The Effect of Warm and Cool Object Colors on Depth Ordering

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Figure 1: Experiment stimuli: Target equiluminant colors (lower left) and corresponding equiluminant teapots.

1 Introduction

Colors that appear closer to the red end of the visible spectrum are said to be warm while the colors that appear closer to the blue end are said to be cool. The phenomenon of warmer colors appearing nearer in depth to viewers than cooler colors has been studied extensively by psychologists and other vision researchers (see [Sundet 1978] for a summary). The vast majority of these studies have asked human observers to view physically equidistant, colored stimuli and compare them for relative depth. However, in most cases, the stimuli presented were rather simple: straight colored lines, uniform color patches, point light sources, or symmetrical objects with uniform shading. Additionally, the colors used were typically highly saturated. Although such stimuli are useful in isolating and studying depth cues in certain contexts, they leave open the question of whether the human visual system operates similarly for realistic objects. This paper presents the results of an experiment designed to explore the color-depth relationship for realistic, colored objects with varying shading and contours.

2 Experiment Design

The stimuli chosen for this experiment is an object (teapot) that appears natural regardless of its color. We begin with a photograph of the object and seven manually selected, perceptually distinct colors. The luminance of these colors was adjusted to match the average luminance of the original teapot. Each of these target colors was then applied to the teapot. The target colors were scaled by the pixel luminance values of the original teapot to create the stimuli used in this study. This approach preserves the shading and specular highlights of the original teapot (see Figure 1).

The experiment takes the form of a paired comparison test. Participants were asked to observe all possible pairs of the differently colored teapots (and all possible pairs of the uniform patches of the target colors (for comparison purposes)) on a computer screen and select the teapot (or patch) in each pair that appears closest to them. Fifteen subjects (4 females, 11 males), between the ages of 18 and 40 volunteered to participate in this study. They all reported normal or corrected-to-normal vision with no color vision abnormalities. Participants were seated in front of a computer screen in a dimly lit room. Stimuli were presented on a 17 inch monitor, operating at 60 Hz with a resolution of 1280 x 1024. Two objects of the same type (teapot or color patch) were presented for each trial. The objects were displayed 1 inch apart on either side of an imaginary central point on the screen. The background could be one of four different uniform levels of gray, ranging from black to white. Participants were instructed to decide which object appeared nearer and responded by moving the mouse over their choice and clicking on it. If participants were unsure, they were instructed to choose based on their initial impulse. Between each trial, a blank screen was displayed for a 2 seconds. This was done because our perception of depth diminishes with viewing time. The 2 second interval prevents total adaptation, thereby ensuring that depth perception remains stable. Each participant experienced every possible comparison against every background for both the color patch and teapot data sets. Participants were given breaks after every 7 minutes of testing.

3 Results and Conclusion

We observed a clear cyclic trend in the depth preferences the object color changes from cool to warm. We also observed that this cyclic relationship between warm-cool color ordering and perceived depth gets stronger as the background gets darker. On the other hand, as the background gets brighter the relationship is lost. The trends for the color patches reveal less variability. This suggests that the more complex an image is, the more an observer may try to gather other depth cues from that image. When complex images are viewed, color is not necessarily the overriding depth cue. Tables, graphs and additional analysis of the results are available as a tech-report [Bailey et al. 2006].

References

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