Pupil role in color brightness perception in relation with “the dress” explanations

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ABSTRACT

It is well known that pupil size is determined mainly by the illumination level and that the entire pupil's reflex mechanism is controlled by the sympathetic and parasympathetic nerves, in an almost exclusively bottom up fashion. On the other hand, it is a less know issue how the pupil size affects perception, and in particular, color perception. Recent studies, triggered since “the dress” image was scientifically considered by the vision community, suggest that pupil size plays an important role in the perception of brightness of colored patches. Our research suggest the existence of two groups of observers: those who have a “big pupil” and perceive colors in a dimmer way and those who have a "small pupil" and perceive colors in a brighter way. Further analysis is needed to grasp these results in a family theoretical framework.

Keywords: *pupil size, brightness perception, color perception, “the dress”*

INTRODUCTION

In a recent study, Vemuri et al. (2016) have shown that the average pupil size in observers who reported seeing the colors of the dress as black / blue were significantly higher than those who perceived the dress as white / gold. The authors conclude that there is evidence supporting the use of the way observers perceived the colors of the dress as a grouping factor that explains some pupil size differences among observers. However, as the researchers expected to find a “differential response to colors from the lower or higher wavelengths (blue or red)” according to this grouping factor, they arranged an experimental set up where color luminances were allowed to vary. This luminance variations have a disadvantage at the moment of pupil size measurement: it blends the effects of luminance and color. Therefore, to analyze how much membership in one of these groups contributes to the size of the pupil, such an experimental design generates data with a lot of noise.

To quantify the effect of belonging to one of these groups on pupil size, we designed an experimental set up where we kept luminance constant. In this way we can isolate and quantify the differences in pupil size for both groups which would allow us to calculate the differences in retinal illuminance. Finally, our hypothesis is that this change in retinal illuminance would play a role in the perception of the dress colors.

EXPERIMENT

To perform this study, we use a high power projector. Onto the center of a screen we displayed a circular stimuli of 10° field of view. Ten different hues at four different luminance values (4, 20, 40 and 80 cd/m2) have been used as test stimuli. One equal-energy white stimulus with an equivalent luminance was added to be used as a reference. All the stimuli were characterized through a spectroradiometer. The background was maintained always black (2 – 4 cd/m2). Forty test stimuli were presented to each observer randomly, always alternating with the reference stimulus. The perceived brightness was evaluated with the magnitude estimation method, in which the observers must estimate the brightness of the test stimuli by assigning numerical values relative to the perceived brightness of the reference stimulus (that has preassigned a brightness value of 100). Pupil size was measured using an EyeTracker while each observer was doing the brightness estimation.

RESULTS AND DISCUSSION

Figure 1 shows the pupil size (y axis) across luminance range (panels) and for each displayed color (x axis). Dots colors encodes the way observers perceive the dress: blue dots for Gold/White; red dots for Black/Blue.

In general, pupil behaves as expected: increasing the luminance causes smaller pupils. However, the first panel shows a clear differentiation between the groups. Those who perceive the dress in “dark” colors have, in general, a larger pupil than those who perceive the dress in “light” colors. This result is similar to that reported by Vemuri et al. (2016) (Figure 1a) for luminances of around 1 cd/m2. Therefore, our results combined with theirs suggest that, whatever the mechanism that is causing the group differentiation according to the perception of the dress, its operation depends on the luminance and its effect on pupil size can be recorded with low luminances.

On the other hand, we show on Figure 2 the results of brightness perception. Color codes are the same: red dots for observers who perceive a black/blue dress and blue ones for those who perceive the dress as gold/white.

A visual inspection of Figure 2 reveals the obvious: regardless of the luminance level of the stimuli, perceived brightness is the same for the two hypothesized groups. It is important to highlight that in our experimental set up, the judgment of color brightness were made in an unrelated way. This experimental detail is key to understanding the difference with what was reported in other works (e.g. Gegenfurtner et al. 2015, Lafer-Sousa et al. 2015, Witzel et al. 2017), where it is stated that between the groups there is a difference in the perception of brightness.

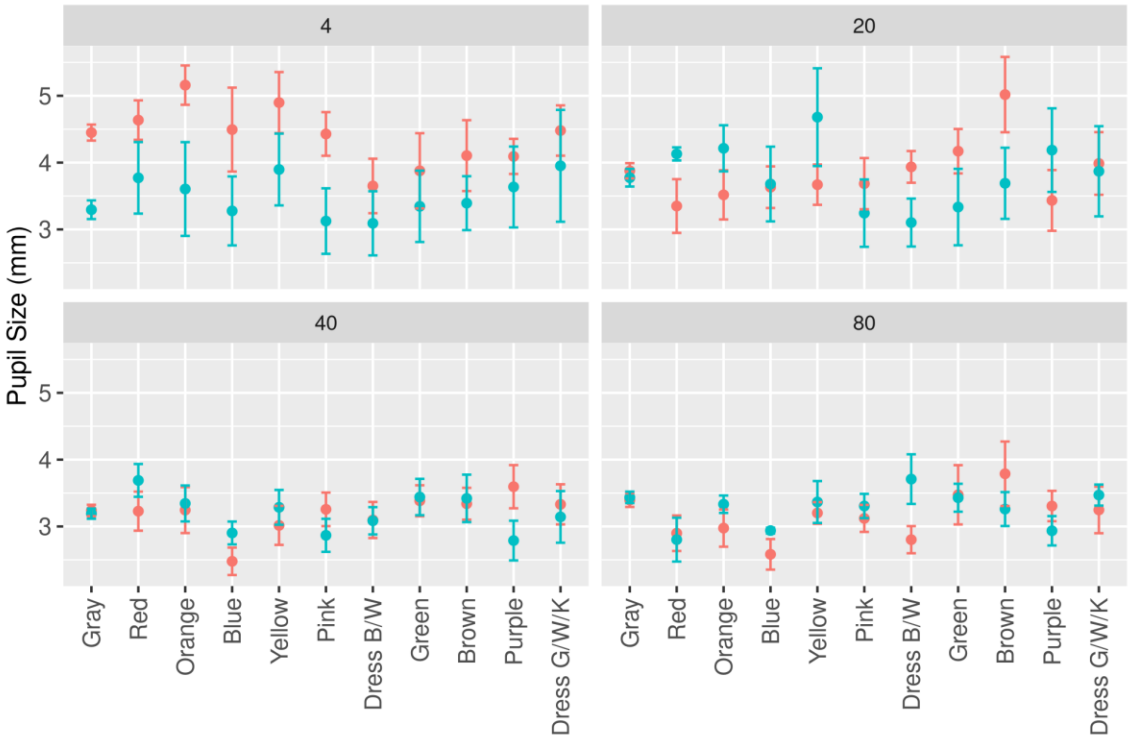


Figure 1: Pupil size depending on the luminance (panels) and the color stimuli. Errors lines represent one standard error above and below the mean. Dot colors encodes how the observers perceive the dress: red dots, Black / Blue; blue dots, Gold / White. Each dot was obtained from at least three seconds of pupil size measurement.

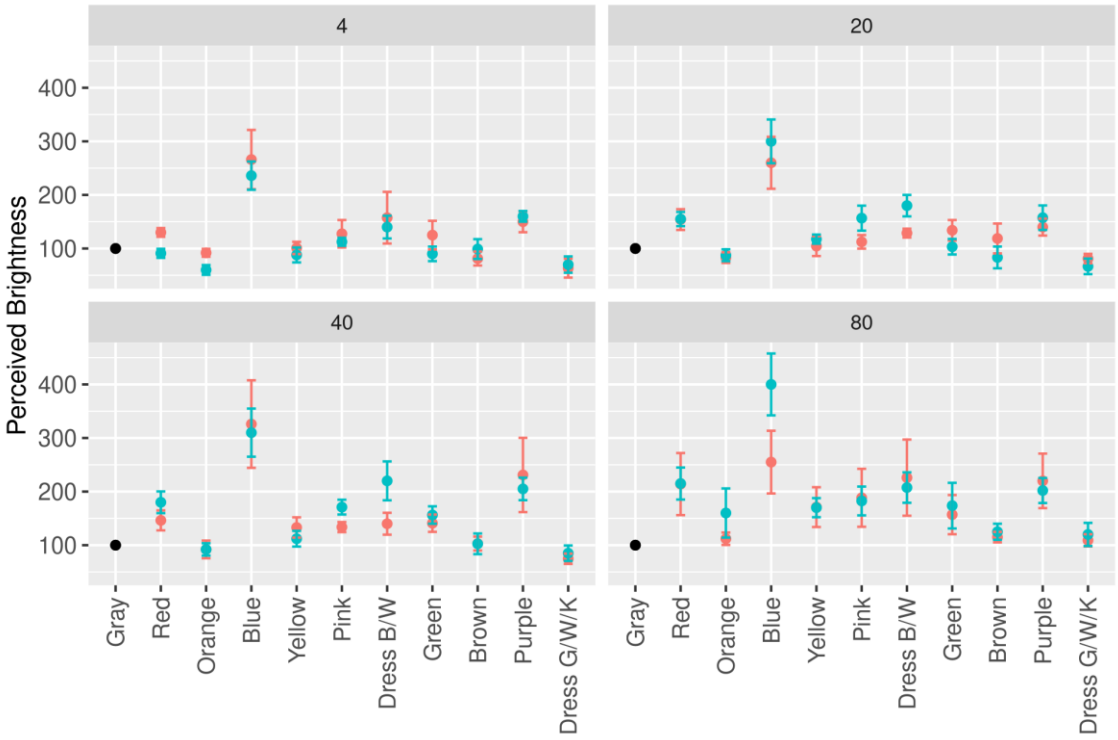


Figure 2: Perceived brightness depending on the luminance (panels) and the color stimuli. The reference was a gray stimulus (black dot) that has preassigned a brightness value of 100. Errors lines represent one standard error above and below the mean. Dot colors encodes how the observers perceive the dress: red dots, Black / Blue; blue dots, Gold / White.

CONCLUSION

We think there is enough evidence to claim the existence of two people groups: those who have "small" pupils and those who have "larger" pupils. Until the irruption of the dress image, there was no way to classify which category each individual belongs to, which is possible today. Far from being innocuous, belonging to one of these groups has consequences on how colors are perceived.

It remains to investigate what is the origin of these groups and the mechanism by which they affect the perception of color.

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