The effects of artificially induced anisometropia on stereomobilization

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Abstract
Stereomobilization refers to the time required to activate stereopsis and perceive depth. Previous studies have examined the temporal effects of stereomobilization but very few have focused on the effects of unbalanced corrections, such as those seen with monovision contact lens fits. A color Macintosh computer was used to assess the effects of increasing anisometropia on stereomobilization in 37 subjects. For each increased anisometropic difference between the eyes, stereomobilization demonstrated a significant reduction in percent correct with shortened presentation times. It was also found that patients tested with larger amounts of induced anisometropia needed to view targets for significantly longer periods of time to gain the same stereoscopic information that a person with lower levels of anisometropia could achieve in a fraction of the time. Of the times tested that were similar to a previous study by Thompson and Yudcovitch (1996), there was no significant difference (p>0.05) found between the two data sets, thus demonstrating the repeatability of their experiment.

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THE EFFECTS OF ARTIFICIALLY INDUCED ANISOMETROPIA ON
STEREOMOBILIZATION

BY

JAY CHRETIEN
GRANT LINDBERG

A thesis submitted to the faculty of the
College of Optometry
Pacific University
Forest Grove, OR
for the degree of
Doctor of Optometry
May, 1997

Advisor:
Paul Kohl, O.D.
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A thesis submitted to the faculty of the College of Optometry, Pacific University, Forest Grove, OR for the degree of Doctor of Optometry, May, 1997

Advisor:
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ABSTRACT:

Stereomobilization refers to the time required to activate stereopsis and perceive depth. Previous studies have examined the temporal effects of stereomobilization but very few have focused on the effects of unbalanced corrections, such as those seen with monovision contact lens fits. A color Macintosh computer was used to assess the effects of increasing anisometropia on stereomobilization in 37 subjects. For each increased anisometropic difference between the eyes, stereomobilization demonstrated a significant reduction in percent correct with shortened presentation times. It was also found that patients tested with larger amounts of induced anisometropia needed to view targets for significantly longer periods of time to gain the same stereoscopic information that a person with lower levels of anisometropia could achieve in a fraction of the time. Of the times tested that were similar to a previous study by Thompson and Yudcovitch (1996), there was no significant difference (p>0.05) found between the two data sets, thus demonstrating the repeatability of their experiment.

KEY WORDS:

stereopsis, stereomobilization, stereoacuity, monovision, contact lenses, anisometropia, normalized data.
INTRODUCTION:

Stereoscopic depth perception is one of the most sensitive qualities of binocular sensory fusion. The measurement of perceived stereopsis, stereoacuity, is calibrated in arc seconds of disparity. Determination of stereopsis is an important part of a visual examination and aids in evaluating the level of binocular function a patient may have. However, like Snellen acuity, stereoacuity is a static measurement and is not normally examined with moving targets or with timed presentations. Subtle changes that decrease a patient's stereoacuity may not appear to alter their visual function. However, under dynamic conditions such as those experienced in day to day life, visual function may suffer far more than expected.

Under dynamic conditions, stereopsis is called on to provide depth information with minimal presentation times. The speed at which this information can be obtained is referred to as stereomobilization time. Previous studies have suggested there is no minimum stimulus duration required for the detection of stereoscopic cues under "normal or corrected vision" (Uttal et al, 1994). In a normative study by Thompson and Yudcovitch (1996), stereomobilization was assessed with the use of a computer program presenting anaglyphic stereoscopic targets as developed by LeRoy and Kohl. A common finding between Uttal et al (1994) and the Thompson and Yudcovitch (1996) study was that there was no stereomobilization endpoint time determined. There are currently no studies which have probed the effects of anisometropic correction on stereomobilization time, an example of such a correction may be found with monovision contact lens prescriptions.

The concept of monovision as a form to correct presbyopia is over 30 years old. Success rates in patients corrected with monovision are close to 80%, making it the most successful form of presbyopic contact lens correction available (Josephson et al, 1991). The advantages of contact lenses are numerous; there are no aberrations, distortions or reductions in field of view as is seen with spectacle lenses. Additionally, monovision patients have constant distance and near vision independent of gaze position. Previous researchers state that approximately 94% of patients corrected with monovision have stereoacuities within "normal" ranges (Koetting, 1970). However, monovision is also known
to cause reduced central visual acuity in one eye, reduced visual quality under scotopic conditions and a general impairment of one's stereopsis ability. Even with these disadvantages, monovision is highly accepted by the public at large.

The key to success or failure for a monovision patient is monocular suppression. A patient must have the ability to suppress central vision in one eye while doing a task and alternate between eyes depending on the distance of the task from the patient. Theoretically, information from the blurred eye's image is summed with the information from the other eye's focused image. Binocularity is therefore maintained at some level of fusion for all viewing distances. Binocularity with monovision is compromised, but not lost.

One of the primary goals of this project is to establish stereomobilization as an indicator of decreased stereo function in conjunction with the currently used method of stereoacuity. Another goal of the current study is to corroborate the data found by Thompson and Yudcovitch (1996) in their normative analysis on the temporal effects on stereoacuity. Specifically, the first hypothesis to be tested in our study is whether artificially created anisometropia (as with monovision patients) has an effect on stereomobilization time. In addition we will further investigate whether differences in the amount of anisometropia effect stereomobilization times.

SUBJECTS:

Our study subjects consisted of 37 students from Pacific University College of Optometry. Participant ages ranged from 22 to 43 years old with 62% female and 38% males. All subjects signed an informed consent release in agreement with the Institutional Review Board standards. Potential subjects were screened for best corrected Snellen acuities of 20/20 or better at 40 cm both monocularly and binocularly. Unilateral and alternating cover tests were used to screen for strabismus objectively and subjectively at 40 cm. Stereopsis ability was screened using the polarized Titmus stereo test with a participation limit minimum of 60 arc seconds. Additionally, all subjects were required to have had a visual examination within the past year and perform the experiment through a current prescription. Passing these screening criteria allowed entry into the study.
METHODS:

Subjects were seated one meter from a Macintosh Centris computer with a 16" color monitor emitting 20 cd/m² luminance. Each subject wore a pair of red/blue glasses (consisting of a powerless red filter over the left eye transmitting 4.9 cd/m² and a powerless blue filter over the right eye transmitting 1.9 cd/m²) modified with lens wells to hold loose trial lenses in front of each filter (Thompson and Yudcovitch, 1996). These spectacles were used from the beginning of the training session through the end of the testing battery. Room luminance throughout the experiment was approximately 2.0 cd/m².

As our study was a continuation of a previous experiment by Thompson and Yudcovitch (1996), our method of testing stereomobilization utilized the same computer program. It began with a uniform pink screen that when observed through the red and blue filters produced a lustrous background. The program would then flash the word "Ready" for 1 second, followed immediately by a fixation cross to direct the subjects' gaze to the location of the target presentation. The fixation cross was located at the center of the upcoming target area. After a 0.125 second pause, the testing target of four rings was presented in a diamond formation, subtending 5 degrees at the test distance (Thompson and Yudcovitch, 1996). In each presentation, the subject observed four rings, one of which appeared to have depth cues, or "float". Three of the rings were solid black while one of the rings provided crossed-disparity information by presenting laterally overlapping red and blue rings separated by 75 arc sec at the one meter test distance. A programmed random number generator determined which position within the target configuration would present with the stereo ring. Following the target presentation, the screen returned to the blank pink background. Subjects were then shown four larger circles in the same configuration as the test target. The duration period of these larger circles was indefinite; they remained on the screen until the subject had used the computer mouse to select the one circle that corresponded to the test ring perceived to "float". Subjects were able to pause at any time during the testing session. Subjects were instructed to respond to the target demonstrating relative depth and were encouraged to guess if they were uncertain which ring had the depth cues. After selection, the "Ready" prompt was again shown to begin the next target presentation sequence. Subjects
were instructed to keep body movements to a minimum throughout the testing period.

Since our testing was designed to assess stereomobilization ability in relation to anisometropia, presentation times of the targets were progressively decreased within each situation of increased artificial anisometropia. To assure understanding of the testing paradigm, subjects were required to complete a training sequence prior to testing. Training was conducted through plano lenses over both eyes and subjects were shown each of the five presentation times twice. Presentation times consisted of 5000, 1000, 250, 62 and 15 msec exposures. During the testing sequence, subjects began with plano lenses in each well of the red/blue glasses. Five presentations using each of the previously described exposure durations were completed. All testing began with the longest exposure (5000 msec) and stepped down to the shortest exposure time of 15 msec. Following the plano testing, anisometropia was artificially introduced by using convex trial lenses over the right eye in the powers of +0.75D, +1.25D, and +1.75D sequentially. For each of the induced levels of anisometropia, the subject was presented with 5 trials for each of the same time periods listed above, for a total of 10 training and 100 testing presentations.

Previous studies have found that there is no improvement in stereomobilization with practice (Uttal et al, 1994). Therefore, we allowed our subjects an orientation period to the increasing anisometropic conditions by allowing them to view the 5000 msec target. Data from the 5000 msec presentation was not included as part of the analysis. When experimental protocol required a new convex lens, it was introduced in the 5000 msec buffer period as exposure times recycled from 15 msec back to 5000 msec.

RESULTS:

Figure 1 shows the effect of decreased exposure time within each of the artificially induced anisometropic conditions. Mean percent correct for each of the 37 subjects were plotted. Data from the plano group is similar to the results gained from the Temporal Effects on Stereoacuity study by Thompson and Yudcovitch (1996). Comparing the common time durations presented between
the two studies (1000, 250 and 62 msec), we found no statistical difference
(p>0.05) between the compared data from the two studies (Table 1).

Table 1: Comparison of common data values between Temporal Effects on Stereoscopic
study (Thompson and Yudcovitch) and Effects of Artificially Induced Anisometropia
on Stereomobilization study (Chretien and Lindberg). Unpaired t-test, 2-tailed.

<table>
<thead>
<tr>
<th>Time of Presentation (msec)</th>
<th>Thompson and Yudcovitch (% correct)</th>
<th>Chretien and Lindberg (% correct)</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>80.65</td>
<td>83.24</td>
<td>p=0.6358</td>
</tr>
<tr>
<td>250</td>
<td>65.57</td>
<td>60.54</td>
<td>p=0.4535</td>
</tr>
<tr>
<td>62</td>
<td>50.33</td>
<td>44.87</td>
<td>p=0.3901</td>
</tr>
</tbody>
</table>

Analysis of variance (ANOVA) for repeated measures with post-hoc Scheffe F-
test was used for statistical comparison within each of the anisometropic
conditions. Significant differences (p<0.05) were found between all times in the
plano category (Figure 1) except for the 62 and 15 msec time presentations.

Within the 0.75 D anisometropic condition, subjects responded with a mean of
60 percent correct to the 1000 msec exposure. Compared to the plano group,
there was a paralleled decline in mean response correct over the presented
times. Significant differences were only detected between the 1000 and 250
msec, 1000 and 62 msec, and the 1000 to 15 msec comparisons. All other
comparisons showed non-significant differences.

Within the 1.25 D anisometropic condition, the subjects responded with a mean
of 43 percent correct for the 1000 msec time presentation and again showed a
decline in mean response correct over the remaining time presentations.
Significant differences were only revealed between the 1000 and 62 msec and
the 1000 to 15 msec exposure comparisons. All other comparisons showed
non-significant differences.

Subject responses to the 1.75 D anisometropic condition had no significant
differences between any of the exposure times and a mean percent correct
approximately equal to that of chance (≈25%).
Figure 1: Mean percent correct stereomobilization response ± 1 S.E. for a 75° stereo target for each anisometropic condition under decreasing exposure durations.

Figure 1 also illustrates the effect of increased anisometropia between each of the exposure periods tested. Significant differences (ANOVA, p<0.05; post hoc Scheffe F-test) were found between all of the anisometropic conditions for the 1000 msec presentation.

Significant differences for the 250 msec exposure times occurred only between the plano and 0.75 D, plano and 1.25 and the plano to 1.75 D comparisons. All other comparisons for the 250 msec data showed non-significant differences.

Significant differences for the 62 msec exposure times occurred only between the plano and 1.25 D and the plano to 1.75 D comparisons, while all other comparisons in this category showed non-significant differences.

The only significant difference between the anisometropic conditions for the 15 msec exposure data was between the plano and 1.75 D comparison; all others were not significant.
Table 2 shows the average stereomobilization values obtained at each of the combined exposure durations and anisometropic conditions for all subjects tested. Mean correct values, out of five presentations, and standard errors are reported for each of the conditions. For each of the anisometropic conditions within the examined time periods, the subjects' responses can be seen to be hierarchically arranged. Each increased anisometropic condition produces a reduced mean correct stereomobilization response within each time duration.

Table 2: Mean number and percent correct (out of 5 presentations) and standard errors for a 75° stereo target under decreasing exposure durations and increasing anisometropic conditions.

<table>
<thead>
<tr>
<th>Exposure duration/Anisometropia</th>
<th>Mean number correct (S.E.)</th>
<th>Mean percent correct (S.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 msec</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plano</td>
<td>4.16 (0.22)</td>
<td>83.24 (4.41)</td>
</tr>
<tr>
<td>0.75 D</td>
<td>3.00 (0.23)</td>
<td>60.00 (4.59)</td>
</tr>
<tr>
<td>1.25 D</td>
<td>2.16 (0.23)</td>
<td>43.24 (4.68)</td>
</tr>
<tr>
<td>1.75 D</td>
<td>1.30 (0.20)</td>
<td>25.95 (4.02)</td>
</tr>
<tr>
<td>250 msec</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plano</td>
<td>3.03 (0.26)</td>
<td>60.54 (5.11)</td>
</tr>
<tr>
<td>0.75 D</td>
<td>1.95 (0.28)</td>
<td>38.92 (5.64)</td>
</tr>
<tr>
<td>1.25 D</td>
<td>1.54 (0.21)</td>
<td>30.81 (4.14)</td>
</tr>
<tr>
<td>1.75 D</td>
<td>1.41 (0.21)</td>
<td>26.11 (4.13)</td>
</tr>
<tr>
<td>62 msec</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plano</td>
<td>2.24 (0.26)</td>
<td>44.87 (5.28)</td>
</tr>
<tr>
<td>0.75 D</td>
<td>1.68 (0.22)</td>
<td>34.05 (4.38)</td>
</tr>
<tr>
<td>1.25 D</td>
<td>1.35 (0.19)</td>
<td>27.03 (3.81)</td>
</tr>
<tr>
<td>1.75 D</td>
<td>1.35 (0.17)</td>
<td>27.03 (3.49)</td>
</tr>
<tr>
<td>15 msec</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plano</td>
<td>1.92 (0.18)</td>
<td>38.38 (3.66)</td>
</tr>
<tr>
<td>0.75 D</td>
<td>1.46 (0.19)</td>
<td>29.19 (3.84)</td>
</tr>
<tr>
<td>1.25 D</td>
<td>1.43 (0.23)</td>
<td>28.65 (4.55)</td>
</tr>
<tr>
<td>1.75 D</td>
<td>1.16 (0.18)</td>
<td>23.24 (3.68)</td>
</tr>
</tbody>
</table>

DISCUSSION:

The results gained from this experiment closely paralleled those previously found by Thompson and Yudcovitch (1996). Considering their normative study as the standard for stereomobilization ability under tachistoscopic presentations, it was found that over the common time durations tested in their study and the plano group of our study, there was no significant difference (p>0.05) between any of the data (Table 1). This comparison of data proves the repeatability of the data gathered by the previous researchers. Credibility to the normalized data set as well as this method for testing stereomobilization ability are also achieved from this result.
Studies by McGill and Erickson (1988), document that in the presence of anisometropia or monocular blur, there is a reduction in a subject's stereopsis ability. Our results confirmed this finding over each of the exposure durations tested by detecting a decline in the percent correct with increased anisometropia (Figure 1). Our original hypothesis of a significant difference in the stereomobilization value between each of the anisometropic groups was confirmed only at the longest exposure period of 1000 msec. With each of the subsequent faster exposure periods the only group that was significantly different at all exposure durations was the plano condition; there was no statistical difference between any of the anisometropic conditions at the faster time durations. Performance for higher amounts of anisometropia at faster times were not significantly different due to the fact that binocular function was compromised under these conditions.

The introduction of anisometropia with decreasing temporal duration also resulted in the production of a family of stereomobilization curves, each demonstrating a similar reduction compared to the curve immediately before it (Figure 1). This outcome partially confirmed our second hypothesis of having a significant difference between the anisometropic stereomobilization values for each of the time presentations. Considering the plano group as the standard of comparison for this study, there was no statistical difference between the 62 and 15 msec presentations. Each additional increase in anisometropia resulted in an increase in the number of non-statistically different data points; to the maximum of no statistical difference between any of the time presentations for the 1.75 D data. Considering there were four target locations to choose from, the flat slope of the 1.75 D plot can be interpreted as the subjects guessing and therefore achieving the chance average of 25% correct.

These results imply that the stereomobilization ability of a subject viewing a target for 1000 msec under 1.75 D of anisometropia is equivalent to a subject viewing a target for 15 msec under 0.75 D of anisometropia (Figure 1, Table 2). Thus, a person under higher levels of anisometropia must view a target for a longer period of time to get the same information that a person under minimal levels of anisometropia can achieve in a smaller period of time. It must be noted that for the two longer time intervals, the plano condition was always significantly better than any of the anisometropic conditions. For the two shorter
time intervals, the plano group was significantly different only from the largest anisometropic conditions. (Figure 1).

Since depth perception at distances greater than twenty feet is primarily based on cues like shadows, texture and motion parallax, stereopsis is not as important at these distances to perceive depth (Josephson et al, 1991). Yet for small, high velocity targets at distances greater than twenty feet, binocular depth ability is still very important (Regan and Beverley, 1979). Monovision patients are at a serious disadvantage; not only is their ability to perceive stereopsis impaired, but so is their ability to perceive it quickly. This type of split-second decision making likely occurs at the subconscious level and becomes of vital importance when rapid depth perception is necessary. Examples of such split-second decisions occur regularly in daily activities such as driving, sports and occupational situations.

Most new monovision patients require an adaptation period to acclimate to their altered visual world. During adaptation they may experience hazy vision and an occasional loss of balance (Josephson et al, 1991). A suggested adaptation period of two to three weeks has been implied by some authors (Sheedy et al, 1988), but in reality practitioners have no clinically objective tests to confirm if a monovision patient has adapted and is thus at risk for injury. Erickson and McGill (1992) have suggested that it is unlikely binocular visual acuity or stereoacuity improves with monovision adaptation, but rather there is an improvement in blur suppression and interpretation. Assuming stereomobilization is a more sensitive indicator of decreased visual ability than stereoacuity, it may be useful to the practitioner when using monovision contact lens fits. Performance changes could possibly be assessed with before, after, and follow-up stereomobilization measurements to identify patients who have not acclimated to the blur suppression required in monovision.

Uttal et al (1994) suggests that there is no minimum stimulus duration required for stereopsis as long as an appropriate fixation and convergence point has be established prior to stimulus exposure. Their findings indicate that exposures as brief as < 1 msec are enough to elicit a stereopsis response, while the perceptual processing time required to process the stereoscopic impression is significantly longer. Our plano condition findings at the 15 msec presentation
did not reach the chance level of stereomobilization (Figure 1). Further studies using this experimental protocol may wish to explore the stimulus durations used by Uttal et al (1994) to find the true boundary of the visual system under these circumstances. As a casual observation, we noticed many of our subjects complained about the difficulty of this study's task. Fatigue was noticeable and subject's attention may have faltered somewhat with the shorter exposures. Furthermore, if this study were to be repeated, the computer program should be changed to allow randomized presentation times. By doing this, subject attention throughout the experiment would likely be increased.

Many strategies for monovision include the determination of the dominant eye to be corrected with the distance lens, others have not found a correlation between sighting dominance and binocular visual acuity (Josephson et al, 1991). During our experiment, all induced anisometropia was in the form of loose trial lenses inserted into wells attached to the front of the anaglyphic glasses. In each incidence, the addition of plus lenses were to the right eye only. Further studies may wish to change our experimental design with the application of anisometropia to the non-dominant eye. One would expect a positive effect on the comfort and adaptation of the subjects through this change, yet an improvement in results would not likely follow since a patient still has to interpret the blur no matter which eye the anisometropia is placed on.

Testing with the use of trial lenses allowed for the necessary anisometropia but also induced aniseikonia at the same time. While our study did not test performance with adds as high as +2.75 D, Josephson et al (1991) reports that with anisometropia of that magnitude, aniseikonia in spectacles is approximately 6%. Yet if that same monovision correction is in the form of contact lenses, induced aniseikonia is only 0.5%. The approximate levels of aniseikonia used in our study were 1.0%, 2.0% and 2.8% for the 0.75 D, 1.25 D and 1.75 D anisometropic conditions respectively. Thus, the monocular size difference between the two eyes may have been another factor to hinder testing performance.

Additionally, Beddow, et al (1966) noted stereoacuity reductions found with contact lens induced anisometropia were less than those with anisometropia induced by spectacles. Another aspect of spectacle use for testing purposes is
the possibility of spectacle awareness with habitual contact lens wearers. Although Thompson and Yudcovitch (1996) found no significant difference between habitual correction modalities it may be arguable that in contact lens subjects, performance during testing could have been reduced due to the noticeable peripheral field restrictions while wearing spectacles. Further studies may wish to induce anisometropia through the use of contact lenses to minimize field restriction, stereoacuity losses, and aniseikonic effects.

CONCLUSIONS:

Several statements can be made as a result of this study. First, the normative data presented by Thompson and Yudcovitch (1996) was reaffirmed. Credibility to the normalized data set as well as this method for testing stereomobilization ability were achieved. Secondly, patients wearing higher levels of anisometropia must view targets for significantly longer periods of time to gain the same stereoscopic information that a person with lower levels of anisometropia can achieve in a fraction of the time. Also, this methodology of measuring stereomobilization may be useful as a technique to reveal when a monovision candidate has acclimated to their new perceptual world. Finally, further studies exploring stereomobilization should present exposure durations faster than 15 msec to discover the physiological endpoints of stereomobilization ability. Modifications of the experimental protocol may include randomizing the presentation of exposure times, applying anisometropia to the non-dominant eye, and the use of contact lenses to minimize aniseikonic differences.
REFERENCES:


