulation transfer function (MTF) [22].

### 3. Results

#### *Criteria for Successful CVTME Testing*

For the present purposes, a child was able to cooperate with and respond to each test plate in order and in demonstration was successful when a subject name each of the black and white figures [32]. OCTs provided information on surface depth and size as well as pigment distribution. This information also applied to surfaces with higher roughness [34].

Subjects preferred daylight for visual acceptance and glare. Photometric variables modulated changes in visual light perception, alertness and mood in the afternoon [35]. Red, green and blue light could affect the colour appearance of the objects illuminated, particularly when they were vivid and saturated by high gamut area index. There was a strong preference for colours with enhanced saturation [16].

Perceptions were measured for different combinations of LEDs and perceived quality and links were assessed [5]. There was a preference for naturalness and colourfulness, and naturalness was weakly related to colourfulness [6]. The judgments for colour preference and comfort were highly correlated, and the whiteness of the lighting influenced colour preference, comfort and discrimination [3]. The average colour difference between the original and the recovered colours was relatively high; when the high value was disregarded, the average colour difference was reduced to 4.2 [1]. For dark objects, chroma was overestimated to lightness [31]. In dichromatic persons, the number of discernible colours was about 7% of normal. Only modest improvements could be obtained for dichromats [33].

The ocular symptoms increased with the use of the smartphone, in comfort, fatigue and drowsiness ( $p \leq 0.02$ ). Accommodation was also reduced ( $p = 0.01$ ). There were no other changes except an increase in the number of incomplete blinks, associated with a general worsening of eye symptoms ( $\rho = -0.65$ ,  $p = 0.02$ ) and fatigue ( $\rho = 0.70$ ,  $p = 0.01$ ) [19]. The accommodative lag was significantly different between schoolchildren and adults [ $F(1219, 35,354) = 11,857$ ,  $p < 0.05$ ] and non-myopic and myopic [ $F(3107, 31,431) = 12,187$ ,  $p < 0.05$ ]. It was higher in myopic schoolchildren ( $0.655 \pm 0.198$  D) than in non-myopic patients ( $0.202 \pm 0.141$  D,  $p < 0.05$ ) and myopic young adults ( $0.316 \pm 0.172$  D,  $p < 0.05$ ). The accommodative delay was greater in the mesopic room (all  $p < 0.05$ ) [20].

Blue measured  $0.45 \pm 0.09$  D, green  $0.07 \pm 0.02$  D, and red  $0.49 \pm 0.10$  D. The monochromatic DOFi was  $1.10 \pm 0.10$  D with 0 D,  $1.20 \pm 0.08$  D with 2 D and  $1.26 \pm 0.40$  D with 4 D. The polychromatic white DOFi was higher than the monochromatic one (19%, 9% and 14%) [21]. MTF values were significantly higher than the values measured at the low range of polychromatic light [22]. Chromatic aberration resulted from a bifocal change in the quality of the near image; objects viewed at a distance were better with the design [23].

### 4. Discussion

It is possible to enhance the colour moderately and with degradation [17]. Use of a 4000 K light source with a Duv value of zero is preferable to enhance and comfortably view colour [3]. OCT measures the volume of pigment in a layer, the thickness of varnish layers, the voids and the depth of microcracks; when applied to cultural heritage it generates spectacular images [34].

The dependence between intensity, duration, pattern, timing, light history and wavelength can change the response of the circadian system. The photopic visual system responds equally to non-visual responses with high intensities [36]. The colour quality (CQ) attributes (naturalness,

colour and preference) of light were assessed in immersive environments. Preference was related to naturalness and colour, however naturalness was weakly related to colour [6]. There was a high correlation of preference with perception. White light improved colour preference, comfort and discrimination [3,31]. Other behavioural variables decreased visual acceptance, including variations in subjective alertness, mood and inter-correlations of these dependent variables. Daylight availability was one of the indicators of individual satisfaction [35].

Protans and deutans have a preference for re-coloured images with enhanced contrast. This information makes it possible to design good visualisations in these cases [29]. WGR mixes produce more attractive colour images than do other types of lights [5].

Eyestrain symptoms and ocular surface symptoms increased tiredness and sleepiness. These visual functions represent a loss of image sharpness. Binocular accommodative facility decreased [19] and focus variation is less accurate.

Among myopics, there was a greater lag in schoolchildren than in young adults. This is therefore a problem of focus among schoolchildren, preventing unintentional maintenance of attention, especially in ametropia such as myopia; this was greater under mesopic room conditions for all ages. Good photopic lighting is necessary to avoid it. Accommodative lag and accommodative fluctuations at far distance (6 m) and near distance (25 cm) were measured using the Grand Seiko WAM-5500 open-field autorefractor [20].

For polychromatic white DOFi with colour versus monochromatisms, some visual aid is essential to relax the accommodative stimulus that colour variations require [21]. Increased effects related to the IOL diopter were observed, and MTF values were found to be increased with the increase in the IOL diopter [22]. This also affects populations of people with cataract surgery or with ametropia, where the lens is replaced by IOLs. Such people are mostly over 60 years of age. For bifocals, adding power produced changes in the near image quality in terms of wavelength and pupil size [23].

Finally, there is a large population with healthy eyes and those with different visual problems due to accommodation, binocular vision, intraocular lenses or pupils, that may not see a well-lit object well in any museum.

## 5. Conclusions

As a first conclusion, the changes in quality of lighting produce subjective alterations in the observers. It is preferable to use a light source with a Duv value of zero to enhance and comfortably view colour. The visual functions affected are accommodation, binocular vision and the quality of the eye, as well as artificial changes in the eye with variations of the pupil or age conditions. Any subjective evaluation procedure for a work of art can be affected by lighting and the living eye.

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