Stereopsis with TNO and Titmus Tests in Symptomatic and Asymptomatic University Students

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Abstract

Introduction: *One factor in the evaluation of binocular vision is the measurement of stereopsis. Several methods are available for this purpose. The most common procedures are anaglyphic (with use of red-green filters) and vectographic (with use of polarized filters) procedures. The purpose of this study is the determination of stereopsis with local (Titmus) and global (TNO) tests in symptomatic and asymptomatic subjects with respect to type of disparity (crossed and/or uncrossed) in exophoric and esophoric subjects.*

Methods: *In this cross-sectional study, 174 randomly selected students of Zahedan University of Medical Sciences served as subjects. Subjects were divided into symptomatic and asymptomatic groups according to the presence or absence of binocular vision symptoms. Dissociated heterophoria was determined with use of the alternate prism cover test and stereopsis with the TNO and Titmus tests.*

Results: *The mean stereopsis with the TNO test in symptomatic and asymptomatic subjects with crossed disparity presentation of the stereo test was 133.1 ± 68.6 and 76.7 ± 81.9 sec arc, respectively. The stereopsis with the TNO test in symptomatic and asymptomatic subjects with uncrossed disparity presentation of the stereo test was 135.0 ± 66.0 and 83.2 ± 49.3 sec arc, respectively. With the Titmus test, the mean stereopsis with crossed disparity presentation of the stereo test in symptomatic and asymptomatic subjects was 44.3 ± 7.1 and 40.7 ± 3.3 sec arc, respectively, and with uncrossed disparity presentation of the stereo test 50.0 ± 11.8 and 40.0 ± 0.0 sec arc, respectively. The Mann-Whitney U test showed a statistically significant difference in stereopsis (with both presentations of the test) between the two groups ($p<0.05$). The difference in stereopsis between esophoric and exophoric subjects was between 30-60 arc seconds for global stereopsis, and less than 2 arc seconds for local stereopsis. Esophoric subjects generally had a higher threshold for symptoms. However, these differences were not statistically significant ($p>0.05$). The best cut-off points for distinguishing between symptomatic and asymptomatic subjects with the TNO and Titmus stereo tests were determined to be 90 and 45 seconds of arc, respectively.*

Conclusion: *Stereopsis is a useful factor in distinguishing between symptomatic and asymptomatic individuals. For that purpose, a global test was more useful than a local test. Specifically, symptomatic subjects could be detected at a higher (90 arc sec) threshold with random-dot stereopsis than the 45 arc sec symptom threshold with Titmus-type stereopsis. Half of esophoric patients and only approximately a quarter of exophoric patients were symptomatic.*

Key Words

binocular vision, global stereopsis, heterophoria, local stereopsis, Titmus stereo test, TNO stereo test

Introduction

The ability to appreciate stereopsis comes in varying degrees. As a form of hyperacuity, target separation in stereopsis can be appreciated by patients with excellent binocular vision down to 3 seconds of arc.[1] This is twenty times smaller than the detail size of a 20/20 letter on the standard Snellen chart.

In addition to the displacement threshold, there are two broad types of stereopsis. These are often referred to as local and global. Both are appreciated starting in visual cortex area V2, and continuing into extra-striate areas whose development may continue well past the critical period for ambylogenesis.[2] It is critical to note that patients can have local stereopsis in the absence of global, but not vice-versa. It has long been established that appreciation of global stereopsis requires specialized right occipital lobe neurons, and that patients with neurological disease can lose global stereopsis ability.[3] In addition, it has been demonstrated in primates that early-onset strabismus can result in the loss of global stereopsis, though gross local stereo-capability may remain.[4]

Figure 1: TNO Stereotest

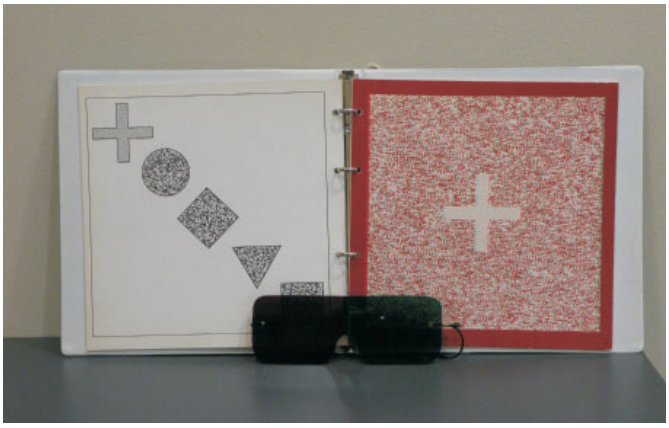


Figure 2: Titmus stereotest – the Stereo Fly

Because one can occur without the other, the presence of local without global stereopsis has implications to clinical patient care. The loss of global stereo-ability may reflect fragile fusion or the presence of tropia in intermittent strabismus. Another indicator of loss of global stereopsis includes poor motion detection,[5] which by itself can cause patient symptoms. If this is the case, global stereopsis may be used as a screening tool for symptomatic patients. The present research study was an attempt to investigate whether there is a difference between local and global stereopsis ability among symptomatic and asymptomatic participants, and if so, to find the threshold above which symptoms are likely to occur in participants with both esophoria and exophoria.

Materials and Methods

In this cross-sectional study, students (n=174) at Zahedan University of Medical Sciences were randomly selected to participate. Inclusion criteria included an absence of strabismus at 6m and 40cm with cover test, no reported ocular trauma, normal eye health, and best-corrected visual acuity 20/25 or better in each eye at 6m and 40cm. Exclusion criteria were myopia, hyperopia, and anisometropia (spherical equivalent) higher than -6.00, +6.00, and 1.50 diopters, respectively; best-corrected visual acuity less than 20/25 in each eye at 6m or 40cm; and history of ocular trauma or disease. The Horizontal Lang Two-Pencil Test was used to screen for stereopsis and binocularity. [6]

Subjects were divided into groups (symptomatic and asymptomatic), according to the presence of self-reported near binocular vision symptoms. Symptomatic subjects had one or more of the symptoms of decompensated heterophoria (headache, aching eyes, diplopia, blurred vision, perceived distortion of space, reduced stereopsis, monocular comfort but binocular discomfort, sore eyes, and general irritation). In order to rule out ocular disease, a complete eye examination was performed. This included a binocular evaluation, refraction, and slit lamp exam. A standardized symptom survey, the Convergence Insufficiency Symptom Survey (CISS), was used when convergence insufficiency seemed likely. It was not used in every case due to the high number of orthophoric and esophoric subjects.

Refractive error was determined by static retinoscopy. The presence of the following factors was used as an indication for cycloplegic refraction: significant esophoria, unstable objective or subjective refraction, and/or large discrepancy between objective and subjective results.[7] If a significant change in refractive error was found during the examination, new spectacles were prescribed and an adaptation period of at least four weeks was observed. A second evaluation was then performed after the new prescription had been worn for at least one month.

Plate four on the TNO test was used to rule out suppression. The near heterophoria was determined using the alternate prism cover test method with best correction in a trial frame. Subjects fixated on an accommodative target, a small isolated letter "E" of approximately 20/30 (6/9) size from the reduced Snellen chart, on a metal rod at eye level at 40 cm. As the alternate cover test was performed, the prism power was adjusted until there was no recovery movement in either eye. For confirmation of the neutral point, the prism power was increased until a reversal movement was seen. The prism power was then reduced until no movement was seen. This method allows for peripheral fusion and is less likely to be contaminated by a proximal effect. The final results were cross checked with the subject's response using a subjective Phi test.

For measurement of global stereopsis, the TNO was used. Red and green anaglyphic filters were worn. The booklet was held perpendicular to the subject's visual axis at 40 cm. The screening plates (plates I-IV) were shown first. If these were successfully completed, the graded plates from 480 to 15 seconds of arc were presented until the subject was unable to identify the three-dimensional shape correctly (Figure 1).

For measurement of local stereopsis, the Titmus stereotest was used. This test was performed at 40 cm with the subject wearing the polarizing spectacles. The booklet was held perpendicular to the subject's visual axis. The Stereo Fly test consists of a large-disparity housefly, animals, and nine sets of circles. Disparity ranges from 3000 to 40 seconds of arc. The fly was shown first. If a positive response was given, subjects were asked to identify the circle and animal that was disparate in each set (Figure 2).

On each test, the lowest disparity that the subject was able to detect was recorded as his/her stereoacuity in seconds of arc. Stereopsis was measured while the test was presented in the usual manner (crossed disparity) and then when the test was rotated 180 degrees (uncrossed disparity). After data collection, results were analyzed in SPSS.17 software with Mann-

Table 1: The distribution of exo- and eso-deviations in symptomatic and asymptomatic participants

Subject / Deviation	Symptomatic	Asymptomatic	All
	N (%)	N (%)	N (%)
Exo	36 (24.0)	114 (76.0)	150 (100.0)
Eso	12 (50.0)	12 (50.0)	24 (100.0)

Table 2: Mean and SD of stereopsis with TNO and Titmus tests

Test & Disparity / Subject		All	Symptomatic	Asymptomatic	p-value
		Mean ± SD	Mean ± SD	Mean ± SD	
TNO	Crossed	92.3 ± 82.2	133.1 ± 68.6	76.7 ± 81.9	0.001
	Uncrossed	97.5 ± 58.9	135.0 ± 66.0	83.2 ± 49.3	0.004
Titmus	Crossed	41.7 ± 4.6	44.3 ± 7.1	40.7 ± 3.3	0.006
	Uncrossed	42.7 ± 7.6	50.0 ± 11.8	40.0 ± 0.0	< 0.001

Table 3: Mean and SD of stereopsis with two types of disparities in esophoric and exophoric group

Test & Disparity / Near Phoria		Exophoria	Esophoria	p-value
		Mean ± SD	Mean ± SD	
TNO	Crossed	81.3 ± 59.5	142.7 ± 137.8	0.06
	Uncrossed	91.9 ± 52.9	123.3 ± 77.2	0.06
Titmus	Crossed	41.8 ± 5.1	43.5 ± 7.0	0.6
	Uncrossed	42.5 ± 7.7	41.2 ± 4.2	0.1

Table 4: Mean and SD of stereopsis in esophoric and exophoric subjects separately in symptomatic and asymptomatic groups.

Phoria & Stereotest & Disparity / Subject			Symptomatic	Asymptomatic	p-value
			Mean ± SD	Mean ± SD	
Esophoria	TNO	Crossed	160.0±80.7	126.5±77.0	0.01
		Uncrossed	148.0±71.2	100.3±77.5	0.04
	Titmus	Crossed	40.6±2.5	41.8±5.4	0.7
		Uncrossed	47.3±8.8	40.0±0.0	0.02
Exophoria	TNO	Crossed	120.9±59.7	69.5±54.5	<0.001
		Uncrossed	129.0±63.8	80.8±43.7	<0.001
	Titmus	Crossed	46.0±7.8	40.5±2.9	<0.001
		Uncrossed	51.2±12.9	40.0±0.0	<0.001

Whitney U, Wilcoxon, and ROC curve tests. In all tests, the significance level was considered to be 0.05.

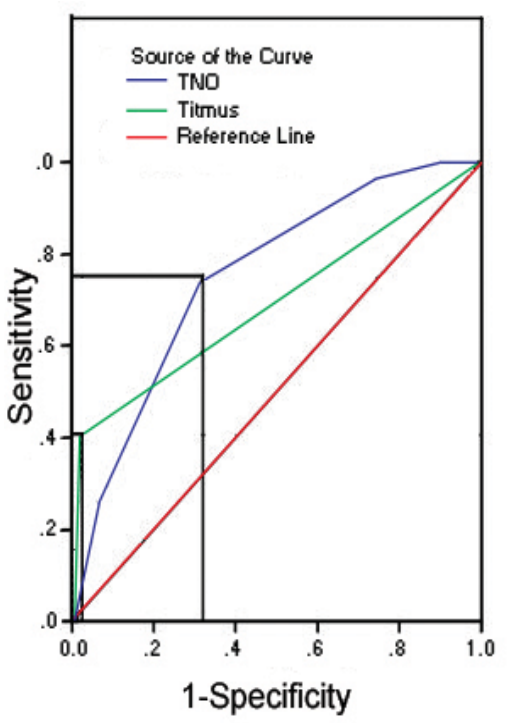
Results

Of the 174 students participating in this study, 95 (54.5 %) were female and 79 (45.5 %) male. The mean ages in all subjects, and separately in females and males, were 20.89 ±1.3, 20.87±1.3, and 21.33±0.5 years, respectively. Symptomatic and asymptomatic subjects numbered 48 subjects (27.6 %) and 126 subjects (72.4 %), respectively. The mean and standard deviation of near deviation was: all subjects (-4.2±3.1), symptomatic subjects (5.6±3.1), and asymptomatic subjects (-3.5±2.9) prism diopters. The negative sign indicates exophoria.

The Mann-Whitney U test showed significant differences in the mean of near deviation between the two groups (p= 0.01). The frequency distribution of exo and eso deviation in symptomatic and asymptomatic groups is displayed in Table 1. The X^2 test shows a statistically significant difference in the distribution of exo and eso deviation with symptoms (X^2 = 7.001, df= 1, p= 0.01).

The mean measured stereopsis with the TNO and Titmus tests (crossed and uncrossed disparity) are presented by symptom group in Table 2. The mean of the stereopsis threshold in the symptomatic group is higher than the asymptomatic group with both tests and both types of disparity. The differences were statistically different with the Mann-Whitney U test.

Figure 3: The ROC for determination of the stereopsis cut-off point of the TNO and Titmus tests



In a comparison of stereopsis among subjects in the entire subject group, the Wilcoxon test did not show a significant difference with either the TNO (p=0.20) or Titmus (p=0.25) test. When the Wilcoxon test was analyzed separately in symptomatic and asymptomatic subjects, it was observed that in symptomatic subjects, neither the mean stereopsis with the TNO nor the Titmus tests showed a statistically significant difference (p=0.95 and p=0.03). The mean of measured stereopsis with the TNO and Titmus tests with crossed and uncrossed disparities separately in exophoric and esophoric subjects are presented in Table 3.

Comparisons between exophoric and esophoric subjects with the Mann-Whitney U test did not show significant differences in stereopsis with either crossed or uncrossed disparity presentation on either test. The Wilcoxon test did not show significant differences in stereopsis using crossed or uncrossed disparity with the TNO (p=0.4) or Titmus (p=0.1) tests in esophoric subjects or with the TNO (p=0.06) or Titmus (p=0.4) tests in exophoric subjects. The mean stereopsis with exophoric and esophoric subjects separately in symptomatic and asymptomatic groups are presented in Table 4. Note that for global stereopsis, esophoric subjects were 30 arc seconds worse than their exophoric counterparts on uncrossed disparity presentation of the stereo test, and 60 arc seconds worse for crossed disparity presentation of the test.

In general, the Mann-Whitney U test indicated that there were significant differences in mean stereopsis between symptomatic and asymptomatic subjects in both esophoric or exophoric subjects. Specifically, there was an approximately 50 arc second higher global stereo-threshold for symptomatic subjects than asymptomatic ones. The Titmus test with uncrossed disparity in esophoric subjects showed a 25 arc second difference instead.

The Receiver Operating Characteristic (ROC) curves determine the amount of stereopsis for the best sensitivity and specificity for separating symptomatic from asymptomatic subjects (Figure 3). According to ROC analysis, the cut-off point for distinguishing between symptomatic and asymptomatic subjects on the TNO and Titmus stereopsis tests was determined to be 90 and 45 seconds of arc, respectively. This can also be seen in Table 4. Note that the wider standard deviation on TNO testing lowered the threshold from its apparent value, which is closer to 140 arc seconds for symptomatic patients.

Discussion

Several trends are apparent from the results of this study. First, both symptomatic and asymptomatic participants have a higher threshold with global stereopsis, as measured by the TNO stereo test, than they do with local stereo, as measured by the Titmus Stereo Fly test. Secondly, the cutoff for symptomatology is 90 arc seconds for the global stereopsis, and half that, or 45 arc seconds, for Titmus stereo testing. Administering either test in the intended uncrossed-disparity way is not significantly different than inverting the test booklet and testing uncrossed disparity, a sort of "off-label" use for the TNO and Stereo Fly tests.

The results of this study make a case for routine baseline stereopsis measurement in clinical practice and vision screenings. Regardless of the test used, patients should be tested to well below 50 arc seconds. Note that there is only one Wirt circle Titmus target smaller than 50 arc seconds on the commonly-used Stereo Fly.

This raises the issue as to which stereopsis test is best for clinical practice in the detection of binocular vision problems. For local stereo, the Randot test booklet does have Titmus targets in the form of Wirt circles with disparity down to 20 arc seconds. However, it does not offer global stereopsis targets below 250 arc seconds. This is well above the 90 arc seconds for global targets that this study determined is the threshold for symptomatology. Other commercially-available options include the Random Dot 2 test.[8] The Random Dot 2 offers Titmus targets with disparity as small as 12.5 arc seconds, but the global targets have a threshold of only 125 arc seconds.

Thus, according to the results of this study, a patient with binocular vision symptoms could be detected using local stereopsis Titmus targets on either the Randot or Random Dot 2 tests, but neither would have a low enough global stereopsis threshold to detect symptomatic patients.

While the anaglyphic TNO stereo test used in this study does allow for low-threshold global stereopsis testing, these types of targets are not widely available, especially with polarized targets. One widely-available global stereopsis test with a low (40 arc sec) threshold is the Random Dot Preschool Stereoacuity Test. This test was originally published as a three-booklet battery, and while it does not offer any local stereo-targets, one booklet does have six global targets at a disparity of 60 and 40 arc seconds.[9] For those who prefer the slightly shorter, faster test while still offering low-threshold random-dot targets, the special-edition "Paul Harris Randot Test"[10] offers random-dot Wirt Circles, animals and shapes down to 20 arc seconds. To the knowledge of these authors, no other ana-

log tests of stereopsis at near meet the criterion of the better than 100 arc second threshold.

It should be noted that one must exercise caution when comparing dissimilar stereopsis tests. Saladin states that "it is very difficult to compare the results of one stereoscopic test with another. Test results depend greatly on the exact method and task, the test conditions, and the threshold chosen."[11] Thus, perhaps it is not surprising that the results found in the current study with the local Titmus test and global TNO differ.

Conclusion

Low-threshold stereopsis testing is both helpful in detecting binocular vision symptoms as well as performance evaluation of optometric treatment. For example, if a patient can only appreciate 100 arc seconds of random dot stereopsis with habitual correction, but improves to 60 arc seconds with a bifocal add, this study would predict that asthenopic symptoms would diminish with the new prescription. If local (Titmus) stereopsis testing is used instead, the threshold will have to improve beyond 45 arc seconds.

Such performance measures of optometric intervention can be very useful in patient education. For example, improved stereopsis with a toric contact lens prescription, in comparison to spherical lenses, can be a convincing demonstration of the value of these somewhat more expensive lenses. Likewise, improvement in threshold stereopsis before and after optometric vision therapy is a powerful, quick, and concrete way to show the successful patient how their visual skills have evolved. In addition to more consistent clinical use of threshold stereopsis testing, more studies like this one are needed to explore what are undoubtedly the myriad of uses of the finest levels of hyperacuity in symptomatic, binocular patients.

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