Color Dominance vs. Eye Dominance

CLPS 1590: Visualizing Vision
Project 1: Stereovision

Sean Perkins

Abstract: Eye dominance is a common observation in humans. In this study, it is demonstrated that normal eye dominance can be counteracted with a form of color dominance by manipulating monocular red intensity in a red-blue stereogram. 8 subjects were presented with a stereographic Kanizsa triangle in color. The non-dominant eye of the subjects was given the dominant lens color (red) and the dominant eye was given the non-dominant lens color (blue). The intensity of red light was adjusted in discrete steps of 10 between 55 and 255 and participants were tasked with identifying the intensity of red light that gave the appearance of a centered Kanizsa triangle. The results show that this form of color-based eye dominance can be achieved and that the red intensity value that leads to a color dominance equal and opposite to natural eye dominance varies by individual.
Introduction

It is a common observation that humans tend to rely more heavily on input from one eye than the other. This asymmetrical processing of visual stimuli is normal and doesn't require any treatment or vision correction (Kommerell et al. 2003). In fact, it can be useful in activities like pointing at an object because it allows the individual to assume a more monocular perspective in which the finger and object can both be seen without diplopia. The extent of this asymmetry varies per individual (Kromeier et al. 2006).

The imbalanced reliance on the two eyes for perception is referred to generally as eye preference. Terms like sighting dominance and stereoscopic prevalence are used to refer to specific kinds of eye preference that are measured in a consistent way (Ehrenstein et al. 2005).

Sighting dominance is measured using a card with a peephole. A symbol is placed on the wall of a room and the subject stands on the other side of the room facing the symbol. The experimenter holds the card up so that the subject (with both eyes open) can see the symbol through the peephole. The experimenter then covers each of the subject’s eyes, one at a time, and asks the subject to identify which eye can still see the symbol – this eye is the dominant one (Ehrenstein et al. 2005).

Stereoscopic prevalence is measured by providing the subject with a stereographic image. Any perceived horizontal deviation of the stereographic image from a reference midline is interpreted as a form of eye preference and is recorded as stereoscopic prevalence (Haase 1995). This measure of eye preference has a strong, positive correlation with the results of sighting dominance tests (Ehrenstein et al. 2005).

The Kanizsa triangle, named after psychologist Gaetano Kanizsa, is an example of an illusory contour (Li 2009). There is no change in luminance, color, or texture along the border of the “triangle”. In fact, the triangle does not exist as anything physically distinct from the background of the image, but the tendency to mentally connect the straight edges from the wedges through amodal completion creates the illusion of a white triangle (see Figure 1).
The Kanizsa triangle has been adapted to a stereogram in this experiment (see Figure 2). Other research has incorporated stereographic Kanizsa triangles (Ramachandran 1986; Stevens 1981), but this experiment brings in one additional element: color. A pair of red-blue 3D glasses fuses the Kanizsa triangles in the image so that a pink triangle appears to float out in front of the screen.

The researchers for this experiment subjectively observed that the red lens filters out nearly all of the blue light, but the blue lens “leaks” some red light. This phenomenon creates some monocular noise because the eye looking through the blue lens sees a less clear image of the Kanizsa triangle.

Monocular noise can be problematic if the monocular images are substantially different. It can lead to a condition known as binocular rivalry in which the brain switches back and forth between the two images or chooses one dominant one, rather than fusing them. However, low levels of monocular noise (like in this experiment) can be overcome so that stereopsis persists. This phenomenon is referred to as binocular single vision (Yang et al. 2012).

The difference in light filtering between the red and blue lenses creates the possibility that one lens may transmit more light or a higher quality image than the other. Furthermore, adjusting the intensity of the red and blue values affects the intensity of the visual input to each eye. One study found that a neutral-grey filter over the dominant eye restricted the amount of light entering that eye and reduced stereoscopic prevalence (Kommerell et al. 2003).
Methods

This experiment used 8 subjects, all young men and women (ages 20 – 30) with normal vision. Each subject was asked to first participate in a variation of the sighting dominance card test. Instead of using a card, each subject held up one arm and made a small ring with their fingers to test sighting dominance using any object in the room. After establishing sighting dominance, each subject was given a pair of 3D glasses and told to use the red lens for the non-dominant eye and the blue lens for the dominant eye.

The subjects were presented with a Kanizsa triangle stereogram as depicted in Figure 2. The disparity between the triangles was set to 15 pixels. The experiment involved 10 trials per subject. For every odd numbered trial the subjects were shown variations of the stereogram in which the red intensity was increased in intervals of 10 from 55 to 255. For every even numbered trial the red intensity decreased in intervals of 10 from 255 to 55. In each trial, the subject had to choose for each image whether to stop the trial or see the next image. Participants were instructed to stop the trial if the Kanizsa triangle appeared centered or appeared to cross the midline of the image from one image to the next. If a subject cycled through all the images in a trial without stopping, the trial was recorded as ‘skipped’. Before collecting data, each subject was given time to try out the program and familiarize him or herself with the stimulus and the experiment.

The first goal of this experiment was to establish whether adjusting red intensity values could create a color-based form of eye preference equal and opposite to the stereoscopic prevalence present without color. If the subject perceives the triangle as centered, this equivalence has been achieved. This was measured by whether trials were skipped (no equivalence) or recorded (equivalence).

The second goal of this experiment was to determine whether the red intensity values at equivalence are the same or varies between individuals. The recorded values for each individual were fed into an ANOVA test with 7 degrees of freedom to determine this. The null hypothesis was that there would be no significant variation between individuals in distribution of red intensity values.
Results

All subjects found a right eye preference in the sighting dominance test. Table 1 shows that subjects recorded equivalence in 71 out of 80 trials. The mean red intensities for ascending red values were lower than the mean intensities for descending red values in every case.

Figures 3 and 4 show the distributions of the red intensities at equivalence for all subjects. The mean red intensities for ascending and descending trials are 133.2 and 168.5, respectively. The standard deviations corresponding to these values are 47.4 and 47.6, respectively. The overall mean red intensity was 151.6 with a standard deviation of 50.4.

The ANOVA test applied to the 8 subjects strongly rejected the null hypothesis (p < .0001) with F = 5.9. The variations in red intensities by subject are depicted in Figure 5.

<table>
<thead>
<tr>
<th></th>
<th>Subject</th>
<th>Skipped</th>
<th>Mean Red Value</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascending</td>
<td>A</td>
<td>0</td>
<td>119.0</td>
<td>23.0</td>
</tr>
<tr>
<td>Descending</td>
<td>B</td>
<td>3</td>
<td>105.0</td>
<td>0.0</td>
</tr>
<tr>
<td>All Trials</td>
<td>C</td>
<td>0</td>
<td>83.0</td>
<td>13.0</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>0</td>
<td>96.0</td>
<td>23.3</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>2</td>
<td>188.3</td>
<td>63.5</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>1</td>
<td>195.0</td>
<td>8.2</td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>0</td>
<td>133.0</td>
<td>41.5</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>0</td>
<td>165.0</td>
<td>46.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>137.0</td>
<td>4.4</td>
</tr>
</tbody>
</table>

Table 1: Means and standard deviations of red intensity values and number of skipped trials for each subject. Data for the 8 subjects is categorically split into the 5 ascending red value trials, 5 descending red value trials, and all 10 trials.
Figure 3: Frequency of red intensity values over 71 trials (8 subjects, 10 trials each, 9 total skipped trials). The data is split into two categories: trials with ascending red values and trials with descending red values.

Figure 4: Frequency of red intensity values over 71 trials (8 subjects, 10 trials each, 9 total skipped trials). All trials are used regardless of ascending or descending red values.
Figure 5: This boxplot shows the distribution (10 trials per subject) of red intensity values at equivalence for each of 8 subjects.


**Discussion**

Sighting dominance was established prior to each experiment and all participants were found to exhibit right-eye dominance. Without color, the sighting dominance would lead to a stereoscopic prevalence giving the apparent position of the triangle as off center. In this scenario, the triangle would never appear centered and all trials would be skipped. However, color was included and in 71 out of 80 trials participants perceived the triangle as centered at a certain red intensity. This suggests that some color-based form of eye preference was present. We can refer to this eye preference as color dominance.

There are two forces that could be contributing to this color dominance. First, the differential ability of the red and blue lenses to fully filter out colored light could lead to a red-blue dominance. Indeed, the researchers observed that stereoscopic prevalence was greater when the subjects’ dominant eyes used a red lens instead of a blue lens. Secondly, the red intensity was modulated for the non-dominant eye. This adjustment of the intensity of light providing input to the non-dominant eye may have lowered stereoscopic prevalence just like the neutral-grey filter did for Kommerell et al. 2003. Furthermore, changing the intensity of the red value may have influenced the red-blue dominance as well. The net effect of these two forces was that, for a particular red intensity, subjects perceived some sort of color dominance equal and opposite to their normal sighting dominance in 71 out of 80 cases.

Figures 3 and 4 show that there was quite a bit of variation in the pooled data about which intensity of red led to the equivalence between normal eye dominance and color dominance. There was no indication of a single preferential red intensity. The ANOVA test confirms that each subject chose values clustered around a mean red intensity unique to that subject.

The individual subjects had high standard deviations as well, ranging from 20.7 to 54.2. This can partly be explained methodologically. The images were shown to the subjects with either ascending or descending red intensities and this created a bias. Each subject had a mean ascending red intensity that was lower than his or her mean descending red intensity. Equal amounts of both types of trials were present.
to try to cancel out this bias for the purposes of deriving a true mean. However, this still drove up the variance. The high standard deviations may also be explained by the difficulty in discerning subtle differences in stereoscopic prevalence. Insufficient blinking may also have led to some errors due to retinal persistence.

This study focused on exploring the interactions between red-blue dominance, color intensity, and normal sighting dominance. The results establish that manipulating red intensity can counteract normal sighting dominance; however, they don’t elucidate the mechanism precisely. It is shown that there is variation between individuals in regard to which red intensity value creates the equivalence, but it is not evident how much of this variation can be attributed to variable perceptions of normal eye dominance, red-blue dominance, or monocular color intensity. Future studies might consider isolating these variables and measuring their variance across individuals.

It would also be worthwhile to test both red and blue intensity variations and find test subjects with left eye sighting dominance. The disparity between triangles could also be manipulated. Lastly, the data might be more accurate if participants are allowed to adjust the monocular color intensity values themselves until they decide the triangle is centered. This might reduce the methodological bias of ascending and descending red values and it would get rid of the oversimplification of large color intensity intervals.
References


