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Lee L. Cornforth
Pacific University

Bryan L. Johnson
Pacific University

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Abstract

This study was designed to determine the effect on stereopsis of interocular retinal chromatic and illuminance imbalance in 30 subjects with normal binocularity. A Randot Circle Stereotest viewed through polarizing glasses was the control condition. In each of the other three conditions, illuminance and chromatic imbalances were created by combinations of neutral density filters, red and green filters, and polarizing filters. The effect of each of four experimental conditions on stereopsis was determined by comparing total stereo judgement errors on the Randot Circle Stereotest. Total average flux through the filter combinations was held constant by adjusting the luminance level of light reflected from the target. The chromatic imbalance created by the red-green filters significantly increased the number of stereo judgement errors (37%, $p < 0.05$); however, the illuminance imbalance (0.2 log units) created by the red-green filters did not significantly increase the number of errors (2.9%, $p < 0.65$); finally, the combined illuminance and chromatic imbalance created by the red-green filters significantly increased the error frequency (46%, $p < 0.05$). The chromatic imbalance caused by red-green glasses significantly degrades stereopsis, whereas the illuminance imbalance caused by these filters has little effect on stereopsis.

Degree Type

Thesis

Degree Name

Master of Science in Vision Science

Committee Chair

Paul Kohl

Keywords

Stereopsis, Retinal Illuminance Imbalance, Retinal Chromatic Imbalance, Stereogram, Polarizing Filters, Red-Green Filters

Subject Categories

Optometry

THE EFFECT OF RETINAL ILLUMINANCE AND CHROMATIC IMBALANCE ON STEREOPSIS

A Thesis Presented to Pacific University
College of Optometry in Partial Fulfillment
of the Requirements for the Degree of
Doctor of Optometry

INVESTIGATORS:
Lee L. Cornforth, B.S.
Bryan L. Johnson, B.S.

ADVISORS:
Paul Kohl, O.D.
Niles Roth, M. Opt., Ph.D.

SUBMITTED:
March 12, 1986

ACKNOWLEDGEMENTS

We would like to thank Jeffery Urness, O.D. and Harold Haynes, O.D. for their valuable project design ideas. We also thank the Oregon Optometric Association for its monetary support and Stereo Optical Company of Chicago for donating the Randot Stereotest Circle plates used in this study. We are grateful for the extensive assistance and encouragement from our advisors; Paul Kohl, O.D. and Niles Roth, M. Opt., Ph.D.

ABSTRACT

This study was designed to determine the effect on stereopsis of interocular retinal chromatic and illuminance imbalance in 30 subjects with normal binocularity. A Randot Circle Stereotest viewed through polarizing glasses was the control condition. In each of the other three conditions, illuminance and chromatic imbalances were created by combinations of neutral density filters, red and green filters, and polarizing filters. The effect of each of four experimental conditions on stereopsis was determined by comparing total stereo judgement errors on the Randot Circle Stereotest. Total average flux through the filter combinations was held constant by adjusting the luminance level of light reflected from the target. The chromatic imbalance created by the red-green filters significantly increased the number of stereo judgement errors (37%, $p < 0.05$); however, the illuminance imbalance (0.2 log units) created by the red-green filters did not significantly increase the number of errors (2.9%, $p < 0.65$); finally, the combined illuminance and chromatic imbalance created by the red-green filters significantly increased the error frequency (46%, $p < 0.05$). The chromatic imbalance caused by red-green glasses significantly degrades stereopsis, whereas the illuminance imbalance caused by these filters has little effect on stereopsis.

Key Words: Stereopsis, Retinal Illuminance Imbalance, Retinal Chromatic Imbalance, Stereogram, Polarizing Filters, Red-Green Filters

INTRODUCTION

Red-green filters[a] and polarizing filters[a] are commonly used clinically to elicit stereopsis and monitor suppression. Red-green filters create two kinds of interocular retinal imbalance, illuminance and chromatic, that are not created by polarizing filters. In a recent study, the illuminance imbalance caused by red-green filters was measured,[1] and others have shown that retinal illuminance differences do not greatly affect stereopsis and suppression.[2,3,4] Matsumoto et. al. has shown that chromatic differences can reduce stereoacuity.[5] In eyes with similar optical properties, the chromatic imbalance induced by red-green filters creates refractive conditions similar to aniseikonia and anisometropia. That is, the red image is larger than the green, and is focused farther from the principal plane than the green image. It is widely known that anisometropia and aniseikonia degrade stereopsis.[2,6,7,8] This study attempts to probe the effect of interocular retinal chromatic and illuminance differences created by red and green filters on stereopsis. Based on the findings of Lovasik and Szymkiw,[2] the aniseikonic/anisometropic condition created by red and green filters, and common clinical experience that stereopsis through red-green filters is degraded, we hypothesize that the illuminance difference has little effect on stereopsis, whereas the chromatic difference degrades stereopsis.

Using a within subjects design, we systematically isolated the retinal chromatic and illuminance variables by using a control and three experimental conditions. The effect of each variable on stereopsis was monitored by comparing the total number of stereo judgement errors on a Randot Circle Stereotest[b] for all subjects.

METHODS

Subjects.

Thirty subjects,aged 17 to 40, volunteered from a population of optometry students, their spouses, staff, and community members. This group consisted of eight females and 22 males with an average age of 27. All subjects exceeded our entrance criterion of 40 arc seconds of maximim stereothreshold, as measured on the Randot Circle Stereotest at 40cm (16 inches).

Methods and materials.

Luminous transmittance through the red and green filters was measured with a Tektronix J-16 Photometer-Radiometer coupled with a J-6511 probe.[c] The percent transmittance difference between the red and green filters represented the illuminance imbalance that was either neutralized or mimicked with neutral density filters[d] in two of the four conditions (see conditions C and D below). Luminous transmittance through the polarizers and neutral density filters was also measured with the above apparatus, using as a light source, a #93 automotive type tungsten lamp operated at its rated 12 volts.

A uniform grey cardboard partition 48.25cm wide and 30.50cm high with a central rectangular aperture of dimensions corresponding to the borders of each standard Randot Circle Stereotest cell separated the subject from the Randot stereogram target. The partition allowed only one Randot cell at a time to be viewed by the subject without a clue as to which cell it was. A subject to target distance of 1.19m was chosen so the highest Randot stereoacuity demand approached threshold for most normal observers.[9] The subject's head was comfortably supported in a chin and forehead rest system[e] at eye level with the base of the target aperture, 1.15m from the floor. The subject wore a Bernell polarizing goggle[a] modified to hold up to three filters before each eye.

Using a Tektronix J-16 Photometer-Radiometer coupled with a J-6523 Luminance Probe,[c] the luminance of the target was measured at the four quadrants surrounding the aperture and averaged. The light sources illuminating the target area consisted of four to five 150 watt bulbs on a movable tripod aligned 45 degrees to the target plane and shielded from the subject by a cardboard square. There were no other light sources in the room. By varying light source to target distance, constant average luminances through the several filter combinations were maintained in each of the four conditions. Where the right and left filter transmittances differed (conditions B & C), illuminance at the target plane was adjusted to give an average luminance through the right and left filter combinations equal to the desired constant level of 17.1 nits.[f]

For each condition, each of the ten Randot cells was presented four times at random, and the order in which the conditions were presented was also randomized among subjects. Between presentations, the subject looked away at a second fixation target so as not to see the change in cell presentation made by the experimenter behind the partition. Subjects were forced to decide within ten seconds which circle in the cell appeared to float from the plane. One of the experimenters recorded the responses and monitored subject fixation.

Condition A.

Control: Subjects viewed the target through polarizing filters only. There was neither chromatic nor illuminance imbalance in this condition.

Condition B.

Combined Illuminance and Chromatic Imbalance: Subjects viewed each of the stereogram cells while wearing a polarizing and a red filter over the right eye and a polarizing and green filter over the left eye.

Condition C.

Illuminance Imbalance only: Subjects viewed the stereogram cells while wearing a polarizing and 0.5 log unit neutral density filter over the right eye and a polarizing and 0.3 log unit neutral filter over the left eye.

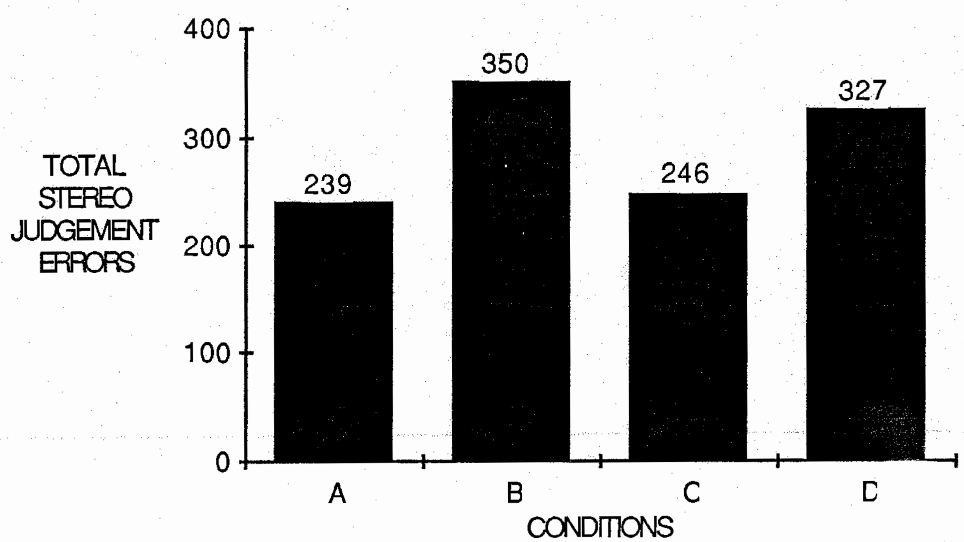
Condition D.

Chromatic Retinal Imbalance Only: Subjects viewed the stereogram cells while wearing a polarizing and red filter over the right eye and a polarizing , green, and 0.3 log unit neutral density filter over the left eye to neutralize the illuminance difference.

RESULTS

Total errors in Condition A for all subjects were 239, in Condition B were 350, in Condition C were 246, and in Condition D were 327 (Figure 1).

Figure 1. Total stereo judgement errors per condition.



Using a related measures T-test, Condition A (the control) and Condition B (illuminance and chromatic retinal imbalance) differed significantly in the number of total errors at the 0.05 level. Condition A versus Condition C (illuminance imbalance) showed no significant difference. Finally, Condition A versus Condition D (chromatic retinal imbalance) differed significantly at the 0.05 level (Table 1).

TABLE 1: Statistics for total stereo judgement errors per condition.

	CONDITON A	CONDITION B	CONDITION C	CONDITION D
TOTAL ERRORS	239	350	246	327
AVERAGE ERRORS	7.97	11.67	8.20	10.90
STD. DEVIATION	5.52	5.24	4.50	5.12
T- VALUE (N = 30)	CONTROL	-4.661	- .429	- 3.014
PROBABILITY	CONTROL	< .001*	0.653	0.005*

*Significant at the 0.05 level, adjusted for number of times T-test was used.

DISCUSSION

The total errors for the Control and Condition C are not significantly different. This suggests that the retinal illuminance difference caused by red and green filters does not significantly affect stereopsis. This magnitude of retinal illuminance imbalance has also been shown by others not to significantly affect stereopsis[2].

The total errors for the Control and Condition D differ significantly, suggesting chromatic imbalance as the cause of increased error frequency.

Many vision therapists utilize red-green filters and a variety of complementary red and green target patterns in their testing and training regimen. Anaglyphs are commonly used for motor fusion training as well as stereopsis and sensory fusion assessment and training. Monocular training under binocular conditions is widely accomplished with red and green filters.[10] A multitude of binocular testing and training methods such as the Bernell Stereo Test[a], Tranaglyphic slides and Stereo Trainers[a], Worth 4-Dot Flashlight Test, and computerized systems[g] rely on colored filters. Results of our study suggest that stereopsis through polarizing filters is superior to that through red and green filters. It then follows that testing and training using polarizers may be superior to using red-green filters in many patients, especially those with tenuous (unstable) binocularity.

During testing , we observed that Randot cell number 7, which tests for 40 seconds of arc at 40cm (16 inches), had by far the greatest error frequency of all 10 cells (See Appendix). This observation has been noted by other clinicians at this institution, and the explanation for this anomaly is presently unknown.

CONCLUSIONS

We conclude that the retinal illuminance difference caused by red and green filters does not significantly affect stereopsis; however, the retinal chromatic imbalance caused by these filters degrades stereopsis. It should be noted that we based our conclusions on stereoaccuracy (error frequency) and not on actual stereoacuity measurement. Future studies should determine the effect of the retinal chromatic difference on actual stereoacuity. Also, if the chromatic imbalance were corrected with lenses the resulting effect on stereopsis should be studied. Future studies should also investigate the effect of anaglyphic materials versus polarizing materials when used for motor fusion training, binocularity testing, and assessment of sensory fusion abilities. The effects of anaglyphic materials on subjects with tenuous binocularity should also be investigated. Another subject for study is the high error frequency that was observed on Randot cell number 7.

FOOTNOTES

a. Bernell Corp., South Bend, Indiana.

b. Stereo Optical Company Randot Stereotest, Chicago, IL.

c. Tektronix Inc., Beaverton, OR.

d. Wratten Neutral Density Filters: 0.3 & 0.5 log units, Eastman Kodak Co., Rochester, NY.

e. Type 71-61-20, B & L Corp., Rochester, NY.

f. Average luminance through filter combinations (17.1 nits) = [Average % transmittance through filter combinations] **X** [Average illuminance at the target plane]

g. Computer Orthoptics Inc., Brooklyn, NY.

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APPENDIX A: Statistics for total errors per Randot cell for all four conditions.

	CELL 1	CELL 2	CELL 3	CELL 4	CELL 5	CELL 6	CELL 7	CELL 8	CELL 9	CELL10
TOT. ERRORS	22	22	72	52	57	89	**323**	149	206	170
AVE. ERRORS	0.73	0.73	2.4	1.73	1.9	2.97	**10.8**	4.97	6.87	5.67
STD. DEV.	1.34	1.53	2.46	2.42	2.06	2.95	3.95	3.41	3.19	3.56