Available online at www.sciencedirect.com
ScienceDirect
Vision Research 47 (2007) 1315–1334
Vision Research
www.elsevier.com/locate/visres

Evidence for the existence of colour mechanisms producing unique hues as derived from a colour illusion based on spatio-chromatic interactions

Alexander D. Logvinenko [a,*], Sara J. Hutchinson [b]

[a] Department of Vision Sciences, Glasgow Caledonian University, Glasgow G4 0BA, UK
[b] School of Psychology, Queen's University, Belfast BT7 1NN, UK

Received 22 October 2004; received in revised form 13 October 2006

Abstract

When its spatial frequency is high enough, a grid of grey horizontal strips presented on a coloured background may change its neutral colour. It was found that some background colours induce a strong illusion and some no illusion at all. The effect of the background colour on the illusion was studied for the spatial frequencies of 0.5, 2.5, 4, and 8 c/deg. Thirty chromaticities (evenly distributed across the colour gamut triangle) of the backgrounds in the equiluminant plane, and 24 in the *ML* plane (where *S*-contrast was zero), were tested. Five matches were made for each frequency and each background chromaticity. Viewing was binocular. For the low (0.5 c/deg) frequency strips, the backgrounds were found to induce the colour, if any, approximately complimentary to that of the background (i.e., chromatic simultaneous contrast). For the high (8 c/deg) frequency, most backgrounds induced only illusory colours close to unique hues (yellow, blue, and green), with a few backgrounds inducing a mixture of green with blue. Then, the method of adjustment was used to determine the unique hues for the same three observers. A remarkable similarity was found between unique hues and illusory loci, suggesting that the illusion is due to a difference in the spatial resolution of the post-receptor channels producing the unique hues.
© 2007 Published by Elsevier Ltd.

Keywords: Colour vision; Colour illusion; High-spatial-frequency tritanopia; Unique hue; Colour channel

1. Introduction

Human colour vision implies the combination of the outputs from three types of photoreceptors (cones), with peak sensitivities in the short-, medium-, and long-wavelength (*S*-, *M*-, and *L*-, respectively) regions of the visual spectrum (e.g., Kaiser & Boynton, 1996; Packer & Williams, 2003; Wyszecki & Stiles, 1982). Since *S*-, *M*- and *L*-cone mosaics interleave each other on the retina, such combining of the outputs of the adjacent cones of different types implies, in turn, a sort of spatial integration on the retina (Williams & Roorda, 1999). Therefore, some spatio-chromatic interaction lies at the heart of colour vision, being its essential feature.

One important consequence of this is that if the size of a light spot is so small that it stimulates just a single cone, the spot either appears hueless, or its hue is uncertain, that is, it invokes various hues at different presentations (Hofer, Singer, & Williams, 2005). In order to use their trichromatic vision, trichromats should be presented with objects that are big enough to stimulate all three cone types. Therefore, the same light spot might look different depending on its size. There is abundant evidence for the effect of the size and other spatial dimensions (e.g., spatial frequency) of an object on its colour. In particular, when one reduces the size of an object to less than 25′ but keeps it well above the level of visual acuity, a change in colour appearance may occur (Konig, 1894; Willmer, 1944). This phenome-

* Corresponding author. Fax: +44 141 331 3387.
E-mail address: a.logvinenko@gcal.ac.uk (A.D. Logvinenko).

0042-6989/$ - see front matter © 2007 Published by Elsevier Ltd.
doi:10.1016/j.visres.2006.10.025

non was called tritanopia of the central foveola (Mollon, 1982; Williams, MacLeod, & Hayhoe, 1981) as the test stimuli were projected onto the central foveola where there are no *S*-cones (Curio et al., 1991). Interestingly, a similar change in colour appearance (so-called small-field tritanopia) can still be observed providing the stimulus size is small enough, even when the stimulus is projected onto an area of the retina outside the central foveola, where *S*-cones are available (Hartridge, 1945; Mollon, 1982). Small-field tritanopia is usually accounted for by the poor spatial resolution of the *S*-cone channel (Brainard & Williams, 1993).

More recently, varying the spatial frequency content of stimuli (square wave gratings), Wandell and collaborators found that the stimuli changed their colour appearance with spatial frequency (Bauml & Wandell, 1996; Poirson & Wandell, 1993). They argued that this direct evidence of the effect of spatial dimensions on colour appearance emerged from the difference in the spatial frequency characteristics of the post-receptor mechanisms, the spectral characteristics of which were found to be close to the yellow–blue (YB) and red–green (RG) opponent mechanisms as suggested by Jameson and Hurvich (1955).

The effect of the spatial frequency content of a pattern on its colour can also be observed in Fig. 1. As the spatial frequency of the grid of physically neutral strips increases (this can be achieved by either receding the page or tilting it), the strips become tinged blue, yellow or green depending on the background colour.

This colour illusion is different to tritanopia of the central foveola since it does not need a gaze fixation and can be experienced throughout the retina except the extreme periphery (Logvinenko, 2001). The illusion is also different to small-field tritanopia as it is observed with quite large patterns. In fact, it is the spatial frequency, rather than the angular size of the pattern that is involved in this type of spatio-chromatic interaction. The illusion was called high-spatial-frequency tritanopia, since, first, the illusory colours were found to be close to those experienced in small-field tritanopia, and second, it could be observed only when the spatial frequency of the background strips was rather high (Logvinenko, 2001).

While there is every indication that the illusion results from the spatial frequency attenuation (filtering-out) of the output of some colour mechanisms (Logvinenko, 2001), it is not clear whether this happens at the level of the receptor or post-receptor mechanisms. It was found recently that patterns as in Fig. 1 with the same *S*-cone contrast between the strips and the background (i.e., differing only in luminance) could produce different strengths of the illusion (Logvinenko & Hutchinson, 2005, 2006). This implies the post-receptor site of the illusion in accord with the finding by Wandell and collaborators (Bauml & Wandell, 1996; Poirson & Wandell, 1993). Still, studying the same colour illusion,[1] Monnier and Shevell (2003, 2004) suggested that it can be accounted for by spatio-chromatic interactions within the *S*-cone mechanism.

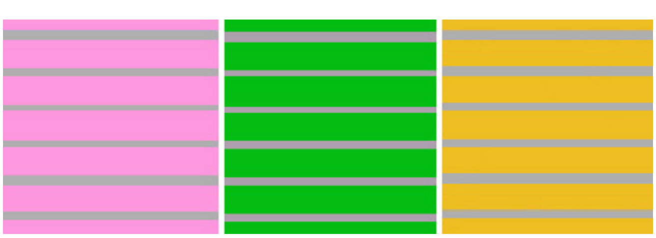

Fig. 1. The high-spatial-frequency tritanopia effect. As viewing distance increases, the neutral horizontal strips become coloured. Neutral strips on the pink, green, and yellow background become blue, yellow, and green, respectively.

In the first experiment, we test the receptor and post-receptor accounts, providing further evidence for the post-receptor explanation of the illusion.

2. Experiment 1 the effect of the background's chromaticity on illusory colours

Assume that the strips in Fig. 1 become tinged at high spatial frequencies because the response of some chromatic mechanism to the strips and the background is attenuated due to the poor spatial resolution of this mechanism as compared to the other chromatic mechanisms, as previously suggested (Logvinenko, 2001; Logvinenko & Hutchinson, 2005, 2006). For example, if the yellow–blue (YB) mechanism has narrower spatial frequency characteristics than the red–green (RG) and luminance mechanisms (e.g., Cavonius & Estevez, 1975; Green, 1968; Hess, Mullen, & Zrenner, 1989; Kelly, 1974), then the colour of the strips will be contaminated by a dc response of this mechanism at spatial frequencies above its spatial resolution. In other words, illusory blue (or yellow) will be the result of the "leakage" of the background's blue (respectively, yellow) component into the strips because of the poor spatial resolution of the YB-mechanism. Therefore, observing the illusory colours one can ascertain, at the first approximation, what chromatic mechanism "leaks". If it is the *S*-cone mechanism then the illusory colours should be tritan colours. If it is the YB-mechanism then these should be yellow and blue colours which this mechanism supposedly "secretes". Another possibility is that the YB- and RG-mechanisms have nearly the same spatial resolution which is nevertheless lower than that of the luminance mechanism (e.g., McKeefry, Murray, & Kulikowski, 2001; Sekiguchi, Williams, & Brainard, 1993). In this case the prediction will be a shift of the strips' chromaticity toward the background's chromaticity, that is, a sort of chromatic assimilation, as Shevell and collaborators suggested (Cao, Pokorny, & Smith, 2005; Hong & Shevell, 2004; Shevell & Cao, 2006).

[1] It must be mentioned, however, that Xian and Shevell (2004) recently showed that the degree of assimilation in similar spatio-chromatic patterns was affected by perceptual grouping. It implies that the illusion they studied might have been more complicated than high-spatial-frequency tritanopia.

Download English Version:

https://daneshyari.com/en/article/4036323

Download Persian Version:

https://daneshyari.com/article/4036323

Daneshyari.com