QUANTIFYING THE EFFECTS OF ANISEIKONIA AND OCULAR DOMINANCE ON STEREO ACUITY AS MEASURED WITH THE HOWARD DOLMAN APPARATUS

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ABSTRACT

Eighteen subjects had their threshold of stereopsis measured with a Howard-Dolman apparatus while wearing their habitual prescription. This was then compared to stereo threshold with 2% and 4% magnification at 90 degrees in front of the right and then left eyes. The decrease in stereo acuity, as measured by the Howard-Dolman apparatus, appears to follow a linear pattern, as noted in previous experiments. It also appears that the threshold will be higher when the magnification is placed in front of the dominant eye.

INTRODUCTION

The presence of aniseikonia has been shown to degrade stereopsis in a linear manner. Ogle,[1] using a tilting plane device, has shown that over a range of zero to six percent the mean deviation of measurements in arcseconds, approximates a straight line. Chang,[2] using random dot patterns, showed the threshold of stereopsis appeared to increase in a linear manner over a range of zero to eight percent magnification. Reading and Tanlamai also showed similar results with magnification up to 33%.[3] They measured stereopsis via Diastereo and Randot tests.

In these tests, only Reading and Tanlamai used the Howard-Dolman apparatus. This was carried out on only two of their subjects. These two subjects also showed a basically linear pattern to the decrease in stereo acuity.

This experiment was designed to verify the decrease in stereo acuity as a linear function of the magnification, as measured by the method of adjustment (Howard-Dolman apparatus). The use of this apparatus is significant as this task requires a higher quality of stereopsis than do other tests. The standard procedure in this type of experiment is to place the aniseikonia inducing lens in front of the non-dominant eye.[4] In order to evaluate the importance of which image is magnified, each subject will have the test run with magnification before the dominant and non-dominant eye.

METHOD

Eighteen subjects were used in this study. They ranged in age from 14 to 51. Each subject possessed acuities of 20/20 or better in each eye. Ocular dominancy was determined by having the subject sight an object through encircled fingers. Subjects that showed no definite preference are not included in the dominancy portion of the results. Interpupillary distances were also measured and recorded.

The horizontal-vertical magnification system from an American Optical Space Eikonometer was used to provide the optically induced aniseikonia. A spherical, minus seven diopter trial lens was placed in front of the ocular pieces to neutralize the near point focus of the space eikonometer. This instrument allowed precise adjustments for interpupillary distance and magnification or minification up to 4% X 90 degrees in the right eye.

Only axis 90 magnification (or geometric effect) is used in this experiment. The use of axis 180 magnification would be the equivalent of axis 90 magnification in the opposite eye (i.e. the induced effect).[5]

The stereoscopic acuities were determined with the Howard-Dolman apparatus. The Howard-Dolman apparatus consists of an elongated box, open at one end, containing two vertical, black pegs. The box was placed such that the stationary left peg was 3m from the subject. The right peg could be moved back and forth in a channel 6 cm to the side of the left peg. The subject was told to look at the left peg and to move the right peg by means of a string and pulley arrangement until the right peg was even with the left peg. Ten settings were made with the experimenter adjusting the right peg to an arbitrary position between settings. The stereoscopic threshold was taken to be the standard deviation of the settings converted to angular measurement (Fig. 1).[6]

Fig. 1

Calculations

average of 10 adjustments = SD in mm

(PD in mm) X (SD) X .023 = seconds of arc at 3 m

To insure that the magnification instrument was not adversely affecting the results, visual acuity of 20/20 through the instrument was required. The subject was then tested with their habitual prescription only. Then, another set of 10 adjustments was done while viewing through the magnifying system with the magnification set at zero. These first two measurements were to act as a baseline threshold and control.

The next four sets of data were carried out in the same manner, but with the following magnification before the eyes:

2% at 90	right eye
4% at 90	right eye
2% at 90	left eye
4% at 90	left eye

The subject was told to look about the room and relax for about 30 seconds between each trial to help eliminate fatigue as a factor.

RESULTS

The average stereo acuities measured with habitual correction only, and through the magnification system were 30.2 arc seconds and 35.1 arc seconds respectively. These numbers compare favorably. The slight difference can be attributed to the system of lenses in the magnifier. It was noted that several subjects achieved slightly lower thresholds (up to nine seconds) through the magnifier when set at zero, than without the magnifier (6 out of 18). It was also noted that four subjects showed much higher thresholds (greater than 20 seconds) through the magnifying apparatus.

Table one summarizes the stereo acuities for all patients. Figures 2 and 3 show this data plotted with percent magnification on the y axis and seconds of arc on the x axis. It is apparent that as magnification increases, so does stereo threshold. This function appears linear when the non-dominant eye is magnified as noted in previous experiments. When the dominant eye is magnified this is not so apparent. Data for the right eye dominant subjects is basically linear, but the left eye dominant subjects showed a less than linear tendency.

TABLE 1 - Stereoscopic acuities in arc seconds.

	Control	2%	4%
OD dom, OD mag	40.9	74.7	90.3
OD dom, OS mag	40.9	54.0	68.3
OS dom, OS mag	30.1	55.1	49.9
OS dom, OD mag	30.1	32.9	42.4
Avg dom mag	35.5	66.1	69.8
Avg nondom mag	35.5	41.3	56.6

FIGURE 2 - Magnification versus stereo acuity. Averaged data for all subjects.

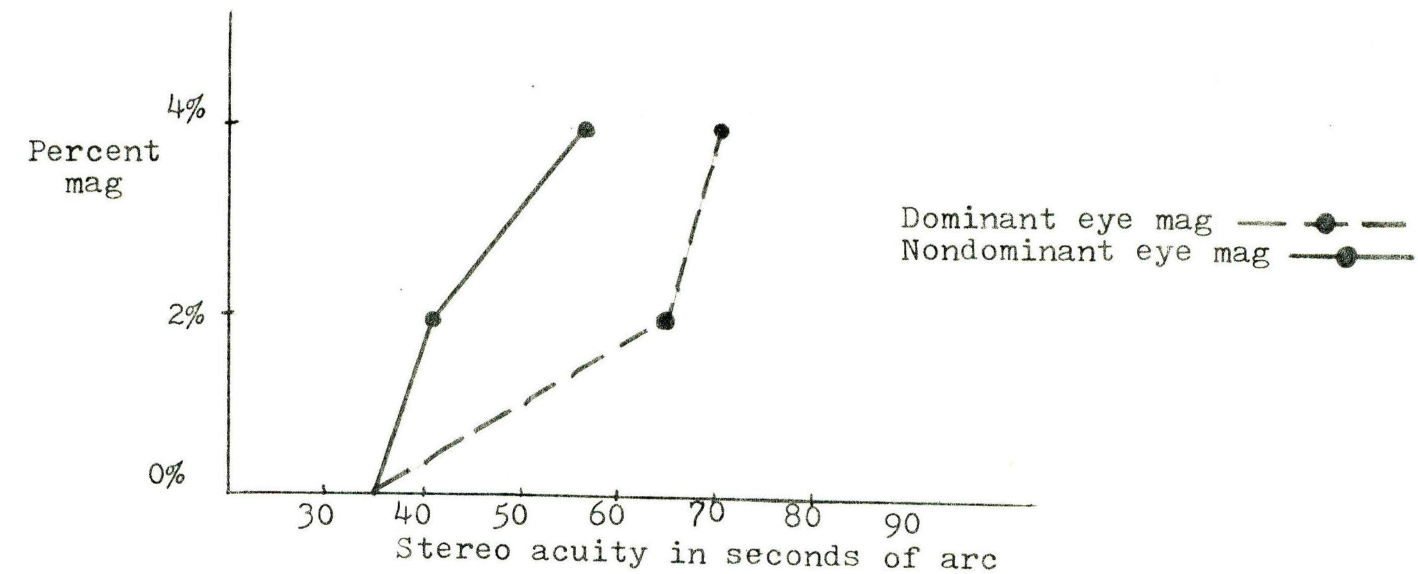
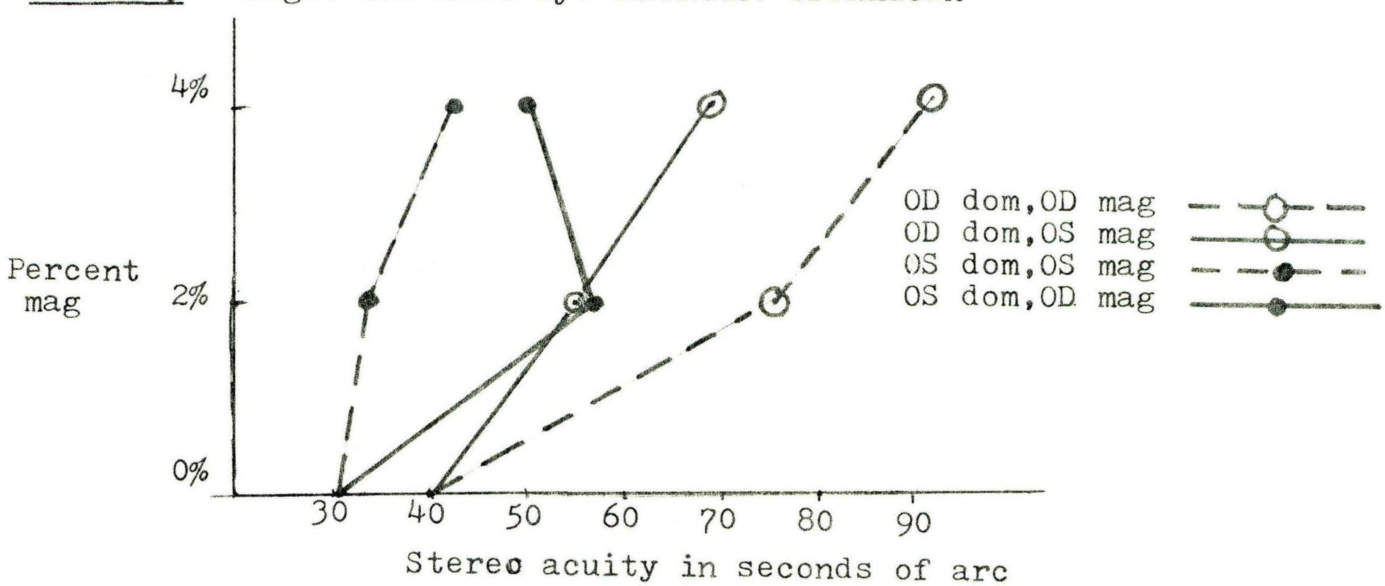


FIGURE 3 - Right and Left eye dominant breakdown



The average stereo acuity for the left eye dominant subjects was about ten seconds of arc lower than the stero acuity for the right eye dominant subjects. This may be accounted for by the small sample size, or some discrepancy in the magnification system.

Figure 3 also shows that there is a significantly greater loss of stereo acuity as magnification increases in front of the dominant eye, as compared to magnification of the non-dominant eye.

A two tailed students t -test was performed with the null hypothesis stating that stereo acuity with dominant eye magnification is equal to stereo acuity with non-dominant eye magnification. This hypothesis was rejected at the 0.05 level of significance for the two percent level. It was accepted at the 4% level of magnification.

Fig. 4

Statistical Comparison of Stereo Acuities

H null = (dom mag - non dom mag) = 0

H alt = (dom mag - non dom mag) ≠ 0

z critical = 1.96

at 2% mag	reject H null	z = 2.59
at 4% mag	accept H null	z = 1.35

These results can be better visualized in Figure 3. The t-test determines if the differences between the average stereo acuities for the dominant and non-dominant eye magnification were statistically significant. It was determined that the difference was significant only at 2% magnification, as noted by the greater separation of the two plotted lines at this point. The left eye dominant subjects did not show a decrease in threshold as magnification was increased over two percent. This may have distorted the data for the right eye dominant subjects, which showed a linear and significant increase in threshold with increasing magnification.

DISCUSSION

The purpose of this experiment was to see if stereo acuity as determined by the Howard-Dolman apparatus, followed a basically linear function, as noted with the random dot, tilting plane and Diastereo tests when the non-dominant eye is magnified. Differences in stereo acuity were also observed for non-dominant and dominant eye magnification. The data from figure 2 shows the linear increase for non-dominant eye magnification. This experiment suggests that this linear function may not hold true when the dominant eye is magnified. The plot of this data shows a sharp upward turn after the two percent test point. This could be due to the small sample size or lack of testing levels. When the data is broken down into subgroups of right eye dominant and left eye dominant subjects we see that the former group gives a very linear graph for both dominant and non-dominant eyes (Figure 3).

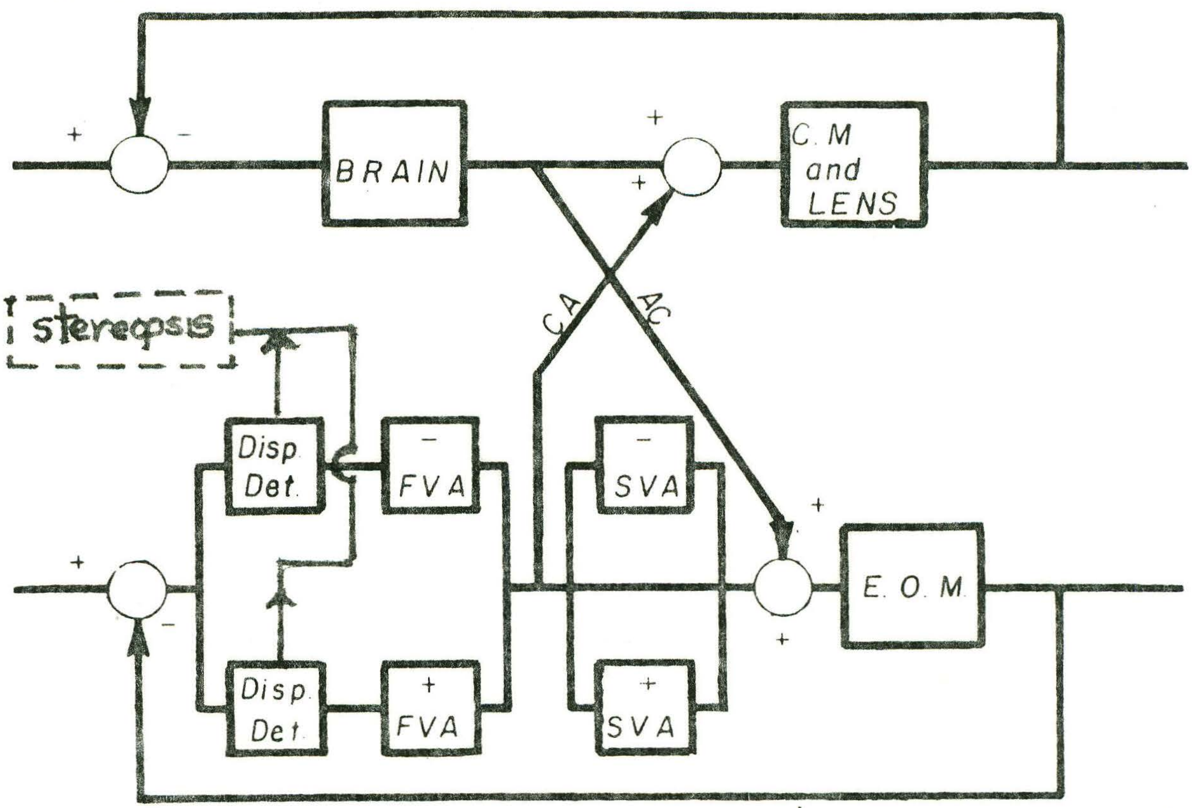
The data for left eye dominant subjects shows the exaggerated up turn noted in Fig.2. The difference between right and left eye dominant suggests some error in the experimental method.

The students t-test, performed on the means for both right and left eye dominant subjects suggests that at two percent magnification the difference is statistically significant, while it is not significant at four percent. If performed on the subgroups the difference is significant at each magnification level except for four percent magnification for left eye dominant subjects. This may also be due to error introduced by the magnifier used for the testing. The construction of the eikonometer assumes that magnification of the right eye provides the same circumstances as minification of the left eye. The axis 90 magnification system for the eikonometer is fixed in front of the right eyepiece. Magnification for the left eye is attained by minifying the image of the right eye. This experiment also assumed axis 90 magnification of the left eye is equal to axis 90 minification of the right eye. If this assumption were not true, then the error introduced may have disrupted the results. Also, the fact that the magnification/minification system was in front of the right eye, and that right eye dominant subjects were affected to a greater extent (i.e. lower stereo acuities), could explain the failure of the left eye dominant subjects to be affected to the same degree as right eye dominant subjects. Another fact that lends some credibility to this last point is the ten arc seconds lower threshold for left eye dominant subjects when compared to right eye dominant subjects. The magnification/minification of the right eye may have affected the right eye dominant subjects to a greater extent.

To further investigate these discrepancies an experiment could be set up where stereo acuities are measured as a control. Then with two, four and six percent magnification in front of the non-dominant eye, and finally with the same amount of minification in front of the dominant eye. In this manner, it could be determined if magnification of one eye truly affects stereopsis the same as minification of the opposite eye.

One interesting observation made during the testing was that after five to six settings on the Howard-Dolman the subject sometimes rapidly increased their stereo threshold. If they looked away for several seconds, and then completed the ten setting series, their responses usually improved. A possible mechanism, suggested by Saladin,[7] is the fatigue of the disparity detectors which are thought to govern stereopsis (Figure 4). This may have affected stereo acuity of the subjects, but the distribution of the error should be equal for each subject.

Fig. 5



A model of the accommodation and convergence systems with possible stereopsis mechanism[8].

Results from this experiment suggest that stereopsis will be affected to a greater degree when the dominant eye's image is magnified. Such situations may include first time correction of anisometropes, contact lens correction for a unilateral aphake, intraocular lens implants for a unilateral aphake, or correction of unilateral astigmatism at 180 degrees. It has been estimated that one diopter of anisometropia could induce anywhere from one percent[8] to two percent[9] magnification difference between the eyes. Therefore, even low to moderate amounts of aniseikonia can adversely affect stereopsis, especially when the dominant eye is magnified with a spectacle lens. In experiments involving the use of aniseikonia inducing magnifiers, it is common to place the magnifier in front of the non-dominant eye. This may not be a totally realistic situation. As we have seen different results may be obtained depending upon which eye is magnified.

CONCLUSIONS

1. Howard-Dolman stereoscopic acuities decreases in a linear fashion as magnification is increased in front of the non-dominant eye.

2. Magnification of the dominant eye produces greater decreases in stereopic acuities than does magnification of the non-dominant eye.

3. Magnification at 90 degrees of one eye may not provide the same visual situation as minification at 90 degrees of the opposite eye.

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