Original Article

Comparison of the Effect of Different Types of Experimental Anisometropia on Stereopsis Measured with Titmus, Randot and TNO Stereotests

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Abstract

Purpose: To assess the effect of experimental anisometropia and monovision on stereopsis using the Titmus, Randot, and TNO stereoacuity tests.

Methods: Sixty adult volunteers were enrolled in the present study. Four different types of anisometropia—myopia, hyperopia, and astigmatism (both 90° and 45°)—were induced by placing trial lenses over the dominant eye (from 3 to 1 D). Stereoacuity was measured using the Titmus, Randot, and TNO tests.

Results: In all the anisometropia types, stereopsis deteriorated with increase in anisometropia in the three stereoacuity tests performed ($P < 0.001$). The largest decrease in stereopsis was attributed to 3 D myopic anisometropia—6.51 ± 2.10, 6.59 ± 2.35, and 7.36 ± 1.89 arc seconds in Titmus circles, Randot circles, and TNO, respectively. Minimal change in stereopsis was observed in 1 D astigmatism of 45°.

Conclusion: Any type of anisometropia may reduce stereoacuity; this reduction is most noticeable with myopic anisometropia, especially in the TNO test, probably due to the lack of monocular cues.

Keywords: Anisometropia; Monovision; Stereopsis

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INTRODUCTION

Stereopsis is defined as the relative ordering of visual objects in depth, that is, in the third dimension. Stereopsis occurs when horizontally disparate retinal elements are stimulated simultaneously. The fusion of such disparate images results in a single visual impression perceived in depth. Stereopsis is necessary for visuomanual coordination, and fine and precise tasks. Indeed, without stereopsis the patient may have considerable difficulty in everyday life. Stereopsis and depth perception are not equivalent. Fine stereopsis requires the formation of high quality foveal images in both eyes.[1-3]

Anisometropia may reduce stereopsis by disturbing binocularity. The precise mechanism by which anisometropia causes a decrease in stereoacuity is not clear. It has been suggested that foveal suppression in the defocused eye is the cause of decreased stereopsis.[4]

Acquired anisometropia, which leads to monovision, can be therapeutic or iatrogenic. Therapeutic anisometropia, especially for presbyopia treatment, may be accomplished with contact lenses, refractive surgery,

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or even cataract surgery. Traditionally, monovision is induced in the non-dominant eye, thereby correcting it for near vision, whereas the dominant eye remains corrected for distant vision.[5] Iatrogenic anisometropia may occur after any intraocular operations. As mentioned above, anisometropia may affect stereopsis but the problem is that there was no gold standard stereotest, and stereoacuity results would be affected by the measurement method. For instance, monocular clues give rise to false positive results in Titmus and Randot circles tests. Random dot based and TNO stereoacuity tests are not dependent on monocular clues and so false positive results can be ameliorated.[6,7] The purpose of this study was to assess the effect of experimentally induced anisometropia on stereopsis in normal individuals and comparing the results of induced anisometropia on stereopsis using three different stereotests: Titmus, Randot, and TNO.

METHODS

Sixty healthy young adults, mainly medical students, participated in this study. A complete eye examination and stereoacuity Randot testing was performed on all volunteers. Inclusion criteria were normal findings in the eye examination, uncorrected visual acuity (UCVA) of 20/20, no refractive error in either eye, normal extraocular motility, and minimum stereoacuity of 40 seconds of arc in Randot. Informed consent was obtained from all participants. The exclusion criteria of this study were history of any binocular visual disturbances such as strabismus, anisometropia, or amblyopia, history of any other significant ocular diseases or surgery, and abnormal stereopsis (worse than 40 arc seconds in Randot test).

Stereoacuity was evaluated in a silent room with sufficient light using the Titmus (animals and fly), Randot (animals and forms tests), and TNO stereoacuity tests. Stereoacuity scores were reported in seconds of arc. The Napierian logarithm (ln) of scores was considered in statistical analysis.

Anisometropia was induced by placing trial lenses in front of the dominant eye, including lenses of −1, −2, −3 D, lenses of +1, +2, +3 D, and astigmatism lenses of +1, +2, and +3 in the axes of 90 and 45 degrees; thus, each participant experienced 12 conditions of anisometropia. The ‘hole in card’ test was used to determine the dominant eye; it was agreed to consider the right eye as the dominant one if neither eye was determined by the test, but such a condition was not faced. The hole in card test is a procedure in which the subject concentrates binocularly on a distant target through a hole in the middle of a sheet. Then the subject closes each eye one by one; if the position of the image changes by closing either eye, that eye is considered dominant. In all 12 conditions, we measured stereoacuity using the above three tests. It was assumed that if the tests were used frequently, the subjects may learn the answers; hence, to avoid the bias effect of learning, we first used the lenses of higher diopters in which answer recognition would be difficult and the order of lens type (negative sphere, positive sphere, and positive cylinder in two axes) was random. Non-measurable stereopsis was recorded at 10000 seconds of arc (ln 9.2). In the stereoacuity measurement procedure, further assessment was accomplished to achieve a definite recordable response in cases of uncertain or doubtful responses. Enough resting time was given to the participants to avoid fatigue and its negative effects on the test results.

RESULTS

Sixty subjects with normal vision enrolled in this study. Mean age was 24.9 ± 2.9 (age range of 19 – 38 years). 81.57% (n = 49) had a dominant right eye and 18.33% (n = 11) had a dominant left eye. 25 (41.7%) were male and 35 (58.3%) were female.

Stereoacuity scores, as measured using the Titmus-circles, Randot-circles, and TNO tests, demonstrated that stereoacuity levels reduced in proportion to the degree of anisometropia ($P < 0.001$).

The 3 D anisometropia caused a marked reduction of stereoacuity in all subjects, regardless of stereotest type, with ln 6.51 ± 2.10, 6.59 ± 2.35, and 7.36 ± 1.89 seconds of arc in Titmus-circles, Randot-circles, and TNO, respectively. Furthermore, minimal reduction of stereoacuity was detected in 1 D astigmatism in the 45 degrees axis, with ln 3.74 ± 0.17, 3.33 ± 0.46, and 4.11 ± 0.96 seconds of arc in Titmus-circles, Randot-circles, and TNO, respectively.

Reduction of stereoacuity scores by increasing anisometropia achieved by the Titmus- animals, Titmus-fly, Randot-animals, and Randot-forms tests, was not statistically significant ($P > 0.5$).

Excellent stereoacuity scores (more than 40 seconds of arc) was obtained in 5% (3), 6.6% (4), and 3.3% (2) of the individuals on the basis of the highest anisometropia (3 D) in Titmus-circles, Randot-circles, and TNO tests, respectively.

The stereoacuity scores obtained using the Titmus circles, Randot circles, and the TNO tests are summarized in Tables 1-3.

One-way ANOVA analysis revealed that stereoacuity scores obtained using the Titmus circles, Randot circles, and the TNO stereotests were significantly different from one another ($P < 0.001$). However, stereopsis mostly reduced in the TNO test, probably due to the lack of monocular cues ($P < 0.001$).

DISCUSSION

Stereopsis is a response to disparate stimulation of the retinal elements. It is the highest form of binocular cooperation that adds a new quality to vision.[1,3]

Table 1. Scores of stereoacuity in Randot-circles

Lens Power	Mean		Median		Inter quartile range	
−1.00	3.41[1]	41*	2.99	20	0.91	30
−2.00	4.30	734	3.91	50	1.20	70
−3.00	6.42	4074	5.29	200	4.60	9930
+1.00	3.50	204	2.99	20	0.80	25
+2.00	4.58	1083	4.24	70	1.72	115
+3.00	6.59	4403	5.29	200	4.78	9915
+1.00 × 45	3.33	31	2.99	20	0.80	25
+2.00 × 45	4.16	406	4.08	60	1.38	75
+3.00 × 45	5.60	2575	4.60	100	3.35	5130
+1.00 × 90	3.46	41	3.21	25	0.91	30
+2.00 × 90	4.32	428	3.91	50	1.54	110
+3.00 × 90	5.88	2923	4.60	100	4.96	9930
Plano	3.13	24	2.99	20	0.22	5

*In each column, left and right scores represent second of arc and ln, respectively

Table 2. Scores of stereoacuity in Titmus-circles

Lens type	Mean*		Median*		Inter quartile range	
−1.00	3.82	49	3.86	40	0.11	5
−2.00	4.52	436	4.09	60	1.25	100
−3.00	6.25	3147	5.29	200	4.60	9900
+1.00	3.84	51	3.68	40	0.00	0
+2.00	4.74	640	4.09	60	1.20	120
+3.00	6.51	3645	5.99	400	4.43	9880
+1.00 × 45	3.74	43	3.86	40	0.00	0
+2.00 × 45	4.39	270	4.00	55	1.25	100
+3.00 × 45	5.46	1507	4.94	140	1.89	340
+1.00 × 90	3.78	45	3.68	40	0.00	0
+2.00 × 90	4.63	462	4.09	60	1.02	90
+3.00 × 90	5.55	1226	5.11	170	1.38	300
Plano	3.68	40	3.60	40	0.00	0

*In each column, left and right scores represent second of arc and ln, respectively

Table 3. Scores of stereoacuity in TNO

Lens type	Mean*		Median*		Inter quartile range	
−1.00	4.11[3]	241	4.09	60	1.03	60
−2.00	4.98	1263	4.78	120	1.38	180
−3.00	6.81	4288	5.82	360	4.07	9820
+1.00	4.34	416	4.09	60	1.03	75
+2.00	5.54	1804	4.78	120	2.07	420
+3.00	7.36	5143	7.69	5240	3.72	9760
+1.00 × 45	4.14	241	4.09	60	1.38	90
+2.00 × 45	5.11	1277	4.78	120	1.03	120
+3.00 × 45	6.63	3648	5.48	240	4.42	9880
+1.00 × 90	4.24	249	4.09	60	1.38	90
+2.00 × 90	5.29	1464	4.78	120	1.38	180
+3.00 × 90	6.64	3649	5.48	240	4.42	9880
Plano	3.70	210	3.40	30	0.69	30

*In each column, left and right scores represent second of arc and ln, respectively

Wheatstone, by his invention of the stereoscope in 1838, was the first to recognize that stereopsis occurs when horizontally disparate retinal elements are stimulated simultaneously. Stereopsis depends on equal visual acuity of both eyes and normal eye alignment.[1] The precise mechanism by which anisometropia causes a decrease in stereoacuity is not clear; it has been suggested that foveal suppression in the defocused eye is the cause of decreased stereopsis. Although there is no documented report of anisometropia prevalence in the general population, some studies estimated it to be at 4-4.7%.[4] Binocular vision may be experienced at lower levels of anisometropia, as Fawcett et al[8] concluded with 6 D anisometropia in their study.

In 2007, Rabaei et al[9] determined stereoacuity thresholds using the TNO test in 2343 Australian children, and indicated anisometropia as the third factor in reduced stereoacuity; amblyopia was the most common identifiable cause followed by strabismus. Presence of anisometropia was significantly associated with reduced stereoacuity. In their study, 78.6% of anisometropic children achieved normal stereoacuity versus 98.9% without anisometropia.

In 2000, Oguz and Oguz[10] determined the effect of experimentally induced anisometropia on stereopsis, by the use of the Titmus stereotest and inducing four types of anisometropia (myopia, hyperopia, and astigmatism in the axes of 90 degrees and 45 degrees) in random order, by placing trial lenses over the right eye in 21 healthy adult volunteers. They concluded that stereoacuity levels were reduced in proportion to the degree of anisometropia in all patients; 1 D of spherical anisometropia reduced stereoacuity to an average of 57-59 arc seconds while 1 D of cylindrical anisometropia reduced the stereoacuity to an average of 51-56 arc seconds. In their study, 3 D of anisometropia, regardless of type, produced a marked reduction of stereoacuity in all patients. They suggested that foveal suppression, which is directly related to the degree of anisometropia, could be responsible for the loss of stereopsis. In many other studies, a considerable decrease in stereoacuity in proportion to the degree of anisometropia was noted. In all these studies, spherical anisometropia can have a potentially significant adverse effect on stereopsis in comparison to astigmatism.

The results of our study confirm other findings suggesting that anisometropia interferes with binocular interaction, and the level of interference is directly related to the degree of anisometropia, i.e., the higher the anisometropia, lower the binocular function. Furthermore, we agree with Oguz that spherical anisometropia can have a potentially significant adverse effect on stereopsis in comparison to astigmatism. Moreover, in our study, 3 D of anisometropia caused marked reduction of stereoacuity in all subjects, regardless of the stereotest type. Our data suggest that stereoacuity was highly reduced in myopia unlike Rutstein et al,[11] who detected hypermetropia as a reason of deterioration of stereopsis.

In the current study, stereoacuity was measured using the Titmus, Randot, and TNO stereotests. The results of these three stereotests were significantly different from each other ($P < 0.001$). However, stereopsis was reduced the most in the TNO test, probably due to the lack of monocular cues and diminished false positive results.[6-8,12] An important finding in our study was the differences of stereotest scores reported in all types of anisometropia, in spite of similar tests. Moreover, numerous effective factors to be considered include: fatigue that causes the scores to diminish; patients becoming accustomed to answers, which is unavoidable but can be decreased by stereoacuity measurement initiation via higher diopters; and sufficient stereotest duration in which the subjects answered the tests (as in our study). Although foveal suppression has been proposed as the cause of reduced stereoacuity in anisometropia, other factors may also play an important role and that merits further investigations.

This study was conducted to assess the relation between different stereotests that express correlation in proportion to stereoacuity. We observed less correlation between the stereotests in lower stereopsis, and more correlation in higher stereopsis. Fawcett et al[8] showed correlation between Titmus, Randot, and preschool Randot tests in higher stereoacuity scores. We recommend that further considerations be given to assess the effects of acquired anisometropia on stereopsis using Titmus, Randot, and TNO stereotests.

Monovision, by virtue of optically or surgically produced anisometropia, results in dissimilar images in the two foveas, and consequently impaired stereopsis. However, it is difficult to determine the exact threshold of anisometropia in which stereoacuity significantly decreases; we observed that small degrees (e.g., 1 D) had little effects. On the other hand, the amount of stereoacuity impairment caused by anisometropia was shown to vary in different individuals, and some even maintained higher degrees of stereopsis despite higher levels of anisometropia. Hence, it is recommended to decide individually in monovision correction.

Our study group's age was less than the usual age of patients undergoing cataract surgery and monovision, which might be one of our main limitations; also, lengthy test time could be another limitation. A study on patients after cataract surgery and monovision, and comparing it with age matched normal population may be the suggested future study.

In conclusion, any type of anisometropia may reduce stereopsis, which should be kept in mind when inducing monovision, i.e., more the anisometropia, more the decrease in stereopsis. Among the three above-mentioned stereotests, TNO had the most reliable results.

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Conflicts of Interest

There are no conflicts of interest.

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