Just another difference: retinal equipment of women and men

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ABSTRACT

Three cone types provide the input signals into to our photopic vision. Their spectral sensitivities peak at wavelengths of about 430 nm (S-cones), 530 nm (M-cones) and 560 nm (L-cones). Almost all cones in color-normal human retinae are L- or M-cones. The ratio between the occurrences of these two cone types - called L/M-ratio - is found to vary considerably between 1 and 7 ([8, 2]).
We have recently developed a new method to determine the relative contribution of the three cone types to the perception of brightness in human observers [11]. This method provides a fast, robust and unbiased procedure including an estimate of L/M-ratios.
We report here that color normal female human observers show a distribution over a wide range of L/M-ratios with two peaks, situated at low and high L/M ratios, respectively. This is opposed to color normal male human observers, whose distribution is found to extend over a smaller range and to have only one peak at low L/M-ratios.

1 Introduction

Three cone types provide the input signals for photopic human vision: S-, M-, and L-cones with specific wavelengths of about 430 nm, 530 nm, and 560 nm in colour-normal humans. L- and M-cones differ in only a few amino acids of opsin, the protein tuning the light-sensitive molecule to specific wavelengths. Due to their similarity, differentiation of those two cone types is difficult in intact retinae.
Using direct (mRNA-analysis, Hagstrom et al. [3]) and indirect (Roorda et al. [7]) methods, the distribution of cones in colour-normal human retinae has been accessed: the large majority of cone types are L- and M-cones with an averaged ratio of L- to M-cones of about 2 [1, 12].
Averaging L/M-ratios is based on the assumption, that L/M-ratios of humans are independent of gender. To test this, we determined the L/M-ratios of 25 women and 25 men using flickerphotometry.

2 Methods

2.1 Flickerphotometry

We determined the L/M-ratios of 25 women and 25 men, aged between 20 and 58, which have normal or corrected to normal acuity and are color-normal as assessed with the Farnsworth Hue 100 test.
We used flickerphotometry [11] to find a set of 16 isoluminant colours for each subject. Brightness und chromatic channels in humans differ in their temporal resolution: while the cut off frequency of the brightness channel is about 25 Hz, that of the chromatic channel is below 12 Hz [4]. Under the conditions used in our experiment a colour flickered against white with a frequency of 15 Hz does not appear flickering when its brightness matches that of the white.

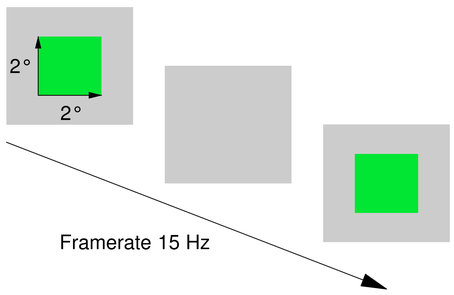

Figure 1: A coloured square was shown alternating with the background with a framerate of 15 Hz; subjects changed the colour of the central square to minimize the appearance of flicker.

Subjects viewed a coloured square of 2° side length imbedded in, and alternating with, a white background at a frequency of 15 Hz (fig. 1). They changed the chromatic appearance of the coloured square to minimize the perception of flicker.

2.2 Stimulus colours

Flicker colours were situated in SML-space on a planar circle with the whitepoint in the centre. The coordinates of the central point are identical to those of the background-colour as shown in figure 2.

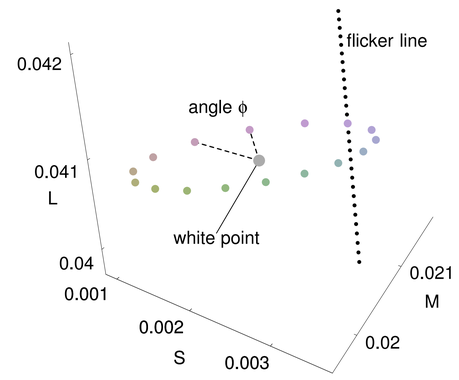

Figure 2: Flicker colours in SML-space, situated at 5.5fold detection threshold around the white point. Colours are equally spaced with angle $\phi = 22.5°$. At each angle changes could be made by pressing +/- -keys and thereby choosing a colour situated on a straight line (called flicker line), as shown in the figure.

Subjects changed the colour of the flickering square along provided straight lines in randomized order. At least two trials were run by each subject.

2.3 Data fitting

The data obtained were transformed into cone excitations using the Stockman (1993) [9] fundamentals and fitted to a plane in cone space (view fig. 3) using the following implicit form of plane equation:

$$\alpha_L * L + \alpha_M * M + \alpha_S * S = 1 \quad (1)$$

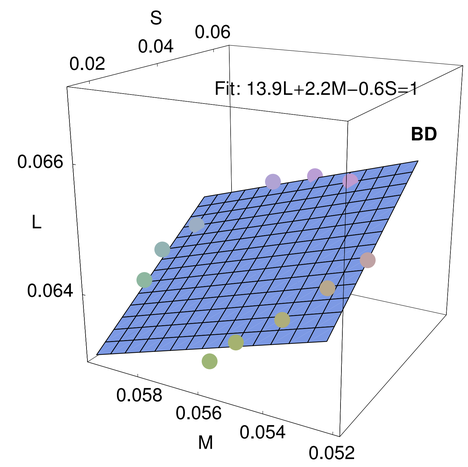

Figure 3: Example of isoluminant colours as obtained by heterochromatic flickerphotometry and the isoluminant plane fit; subject BDs L/M-ratio is 6.3, i.e. $13.9L/2.2M$.

The fit yields three coefficients α_L, α_M and α_S representing the relative contribution of the cones to the perception of brightness.

3 Results

3.1 L/M-ratios

The distribution of L/M-ratios is plotted separately according to gender in fig. 4.

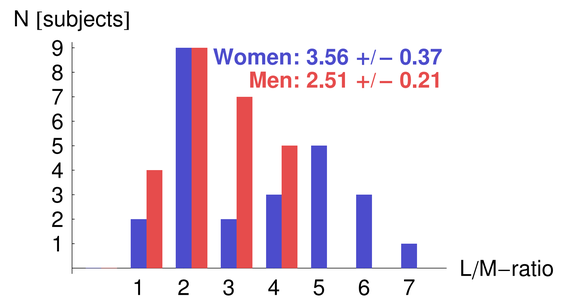

Figure 4: The number of subjects is plotted against the respective L/M-ratios according to gender (women shown in blue, men in red). The distribution of L/M-ratios in women exhibits two maxima, thus indicating a bimodal distribution.

Application of the Kolmogornov-Smirnov test [6] yields a probability $p < 0.03$ that the two distributions are the same. This implies that the variability in the dominating cone types of men and women is highly different, indicating a gender-specific probability for the occurrence of L- and M-cones, respectively, during ontogenesis.

3.2 S-cones

The third parameter extracted from the data is α_S, measuring the relative influence of S-cones on the perception of brightness (see fig. 5).

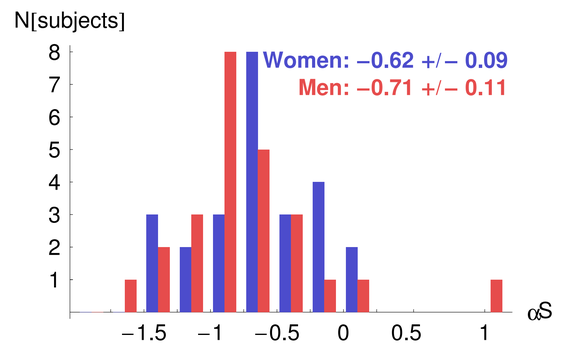

Figure 5: The number of subjects is plotted against the respective α_S according to gender (women shown in blue, men in red). The two distributions are not different.

Values of α_S are Gaussian distributed with mean -0.66 ± 0.07, rarely including positive values. Small, negative contributions of the S-cones to the perception of brightness were reported earlier (Teufel et al. [11], Stromeyer et al. [10]).
Here, application of the Kolmogornov-Smirnov test yields a probability $p < 0.28$ that the two distributions are the same, indicating that distributions of α_S are independent of gender.

4 Discussion

We have shown, that the distribution of L/M-ratios in women shows a larger variability than in men; men´s L/M-ratios are distributed over a small range, women´s over a large range, also showing two maxima. This indicates a bimodal distribution.
In contrast, the distribution of α_S, showing only small variability, is independent of gender. We suggest, therefore, that the differences in the occurrence of L/M-ratios found here reflects differences in retinal equipment of women and men.
How might this gender specific difference in L/M-ratios arise? The genes encoding L- and M-cone pigments reside on the X-chromosome [5]. Unlike the gene encoding the S-cone pigment on chromosome 7, these are present twice in the genome of women, but only once in men. The variability in the L/M-ratios in men may be restricted because only one copy of each gene encoding L- and M-opsin can be accessed during ontogenetic development.

References

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