Color perception difference: White and gold, or black and blue?

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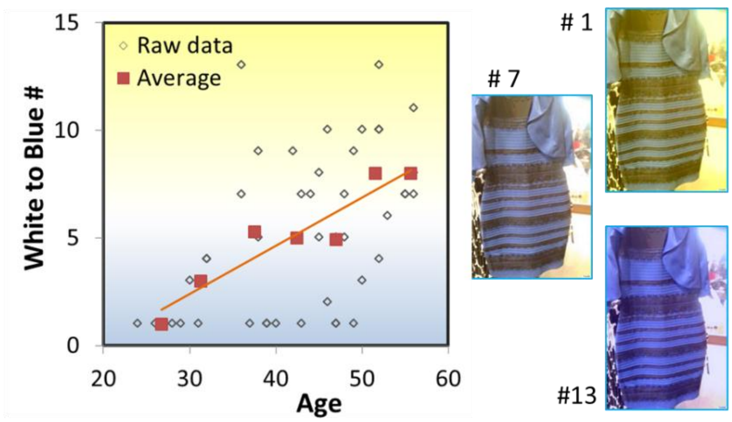

Fig.1. Color perception difference as a function of age

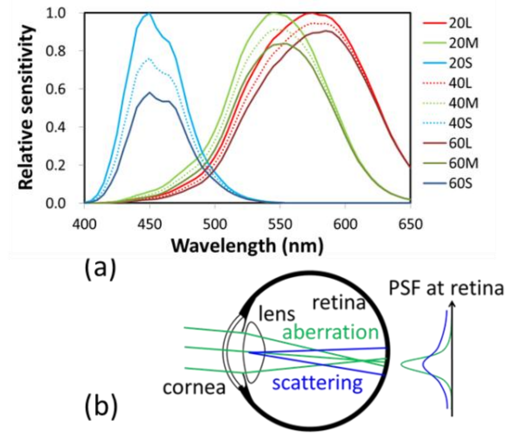

Fig. 2. (a) Relative cone sensitivity at ages of 20, 40 and 60, (b) Light scattering in the human

Introduction

It is a common philosophical question as to whether your blue is the same as my blue. The two-tone striped dress[1] shown in Figure 1, which attracted a lot of attention on the Internet, gave us a clear answer: "No." Some people see the dress as blue and black, whereas others insist it's white and gold. So your blue can be my white. Why is it that people looking at the same picture perceive totally different color combinations?

Technical approach

Color perception is strongly affected by the display and illumination environment. To control the survey conditions, color perception experiments were performed, using a single notebook PC display in the same room, with 48 subjects. For quantitative analysis, 13 photographs, in which the color tones were gradually changed from yellowish to bluish from #1 to #13, were shown on a single page. The question asked was, "At which photograph does the color of bright tone stripes change from white to blue?" The results in relation to the subjects' ages are shown in Fig.1. Though the raw data shows considerable variation, the averaged data clearly shows the ratio of those who see white and gold to increase with age.

Since the proportion of shorter wavelength absorption by the eye's lens increases during life, older people progressively become less sensitive to blue light, as shown in Fig. 2(a). This fact appears to explain the different color perceptions of older people: they would seem to perceive the dress as white and gold because of a lack of blue sensitivity. However, there is no significant difference between young and old people as to color perception[2]. Older people rebalance their color vision, using a chromatic adaption process, to maintain color constancy.

As well as light absorption, light scattering increases in the aged lens[3]. We assumed image blur in blue images caused by scattering to be the root cause of the difference and therefore investigated the effect of light scattering on the image. The Gaussian blur filter *g(x,y)* is convoluted to the blue image *f(x,y)* of for calculating the scattering effect.

$$f(x,y) * g(x,y) = \sum_i \sum_j (x+i, y+j) g(i,j)$$

The Gaussian filter removes the high spatial frequency component that corresponds to the blue image blur caused by light scattering in the eye. The original red and green images are added to the blurred blue images. The calculated images are shown in Fig.3. A larger σ, which corresponds to greater scattering within older persons' eyes, makes the color images yellowish. In the bright stripes, the blue component in each pixel decreases, whereas it increases in the dark stripes. The observer senses bluish illumination, which causes the brain to subtract a certain amount of blue tint from the image. The bright stripes are slightly bluish (R/G/B values of approx. 130/140/190) and contain narrow dark lines of high spatial frequency. These enhance the optical illusion effect of 'the dress' picture.

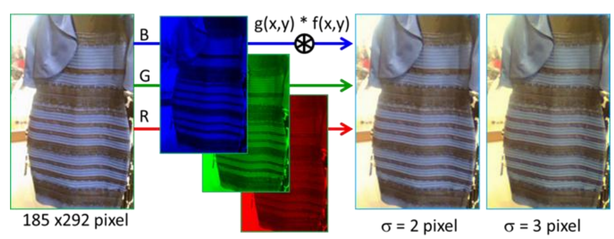

Fig.3. Calculated photos with a Gaussian filter to blue image

Conclusion

Individual differences in color perception were investigated using the controversial striped dress. A controlled survey showed the differences in color perception to be age-dependent. We conclude that the difference is not due to reduced color sensitivity caused by aging, but by increased light scattering within the aging eye. These scattering effects caused by the image can be simulated using a Gaussian blur filter. The calculated images fully explained the difference in color perception. Individual variations in color perception may be also caused by the chromatic aberration in observers' eyes.

References

(1)http://swiked.tumblr.com/post/112073818575/guys-please-help-me-is-this-dress-white-and
(2) K. Okajima et al., Optical Review, 8(1), 64 (2001).
(3) J. E. Coppens et al., Exp Eye Res. 82(4) 688 (2006)

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