Senior Project

An Investigation of Vergence Minification Effects on Measures of Spatial Vision

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Abstract: Under horizontal prismatic viewing conditions, the literature on macropsia/micropsia would predict altered size perceptions in normal subjects. Little data exists, however, as to the range of prism powers over which these effects occur. Moreover, it is undetermined whether these effects are constant and/or predictable across stimulus sizes and for all subjects. We set out to study the effects of a range of base in and out prisms on the apparent sizes of single vertical line (bar) and spatial gratings in a contrast sensitivity test setting at a 3 meters distance. The results suggest that 1. Minification may not be linear with prism-induced vergence in any given patient. 2. The amount of minification for a given amount of disparity vergence stimulus varies among subjects.

Methods/Materials: Patients (optometry students) were randomly selected and given instructions that they were to estimate the size of a projected vertical bar (on a screen) from a distance of 3 meters (a test of contrast sensitivity). A trial was then conducted to determine if the patients had the ability to make consistent estimations of length, and thus be a valid test subjects. Vertical bars of lengths: 7, 8, 9, 10, 11, and 12 cm. were projected on a screen, in random order, from a distance of 3m. Patients were asked to estimate the length of a vertical bar projected on a screen by making a gap between their thumb and index finger equal to the size of the bar, and the distance of the gap was then measured on a calibrated board. The calibrated board was covered so that the subject could not get any visual feedback, or make any mental notes as to the size of their estimations. The data was then calculated to see if the subjects showed the ability to distinguish between the different size vertical bars.

Patients who met the above criteria were then asked to participate in the study. The room illumination was set to a minimum—slide projector screen light and a penlight used by the test giver to read the calculated estimations, constituted all of the volume of light, i.e. no overhead lights. The subjects were instructed that similar to the trial, they were going to see a vertical bar projected on to a screen 3 meters away. A vertical bar of 10 cm in length was presented for a period of 60 seconds. The patients were asked to estimate the size of the bar and a pre-prism insertion measurement was taken from the covered calibrated board and recorded by the test administrator. The projector was advanced leaving a blank screen for the patient to view. Then a randomly selected prism of 8 prism diopters base out (8^{Δ}BO), 16^{Δ}BO, plano, or 4^{Δ}BI was placed binocularly in front of the patient via a lens flipper. The patients were not instructed or given any prior knowledge of what was being placed in front of their eyes--it was explained that lenses were going to be put in front of their eyes. The patients were also not given any information as to the size or number of test stimuli they were going to estimate. The same 10 cm bar was then projected back on the screen. The prisms were held in front of the patient's eyes for a set amount of time, 30 seconds, and a prism induced perceived size was then estimated, measured, and recorded. The projector was advanced again leaving a blank screen for the patient to view. The patient was instructed that another bar was going to be placed back on the screen and that they would once again estimate its size with their index finger and thumb and a measurement would take place—this constitutes the post-prism measurement. The patients were then instructed that they would have a new visual stimulus, and to estimate its size with their thumb and index finger. The above process was repeated with the slide projector advancing to a replica of the previous 10 cm stimulus. The contrast sensitivity data from the pre, with, and post prism measurements were calculated to see if convergence/divergence had an effect on size perception. A monocular trial was also run, as a control group, to show that the decrease in perceived size was due to micropsia and not an induced effect by virtue of having a lens flipper placed in front of the eyes. For the monocular trial the same randomized prism insertion task described above was completed with a patch over the subject's right eye. Micropsia/macropsia involves convergence/divergence of the two eyes; and therefore prism insertion under monocular conditions should not lead to any perceived minification or magnification or of objects.

Data: The test was run on five subjects (three males and two females ranging in ages from 23-26 years of age) with each subject completing the tasks 10 times. The prism power order was randomly selected prior to each testing session. The high and low measurements were thrown out for statistical analysis and an average of each pre/with/post prism insertion perceived size was tabulated. The change in perceived size from the pre-prism insertion reading to the with-prism insertion reading, and the with-prism insertion measurement and the post-prism insertion measurement were tabulated. The results, including the monocular trial, are included in figures two and three.

Discussion: Oculomotor micropsia (also known as convergence micropsia, and accommodation micropsia) is defined as an illusion of objects looking small and is caused by changes in the activity of the eye muscles, expressly the medial and lateral recti muscles. Micropsia directly relates to our investigation of vergence minification effects on measures of spatial vision. If an object of fixed linear size (e.g. the 10 cm bar of spatial frequency) is viewed at a fixed distance from the eyes (e.g. 3m) and then viewed while the eyes are converging (e.g. from binocular prism insertion) the bars constant angular size will look slightly smaller (McCready, 1965). The opposite is also true; if the eye muscles cause the eyes to diverge then the effect is increase in perceived size (macropsia). It is important to understand a few other definitions related to our investigation. The relationship from the top of the spatial frequency bar to the bottom represents the linear size. Each end of the bar (separated by 10 cm in this case) subtends an angle to the viewer's eye. i.e. the top part of the bar forms a line to the eye forming an angle with another line from the eye to the bottom part of the bar, thus representing the angular size (in degrees) (McCready, 1994). Both angular size and linear size will appear different at the same time when viewing an object during convergence or divergence (micropsia/macropsia). Therefore, when micropsia occurs the angular size perceived by the viewer is smaller as is the linear size, even though the visual stimulus remains the same size (e.g. 10 cm stimuli that is perceived as being 9.2 cm during convergence) (Joynson and Kirk, 1960).

The data obtained from our research indicated that 1. Minification may not be linear with prism-induced vergence in any given patient. 2. The amount of minification for a given amount of disparity vergence stimulus varies among subjects.

Figure 1. (Page 5) shows the actual size vs. the estimated size for the randomized trial of visual bars, with lengths of 7-12 cm. The data clearly shows that the individuals (A-E) can make a consistent estimation of size and distinguish between test sizes. Even though some test subjects viewed the stimuli as larger (or smaller) than the projected bar, they were consistent for all sizes. i.e. They perceived the smaller targets as being smaller than the other targets (which varied in length of 1-5 cm) and larger targets as being larger, all from a 3 meters distance. The graph only includes those who could make distinctions of length from the projected stimuli. Those individuals who could not differentiate were not included in the study and were thus left off the graph. There was one subject that displayed inconsistent size estimations.

Figure 2. (Page 6) displays the perceived size in cm under both monocular and binocular conditions. It shows that there is no micropsia/macropsia under monocular conditions for the prism powers (in diopters) of 4^{Δ}BI, plano, 8^{Δ}BO, and 16^{Δ}BO. The graph does display a linear relationship for perceived size under binocular conditions. The 10 cm bar appeared, to the test subjects, to be largest with the 4^{Δ}BI prism and smallest with the 16^{Δ}BO prism.

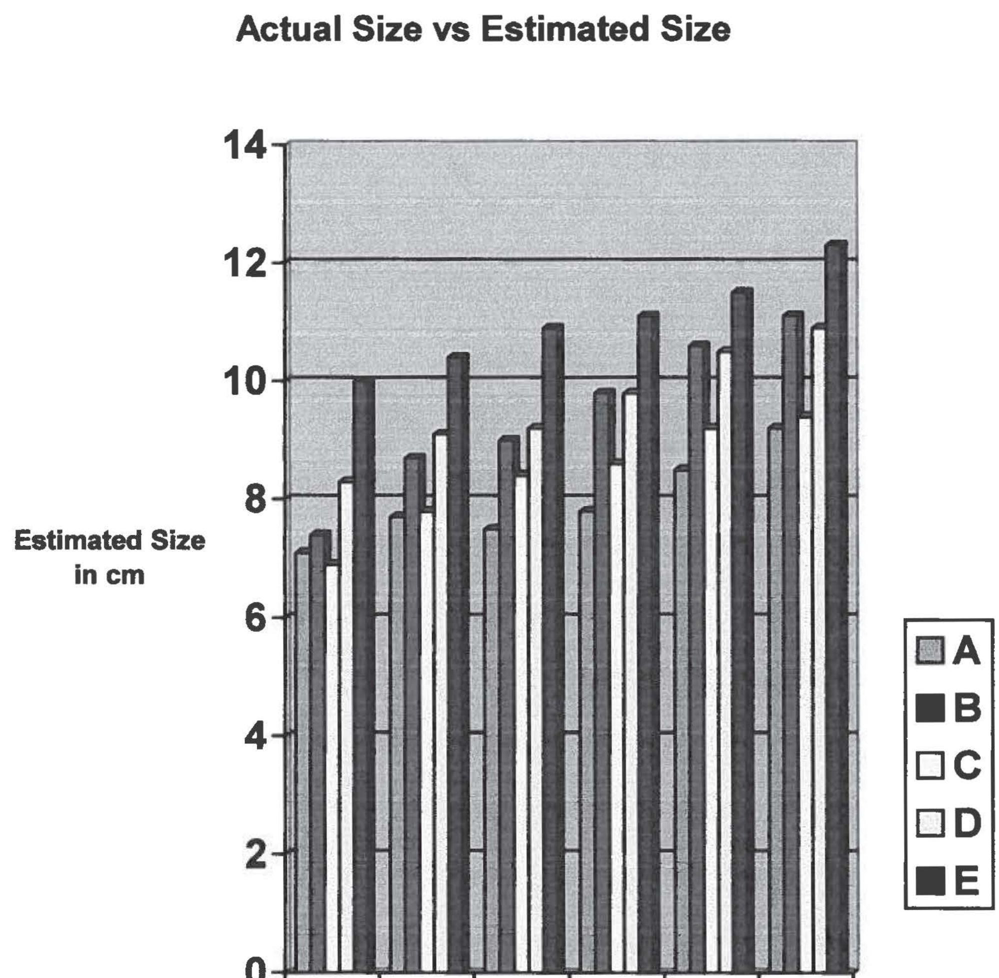
Figure 3. (Page 6) displays the perceived change in size under binocular conditions for the four prism powers. The perceived size measured previous to insertion of binocular prism insertion was recorded and then the value of the estimated size, with the prisms, was subtracted to derive the Pre-With Size. The post-prism insertion value was then subtracted from the same pre-prism insertion reading (from above) and thus the Pre-Post Size was deduced. Theoretically, the pre-prism insertion reading and the post-prism insertion reading should be equal. One reason for conducting the post-prism insertion reading was to test for hysteresis. We wondered if the effects of minification (prism induced micropsia) would linger and make the subjects perceive the post-prism insertion 10 cm bar as larger than previously estimated. The data shown in figure 3 shows that there was an insignificant amount of hysteresis in all subjects. The figures do indicate that the greatest change in perceived size occurred with the 16^{Δ}BO, and the least occurred with the 4^{Δ}BI. The 16^{Δ}BO showed an induced decrease in perceived size of approximately 6.4% while the 8^{Δ}BO showed a minification of about half that (3.4%). Base in prism did not have an equal effect (induced macropsia), as did the base out prisms. The 4^{Δ}BI demonstrated an increase in perceived size of 0.72%. This tells us that the visual system is more sensitive to micropsia than to macropsia (convergence movements/divergence movements). It indicates that macropsia is not a mirror image of micropsia. It could be deduced that macropsia is not as important to the visual system as micropsia. This would go hand in hand with the current theory for why micropsia exists. Micropsia is theorized to exist because it is part of the correcting orientation reflex of head rotation and is explained in Don McCready's article "Toward the Distance Cue Theory of Visual Angle Illusions" (1994).

It should also be noted that the 0^{Δ} (plano) lens flipper also induced micropsia. The test subjects had experienced a decrease in perceived estimated size of 1.2% with the plano lenses. Reasons for this induced micropsia could include proximal vergence, or some other form of convergence and/or accommodation. Any increase in convergence or accommodation would yield results similar to the plano prism induced micropsia.

All of the data included in figure 3 are pooled means of perceived change in size. Some individuals had a greater perceived minification than others. Therefore, it can be concluded that not all people will experience ocular motor micropsia to the same degree. The reasons for increased sensitivity, or decrease in sensitivity, to minification is unknown and calls for further research in the area of micropsia.

Conclusion: The results suggest that 1. Minification may not be linear with prism-induced vergence in any given patient. 2. The amount of minification for a given amount of disparity vergence stimulus varies among subjects. The above data implies that this phenomenon precedes the processing of visual acuity. This data has clinical implications.

Figure 1.



	7	8	9	10	11	12
A	7.1	7.7	7.5	7.8	8.5	9.2
B	7.4	8.7	9	9.8	10.6	11.1
C	6.9	7.8	8.4	8.6	9.2	9.4
D	8.3	9.1	9.2	9.8	10.5	10.9
E	10	10.4	10.9	11.1	11.5	12.3

Actual Size in cm

Figure 2

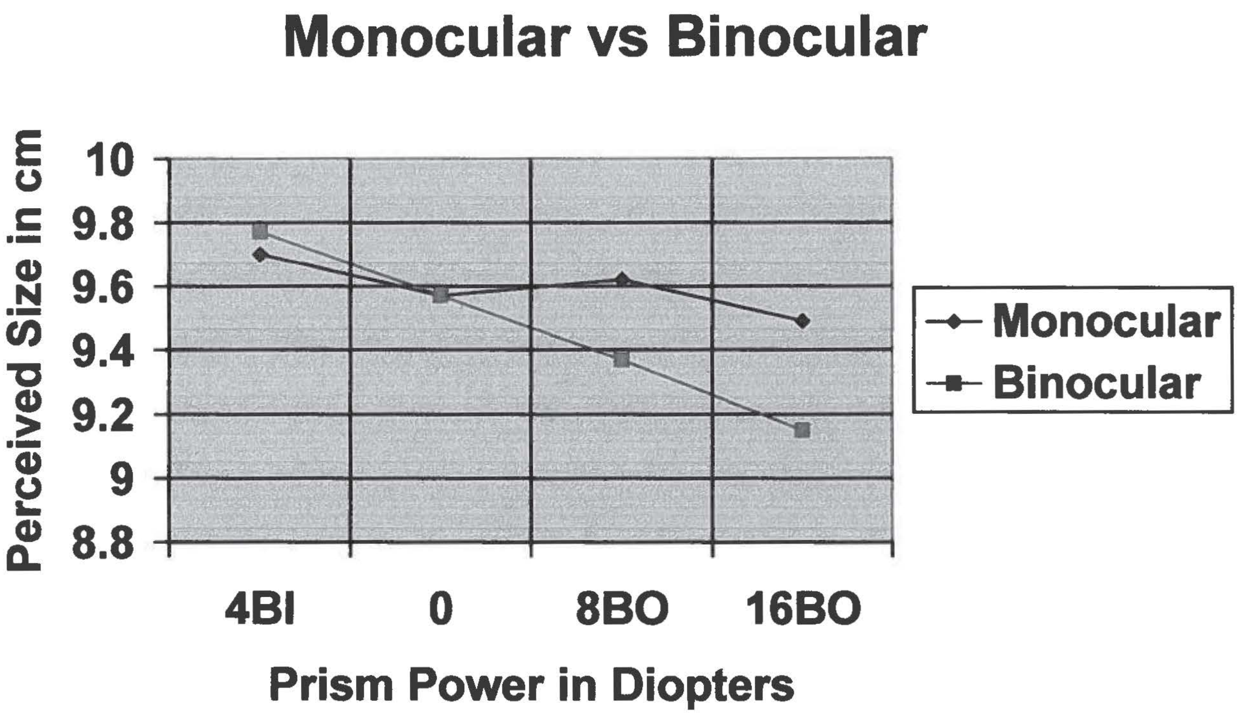
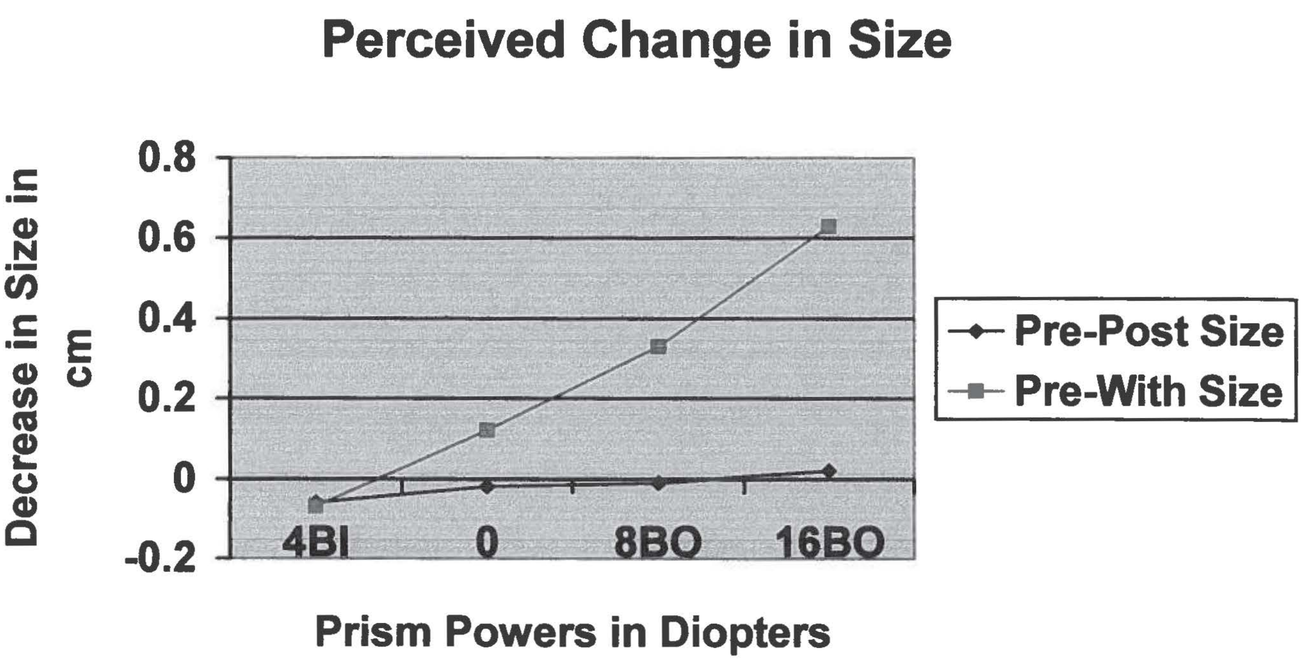


Figure 3



Bibliography

Heinemann, E. G., Tulving, E., and Nachmias, J. "The Effect of Oculomotor Adjustments on Apparent Size." *American Journal of Psychology* 72 (1959): 32-45.

Higashiyama, A. "Anisotropic Perception of Visual Angle; Implications for the Horizontal-Vertical Illusion, Overconstancy of Size, and the Moon Illusion." *Percept Psychophysics* 51.3 (1992): 218-230.

Joynson, R. B. and Kirk, N.S. "An experimental Analysis of the Associations and Gestalt accounts of the Perception of Size: Part 3." *Quarterly Journal of Experimental Psychology* 12 (1960): 221-230.

McCready, Donald. "Size-Distance Perception and Accommodation-Convergence Micropsia—A Critique." *Vision Research* 5 (1965): 189-206.

McCready, Don. "On Size, Distance, and Visual Angle Perception." *Perception & Psychophysics* 37.4 (1985): 323-334.

McCready, Don. "Moon Illusions Redescribed." *Perception & Psychophysics* 39.1 (1986): 64-72.

McCready, Don. "Toward the Distance-Cue Theory of Visual Angle Illusions." *A Perception Labs Monograph.* Professor of Psychology, University of Wisconsin (1994): 1-40.

McCready, Don. "The Moon Illusion Explained." 47 pp. Mailed to Illusion Researchers, and placed on the web site < http://facstaff.uww.edu/mccreadd/>.