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Research Article

Gender Differences in Contrast Thresholds Measured by a Saturation Task

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Abstract

The purpose of this work is to report the results of an experiment that examined gender differences in response to a chromatic saturation-like task. We measured contrast thresholds of 37 subjects (19 women, 18 men) to circular patches of uniform color—blue, green, yellow, and red—that alternated temporally with colored patches containing varying amounts of white. Based on previous findings, we predicted that more white would be required for women to disrupt the sensation of color. Women in our study did in fact have significantly higher contrast thresholds than men across all four colors ($F = 7.82$, $p < 0.001$) and at each color—blue ($F = 6.59$, $p < 0.005$), green ($F = 6.42$, $p < 0.005$), yellow ($F = 8.30$, $p < 0.001$) and red ($F = 5.26$, $p < 0.01$). The results reported here add to the body of evidence that women may rely more on chromatic processes than do men.

INTRODUCTION

There is a large body of literature supporting gender differences in visual processing. Most notable is the male advantage in mental rotation tasks [1]. There is also evidence that there may be a female advantage over males in parvocellular (PC) visual processing [2], which is thought to be more involved with object and pattern recognition as well as color opponency [3,4]. Recent work by the authors [5] has added support for this apparent advantage, but the small effect and stimulus design limited our ability to determine whether the advantage was an increased sensitivity to chromatic brightness or fine spatial details. In this work, we eliminated the influence of spatial frequency by using circular patches of uniform color—blue, green, yellow, and red—that alternated temporally with colored patches containing varying amounts of white. Based on the balance of evidence in the current literature as well as our previous findings, we predicted that more white would be required to disrupt the sensation of color in women.

MATERIALS AND METHODS

Subjects were eligible if they were between 18 and 45 years old, reported a complete eye examination within the last twelve months, had best-corrected visual acuity of 20/20 or better in each eye, and passed two color vision tests—pseudoisochromatic plates and Farnsworth D-15 color panels—without error. Thirty-seven adults (nineteen women, eighteen men) participated in the experiment. The institutional review board of the University of Missouri – St. Louis approved the experimental protocol, and informed consent was obtained from each participant. Circular patches of uniform color were designed using the following (R,G,B) percent gun ratios: Blue = (0,0,100), Green = (0,100,0), Yellow = (74,74,0), and Red = (100,0,0). Their positions in CIE color space are plotted in Figure 1. Each color patch subtended two degrees of visual angle and alternated temporally at 5 cycles per second (Hz) with a second patch of identical size. This flicker rate was chosen to facilitate ease of flicker detection (i.e. very slow

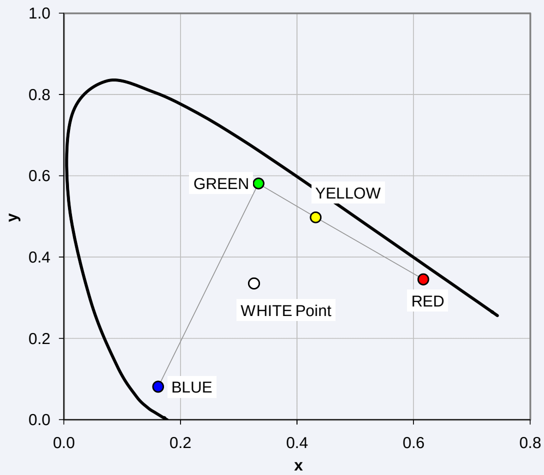

Figure 1 Chromaticity of stimuli and white point. The black line represents the boundary of visible colors in CIE 1931 space. The gray line represents the extent of available colors on the computer monitor.

rates are no longer seen as flicker) while reducing the influence of achromatic processing that occurs at flicker rates greater than 7 Hz [6]. Vision Works 4.0 Contrast Sensitivity Software (Vision Research Graphics, Durham, NH) was used to generate and display the stimuli on a 21" RGB analog monitor (FlexScan F750i, Eizo Nanao Technologies Inc., Cypress, CA) located 250 cm from the observer. The onset of each trial was signaled by a short tone, after which the two temporally alternating stimuli were presented. Participants were instructed to indicate with a keyboard stroke whether or not they could detect any flicker present in the stimuli. Contrast thresholds were measured in blocks of trials (i.e., one color completed at a time) with the order of colors randomized. Initial trials for each stimulus compared the color patch (blue, green, yellow or red) with a second patch of identical color with twenty-percent white (R,G,B = 20,20,20) added. The task was to determine if the stimulus flickered or not. If the participant responded with a keyboard stroke that flicker was present, the algorithm subtracted white from the desaturated patch while the color patch remained constant. The adaptive QUEST algorithm added and subtracted white from the desaturated patch until no flicker was detected. Contrast for each trial was calculated as the Michelson ratio: $(L_F - L_B)/(L_F + L_B)$, where L_F and L_B represent foreground (i.e. color plus white) and background (i.e. color only) luminance, respectively. Monocular contrast thresholds were measured for each color for each eye, and the two monocular measurements were averaged into a single measure for analysis using SPSS statistical software (SPSS Inc., Chicago, IL).

RESULTS AND DISCUSSION

Contrast thresholds distributions were positively skewed. Therefore, log transformed contrast thresholds were used for analysis of main effects of gender by repeated measures ANOVA. The effects of gender for each stimulus were determined by multivariate ANOVA. Women had significantly higher contrast thresholds than men across all four colors ($F = 7.82$, $p < 0.001$; see Figure 2). In addition, for each color, women had higher thresholds than men—blue ($F = 6.59$, $p < 0.005$), green ($F = 6.42$, $p < 0.005$), yellow ($F = 8.30$, $p < 0.001$) and red ($F = 5.26$, $p < 0.01$). In this experiment, we suggest that the higher thresholds for females represented higher spectral sensitivities. The algorithm to determine thresholds kept the color constant in the first patch and mixed white with the color in the second patch until the observer could no longer discriminate between the two when temporally alternated. Thus, the more sensitive an observer is to the brightness of a given color, the more white that will be required to disrupt that sensation. In the limit, let us think of an observer that has very low sensitivity to the brightness of a particular color. Adding white to that color will be easily detected as a brightness change for that observer, resulting in a lower contrast threshold difference. Conversely, if an observer is more sensitive to the original color's brightness, more white light will be required to cause a detectable brightness change. Therefore, we believe the higher thresholds for women on this task indicate more contribution of color to the overall sensation of brightness in women than in men.

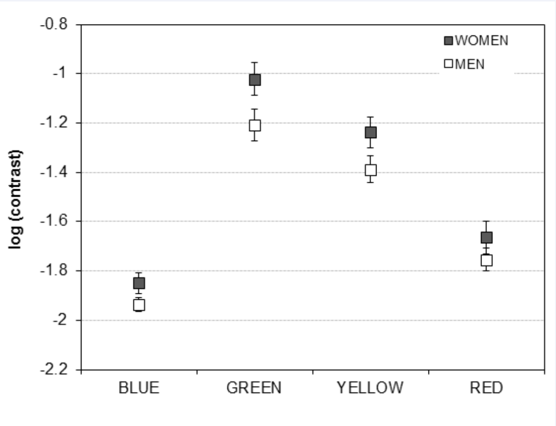

Figure 2 Mean color contrast thresholds. Women had higher thresholds overall and at all four colors (Error bars represent +/- 95% CI).

CONCLUSIONS

The results of this study further add to the body of evidence that women may rely more than men on chromatic processes. In particular, women may rely more on color brightness. The subject inclusion criteria would not have been sufficient to exclude heterozygous carriers of color deficient vision, and it could be argued that carriers could have affected our results. However, current evidence is equivocal, at best, in describing an overall chromatic advantage for carriers [7-13], and no information to date would ascribe an advantage across all colors. It could also be argued that these results represent differences in saturation, rather than chromatic brightness perception. However, at least two studies have suggested that saturation sensitivity is equivalent to the ratio of chromatic sensitivity to overall brightness sensitivity [14,15]. Therefore, further investigations into gender differences in chromatic processing should directly measure spectral sensitivity using photometric techniques.

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