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Abstract

The visual function of stereomobilization relates to the effects that temporal information has on the ability to detect stereopsis and perceive depth. In order to validate performance norms of stereomobilization found in prior research, a computer program generated on the ·Macintosh color computer was utilized to determine the effects of varying exposure durations on the ability to perceive stereopsis. Forty-four subjects were tested for stereomobilization. Findings were statistically similar to the studies of Thompson and Yudcovitch (1996) and Chretien and Lindberg (1997) at a gross target disparity value of 450 arc seconds. Although normative values were significantly different between the three studies for the fine disparity target measurements (75 arc seconds), performance patterns for all the studies showed a consistent decrease in stereomobilization performance with a decrease in target exposure duration. At exposure durations of 0.125 seconds and below, for both gross and fine disparities, a threshold level for stereomobilization performance was achieved.

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REASSESSMENT OF THE MACINTOSH STEREOMOBILIZATION TESTING SYSTEM ON NORMAL ADULT SUBJECTS

BY

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ABSTRACT

The visual function of stereomobilization relates to the effects that temporal information has on the ability to detect stereopsis and perceive depth. In order to validate performance norms of stereomobilization found in prior research, a computer program generated on the Macintosh color computer was utilized to determine the effects of varying exposure durations on the ability to perceive stereopsis. Forty-four subjects were tested for stereomobilization. Findings were statistically similar to the studies of Thompson and Yudcovitch (1996) and Chretien and Lindberg (1997) at a gross target disparity value of 450 arc seconds. Although normative values were significantly different between the three studies for the fine disparity target measurements (75 arc seconds), performance patterns for all the studies showed a consistent decrease in stereomobilization performance with a decrease in target exposure duration. At exposure durations of 0.125 seconds and below, for both gross and fine disparities, a threshold level for stereomobilization performance was achieved.

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INTRODUCTION

The quality of efficient binocular vision is improved by the awareness of three-dimensional vision, known as stereopsis. The ability to quickly perceive stereopsis under dynamic conditions is commonly present in daily life and is referred to as stereomobilization. To test the awareness and accuracy of stereomobilization a Macintosh computer program was developed by Leroy and Kohl at Pacific University. The computer program presents random anaglyphic stereo targets at various time intervals to be identified by the patient in the assessment or training of stereopsis.

Previous studies [Thompson and Yudcovitch (1996) and Chretien and Lindberg (1997)], utilizing the computer stereomobilization program, have shown that the exposure duration of a stereo target significantly affects the viewer's sensitivity to that target. It was also shown in both studies that decreased exposure time resulted in decreased performance. Both of the previously mentioned studies were compared to a 1975 study by Uttal et al which reported a definite decline in performance as disparity and time intervals were decreased. The latest study by Uttal et al (1994) found no definite stereomobilization endpoint time, which agrees with the 1996 stereomobilization study of Thompson and Yudcovitch (1996).

The study by Thompson and Yudcovitch (1996) provided initial normative stereomobilization values for the 20-40 year old population as a baseline for clinical comparison. The goal of this follow-up project is to validate performance norms of stereomobilization found by the previous study of Thompson and Yudcovitch (1996), by testing stereomobilization of fine and gross disparity targets at both similar and shorter time intervals. All data from the current study is also compared with the corresponding exposure times of fine and gross disparity targets on patients wearing their habitual correction only (plano, with no induced anisometropia) from the Chretien and Lindberg study (1997). An additional goal of the study is to see if a threshold for stereomobilization can be determined by utilizing shorter time intervals. The potential benefits for the information found include use in vision therapy and vision enhancement, along with occupational and avocational applications.

SUBJECTS

The subjects for the study were comprised of 44 students from Pacific University College of Optometry. The majority (95%) of the subjects were from the first year class, with all subjects having a pre-requisite of no prior experience with previous stereo mobilization testing studies. The subjects ranged from 21 to 43 years of age. All of the potential subjects were required to read and sign an informed consent form, approved by the Institutional Review Board, which described the project and procedures. A screening examination was then performed, consisting of a case history, near habitual visual acuity, and the Stereo-Butterfly 4-Ball Stereogram test for binocular vision. Those subjects with 20/20 near vision at 40 cm and 100 arc min. on the stereo test, were allowed to continue with the training and testing procedures.

METHODS

Experimentation was conducted on the 44 subjects with passing criteria. Room illuminance was kept at 2.5 lux. Subjects were seated at a one meter testing distance from a Macintosh Centrus computer. The 16-inch color monitor emitted 19.6 cd/m^2 of luminance. The screen was of a uniform pink which appeared as a lustrous background to the patients wearing powerless red-blue acetate glasses. The red filter was placed over the left eye and had a transmission of 28.06%. That of the blue filter over the right eye had a transmission of 0.08%.

In order to allow for comparison to the data found by Thompson and Yudcovitch (1996), the same computer program was utilized under similar protocol. Target exposure for each presentation consisted of four rings in a diamond pattern (up, down, left, and right). Three of the rings were black, whereas one of the rings possessed a crossed disparity by presenting laterally overlapping red and blue rings separated by either 450 arc seconds gross disparity or 75 arc seconds fine disparity to provide stereo information. The presentation, in sequence, consisted of: 1) "Ready" prompt for 1 second, 2) centered fixation cross relative to the upcoming target presentation, 3) bare pink screen, 4) target exposure, 5) bare pink screen, and 6) selection rings. Each target exposure of the rings was done at varying times. At this point the subject was to decipher which ring was perceived to "float" towards them (crossed disparity). When the larger selection rings were shown, subjects used this screen as an answer key by making a selection with the computer mouse on the selection ring perceived to contain the disparity . After selection, the "Ready" prompt was again shown to prepare the subject for the next target presentation.

The training sequence involved a single target exposure at each time interval for both the gross and the fine disparity. No performance requirement from the training sequence was needed to advance to the testing sequence. Testing protocol consisted of five trials for each of the six varying exposure times: 1.000, 0.500, 0.250, 0.125, 0.0625, and 0.031 seconds. This procedure was done at both gross and fine disparity values for a total of 60 presentations in the testing regimen. The computer calculated and displayed the number correct out of the 5 trials for each exposure time. This differed from Thompson and Yudcovitch (1996) both in some of the time intervals chosen and the number of trials (they used 10 trials per time interval), as well as an altered training session.

If necessary, subjects were allowed to pause during the training or testing sequence by waiting to choose a selection ring until ready to proceed (the computer remains idle until this option is selected). Guessing was allowed throughout the training or testing process if the depth cue was not obviously perceived.

RESULTS

Figure 1 presents the average number correct versus exposure duration for the 450 arc second target. Note the decreased performance and eventual plateau of accurate use of stereo ability as the duration time of the stimuli are decreased. Analysis of variance (ANOVA) for repeated measures designs with post-hoc Scheffe F-test was used for statistical comparison of the subjects results at the various time intervals. Significant differences are found between exposure times not immediately longer or shorter in duration from one another. The only times that do show a significant difference at the next time interval are the 0.250 second and 0.125 second intervals. The shortest three time intervals, from 0.125 seconds to 0.031 seconds, showed no significant difference when compared, producing a plateau performance curve.

Figure 2 shows the decrease of accurate detection of stereomobilization as the duration time of exposure is again decreased, using the same time intervals as with the 450 arc second, gross disparity target. The information obtained from the presentations of the 75 arc second fine disparity target is plotted as the average number correct from all of the 44 subjects. The overall curve for the fine disparity stereo target is reduced in amplitude compared to the mean percentage correct for the gross disparity target. Again, this indicates a decreased ability by the subjects to correctly identify stereo targets as exposure time is decreased and the disparity is made finer. A significant difference is found between exposure times not immediately longer or shorter in duration from one another. Times that are at the next interval to one another and do show a significant difference are again 0.250 seconds and 0.125 seconds. Again, the time intervals of 0.125 seconds and 0.031 seconds show no significant difference when compared, indicating a plateau effect.

An increased difficulty in correctly identifying a finer disparity target versus a grosser disparity target is evident. Using a paired t-test, significant differences ($p<.05$) are found between the gross and fine disparities at the same time interval for all time intervals.

Figure 3 graphically shows the comparison of stereomobilization ability using the gross disparity (450 arc seconds) targets between this study and the study by Thompson and Yudcovitch (1996). Overall, this study shows subjects performing at levels slightly below the subjects in the Thompson and Yudcovitch study (1996). Table 1 illustrates the mean percent correct for each time interval from each study. Comparing the common time durations presented between the two studies (1.000, 0.500, 0.250, 0.125, 0.062 seconds), we found no statistical difference ($p<0.05$) between the compared data from the two studies (see Table 1).

Table 1: Mean percent correct at each decreased exposure time interval for a 450 arc second stereo target.
<u>Study 1</u>= Thompson/Yudcovitch
<u>Study 2</u>= Jahner/Moffit

Exposure duration	Mean Percent Correct (Study 1)	Mean Percent Correct (Study 2)	P-value
2.00 sec	88.82	-	-
1.00 sec	86.72	82.28	p=.3763
.500 sec	81.64	77.72	p=.4429
.250 sec	73.44	70.90	p=.7293
.125 sec	66.39	55.90	p=.1253
.062 sec	57.88	53.64	p=.4915
.031 sec	-	49.54	-

(-) = not tested

Figure 4 graphically illustrates the comparison of stereomobilization ability using the finer disparity (75 arc seconds) targets between Thompson and Yudcovitch (1996), Chretien and Lindberg (1997), and our data. When comparing the results of each study at similar time intervals, the current study shows significantly poorer results at each time interval, with a non-linear curve that dramatically decreases at shorter stimuli exposure times. Table 2 presents the mean percentage correct from each time interval in each study, this is also illustrated in Figure 4. Each decreased exposure time shows a decreased percent of correctly identified stereo targets (see Table 2).

Table 2: Mean percent correct at each decreased exposure time interval for a 75 arc second stereo target.
Study 1=Thompson/Yudcovitch
Study 2=Jahner/Moffit
Study 3= Chretien/Lindberg

Exposure duration	Mean percent correct (Study 1)	Mean percent correct (Study 2)	Mean percent correct (Study 3)	P-value (Comparing Study 2 to Study 1&3)
2.00 sec	84.75	-	-	-
1.00 sec	80.66	51.36	83.20	$p<.0001$
0.500 sec	73.11	52.72	-	$p<.0001$
0.250 sec	65.57	47.28	60.60	$p<.0001$
0.125 sec	58.69	29.54	-	$p<.0001$
0.062 sec	50.33	30.46	44.80	$p<.0001$
0.031 sec	-	27.72	-	$p<.0001$
0.015 sec	-	-	38.40	-

(-) = not tested

DISCUSSION

Previous research on the topic of stereomobilization has not produced a point where stereomobilization ability levels off. This study found stereomobilization performance reaching a chance or guessing level from 0.125 seconds and faster for both the gross and fine disparities. One Factor ANOVA-Repeated measures showed no significant difference for stereomobilization abilities between the exposure durations of 0.125 seconds, 0.062 seconds, and 0.031 seconds for both gross and fine disparities. This indicates that when stereoscopic targets are exposed for 0.125 seconds or less, accurate detection is conditional on the probability of chance.

Various studies reporting on the speed of stereoscopic perception have all concluded that the amount of exposure time has a direct impact on this visual function. The three studies executed at Pacific University College of Optometry confirmed that the ability to use stereo cues is less efficient when the duration of the stimulus is reduced. Results comparing the same timed trials of equal disparities revealed statistical similarities. There was no significant difference ($p>0.05$) between the study by Thompson and Yudcovitch (1996) and the current study for the gross stereo disparity chosen. This support and confirms the data and repeatability of the testing procedure. The data for the fine disparity stereo target does in fact show significant differences ($p< 0.05$) between the current study and that of Thompson and Yudcovitch (1996) and Chretien and Lindberg (1997), while the two latter studies do not show significant differences between each another.

Why the lowered performance for fine disparity target in our study when compared to the two earlier studies? The study by Thompson and Yudcovitch (1996) presented 132 target exposures to each subject, including training and testing protocol, and that of Chretien and Lindberg (1997) presented 90 exposures to each subject. This study presented 72 presentations to each subject. The reduced amount of target exposures may have eliminated some subject fatigue as discussed in the previous studies, but may have also been responsible for lowered performance due to the reduced learning effect potential. The number or trials experienced by each subject prior to viewing the fine disparity targets was significantly greater for the previous two studies.

Another factor which may have resulted in lowered performance in our study was the stereo acuity criteria chosen prior to testing. All three studies used a different method for measuring stereoacuity for this purpose. This study and that by Chretien and Lindberg (1997) used different stereo tests and different stereo acuity requirements, while the study by Thompson and Yudcovitch (1996) used the training session on the computer program itself for the study entrance criteria. A measurement of stereoacuity on one test is not indicative of the stereoacuity found on a different test. Thus the different stereoacuity criteria used may have provided different binocular ability populations to each study.

Regardless of slight variations in experimental conditions, a consistent pattern has been established through the three studies compared: accuracy of stereo ability is reduced with decreased exposure durations of a stereo target. This re-evaluation of stereomobilization norms has validated the repeatability of the computer program used and corroborated the fact that stereoacuity is dependent on the duration of stimuli presentation displayed and stereo disparity of the target. The knowledge that stereo accuracy decreases with limited viewing time was also reported by Laby et al (1996). This specific study measured distance stereoacuity, both with contoured and random dot targets, on professional baseball players. The results showed a decrease in accuracy by 15 to 30% when comparing timed to untimed conditions.

Normative data of stereomobilization for the purpose of clinical application and comparison has been provided by this and previous studies. The ability to detect fine differences in depth between two objects using both eyes together is dependent on the duration of stimulus exposure. This plays an important role in everyday performance, such as driving a motor vehicle or sports and recreational activities. The speed with which one reacts to stereoscopic information in the environment can affect the outcome of visual information processing. Future studies should assess whether performance on stereomobilization tasks truly is predictive of performance of these "real life tasks".

Figure 1: Mean No. Stereo Correct vs. Time for 450 arc. sec. target.

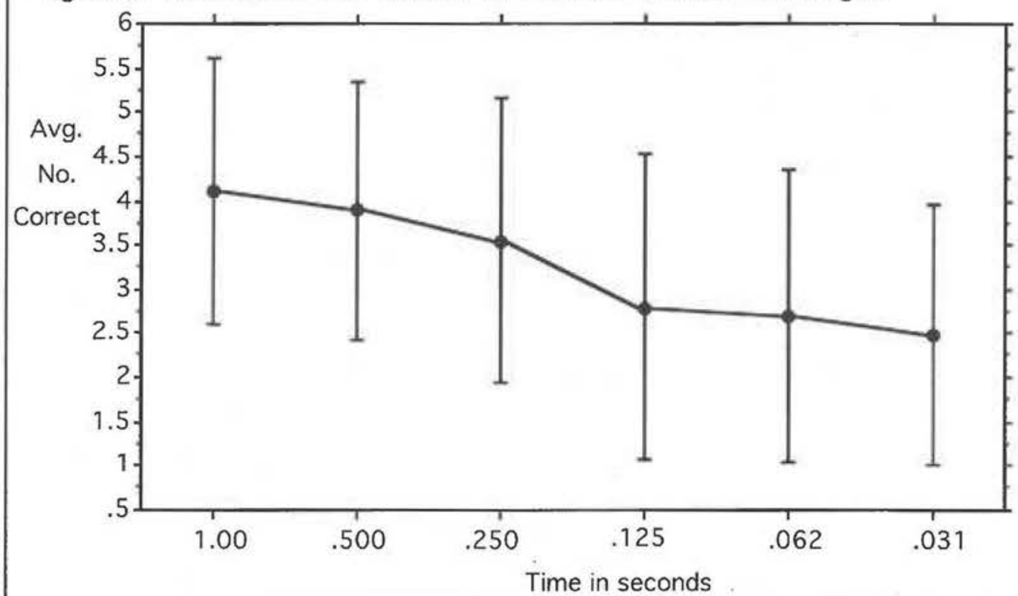
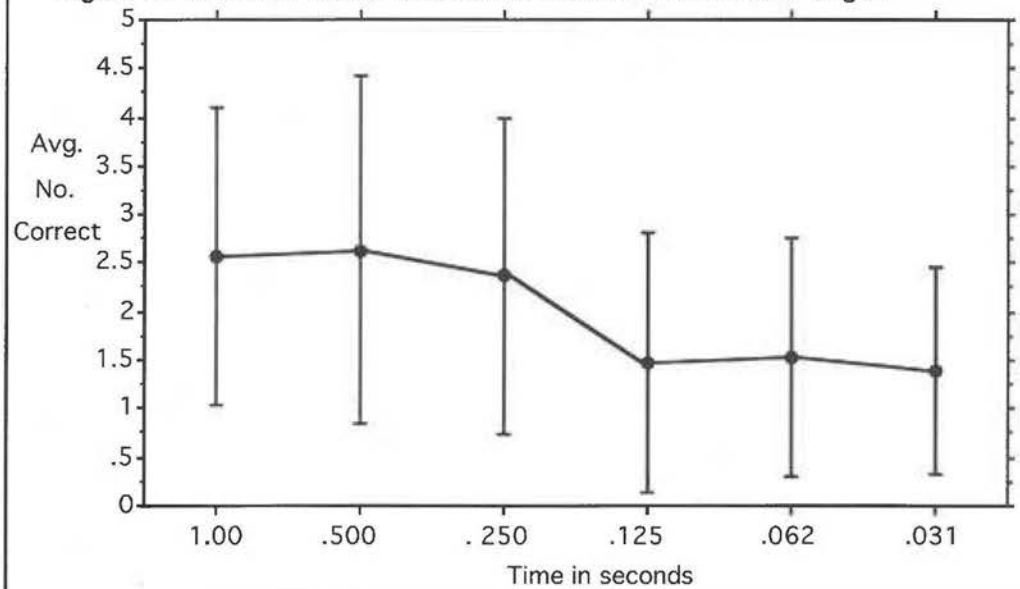


Figure 2: Mean No. Stereo Correct vs. Time for 75 arc. sec. target.



Comparison of Gross Stereomobilization

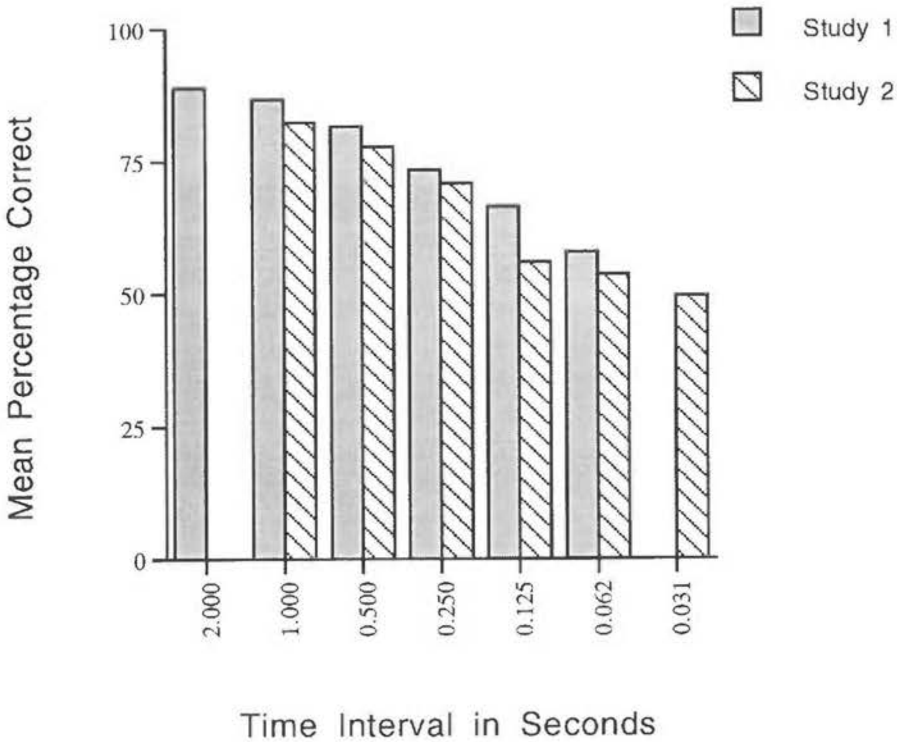


Figure 3: Study 1- Thompson/Yudcovitch
Study 2- Jahner/Moffit

Comparison of Fine Disparity Stereomobilization

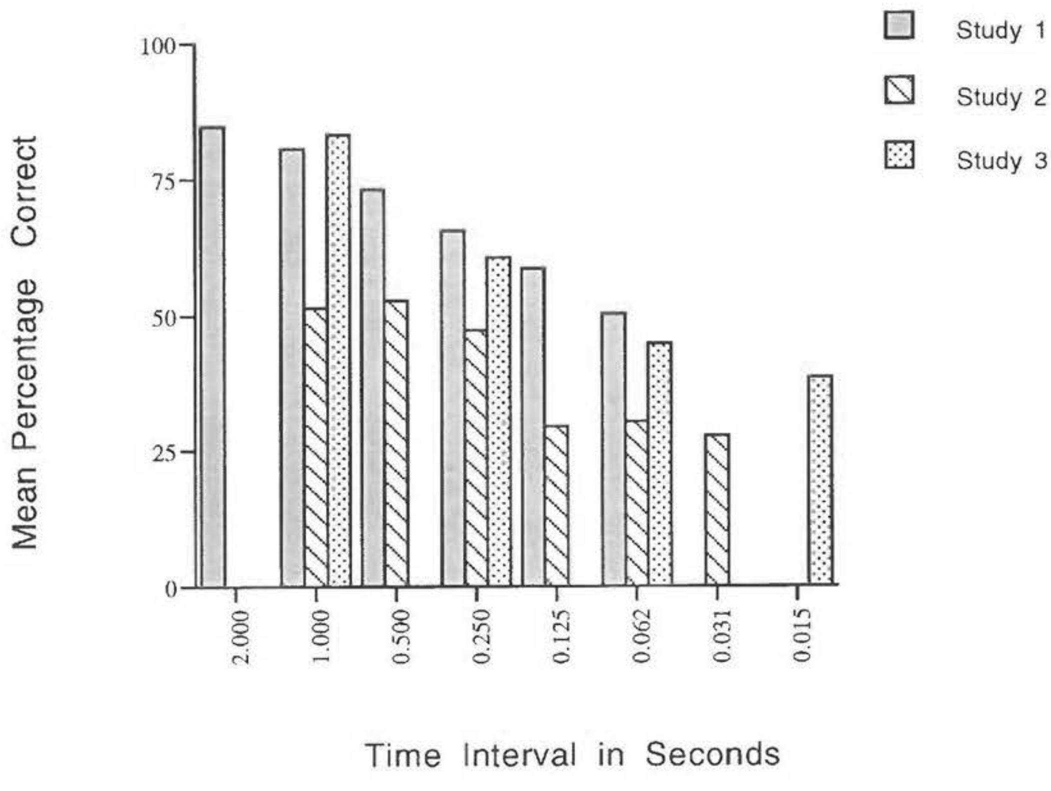


Figure 4: Study 1- Thompson/Yudcovitch
Study 2- Jahner/Moffit
Study 3- Chretien/Lindberg

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