The Comparison of Stereopsis with TNO and Titmus Tests in Symptomatic and Asymptomatic University Students

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The Comparison of Stereopsis with TNO and Titmus Tests in Symptomatic and Asymptomatic University Students

Description

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 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 that met inclusion criteria 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 TNO and Titmus tests. After data collection, data were analyzed in SPSS.17 software using the Mann-Whitney U, Wilcoxon and receiver operating characteristic (ROC) curve.

Results: The results of this study showed that the mean stereopsis with TNO test in symptomatic and asymptomatic subjects was 133.1 ± 68.6 and 76.7 ± 81.9 sec arc, respectively, in subjects with crossed disparity, and 135.0 ± 66.0 and 83.2 ± 49.3 sec arc, respectively, with uncrossed disparity. With Titmus test, mean stereopsis with crossed disparity in symptomatic and asymptomatic subjects was 44.3 ± 7.1 and 40.7 ± 3.3 sec arc, respectively, and with uncrossed disparity 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 crossed and uncrossed disparity) between the two groups (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. Also, there was no any difference between crossed and uncrossed disparity stereopsis in symptomatic and asymptomatic subjects.

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This is a preprint of an article published in the Journal of Behavioral Optometry:


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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 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.

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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. Also, there was no any difference between crossed and uncrossed disparity stereopsis in symptomatic and asymptomatic subjects.

Keywords: Stereopsis, Binocular vision, Heterophoria
Introduction

Stereopsis exists only in the visual cortex, where the information from the two eyes is first combined. Even in the lateral geniculate nucleus of the thalamus, where optic nerve fibers from the two eyes are first in near proximity, individual layers of each LGN are monocular in patients with normal correspondence. Starting in the primary visual (striate) cortex, in patients with normal visual development, the potential for stereopsis first emerges. However, recent evidence has suggested that only pre-processing for stereopsis occurs in V1.

From patient to patient, the ability to see 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. 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 area visual cortex area V2. 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 global stereopsis appreciation requires specialized right occipital lobe neurons, and that patients with neurological disease can lose global stereopsis ability. In addition, it has been demonstrated in primates that early-onset strabismus can result in the loss of global stereopsis, though gross local stereocapability may remain.

Because one can occur without the other, the presence of local without global stereopsis has implications to clinical patient care. The loss of global stereocapility may reflect fragile fusion, intermittent strabismus, poor motion detection and therefore 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 if 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 at Zahedan University of Medical Sciences were randomly selected from the list of students. 174 students who met inclusion criteria were entered into the study. Inclusion criteria were absence of strabismus at 6m and 40cm with cover test, no history of ocular trauma, normal eye health and best-corrected visual acuity 20/25 or better in each eye at 6m and 40cm. Exclusion criteria were presence of strabismus at far or near, amblyopia, myopia and 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 far or near and history of eye trauma or eye disease. The Horizontal Lang Two-Pencil Test was used to screen for stereopsis and binocularity.

Subjects who had no exclusion criteria were divided into symptomatic and asymptomatic groups, according to 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, general irritation).

Refractive errors were determined by static retinoscopy using a Heine β-200 retinoscope, with cyclopentolate 1%, if needed. Before data collection began, refractive errors were corrected and subjects used their correction at least four weeks. After this, we used plate four on the TNO test to rule out suppression. The near heterophoria was determined with alternate prism cover test method with best correction in trial frame, and with subjects fixating on an accommodative target which was a small isolated letter "E" of approximately 20/30 (6/9) size from reduced Snellen chart on a metal rod at eye level at 40 cm. Base out prism was used to neutralize eso-deviations and base in prism was used to neutralize exo-deviations. As the alternate cover test was performed, the prism power was adjusted until there were no recovery movements in either eye. For confirmation of the neutral point, the prism power was increased until a reversal movement was seen. Then power was reduced until no movement was seen. The angle of deviation was recorded in prism diopters.

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

Figure 1: TNO Stereotest (photo credit: H. Momeni-Moghadam)

For measurement of local stereopsis, the Titmus stereotest was used. This test was performed at 40 cm with the subject wearing the polarizing spectacles and the booklet was held at 40 cm perpendicular to the subject’s visual axis. On this test, the disparities range from 3000 to 40 seconds of arc. The Stereo Fly test consists of a large-disparity housefly, animals and nine sets of circles seen stereoscopically. The fly was shown first, and then subject identify the one circle and animal that was disparate in each set. See Figure 2.

Figure 2: Titmus stereotest – the Stereo Fly (photo credit: H. Momeni-Moghadam)

On each test, the lowest disparity that the subject was able to detect was recorded as his/her stereoacuity in seconds of arc. We measured stereopsis while the test was presented in usual condition (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-Whitney U, Wilcoxon and ROC curve tests. In all tests, the significance level was considered to be 0.05.

Results

Of the 170 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 in all subjects and separately in symptomatic and asymptomatic subjects was -4.17±3.12, -5.6±3.1, -3.5±2.9 prism diopters, respectively (the negative sign indicating exophoria). The Mann-Whitney U test showed significant differences in the mean of near deviation between the two groups. (P= 0.01). The distribution of frequency of exo- and eso- deviation in symptomatic and asymptomatic groups is displayed in Table 1.

<table>
<thead>
<tr>
<th>Type of deviation</th>
<th>Symptomatic</th>
<th></th>
<th>Asymptomatic</th>
<th></th>
<th>Total</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent</td>
<td>Number</td>
<td>Percent</td>
<td>Number</td>
<td>Percent</td>
</tr>
<tr>
<td>Exo</td>
<td>36</td>
<td>24.0%</td>
<td>114</td>
<td>76.0%</td>
<td>150</td>
<td>100.0%</td>
</tr>
<tr>
<td>Eso</td>
<td>12</td>
<td>50.0%</td>
<td>12</td>
<td>50.0%</td>
<td>24</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

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

The $X^2$ test shows 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 TNO and Titmus tests and using the default crossed disparity, with the test booklets upright, and uncrossed disparity, with the stereo- tests inverted, presented for all subjects by symptoms are in Table 2.

<table>
<thead>
<tr>
<th>Test</th>
<th>All subjects</th>
<th>Symptomatic subjects</th>
<th>Asymptomatic subjects</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td></td>
</tr>
<tr>
<td>TNO</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crossed disparity</td>
<td>92.3 ± 82.2</td>
<td>133.1 ± 68.6</td>
<td>76.7 ± 81.9</td>
<td>0.001</td>
</tr>
<tr>
<td>Uncrossed disparity</td>
<td>97.5 ± 58.9</td>
<td>135.0 ± 66.0</td>
<td>83.2 ± 49.3</td>
<td>0.004</td>
</tr>
<tr>
<td>Titmus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crossed disparity</td>
<td>41.7 ± 4.6</td>
<td>44.3 ± 7.1</td>
<td>40.7 ± 3.3</td>
<td>0.006</td>
</tr>
<tr>
<td>Uncrossed disparity</td>
<td>42.7 ± 7.6</td>
<td>50.0 ± 11.8</td>
<td>40.0 ± 0.0</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

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

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.

In a comparison of stereopsis with crossed and uncrossed disparity in two groups, the Wilcoxon test did not show significant difference with either TNO ($p=0.20$) or Titmus ($p=0.25$) test. But when the Wilcoxon test was performed separately in symptomatic and asymptomatic subjects with attention to disparity, it was observed that in symptomatic subjects, the mean stereopsis with TNO test with crossed and uncrossed disparity did not show a statistically significant difference ($p=0.95$). Similarly, with Titmus with crossed and uncrossed disparity had ($p=0.03$) and in asymptomatic subjects, the mean of stereopsis with TNO with crossed and uncrossed disparity ($p= 0.18$) and Titmus with crossed and uncrossed disparity ($p=0.08$) test did not show a statistically significant difference.
The mean of measured stereopsis with TNO and Titmus tests with crossed and uncrossed disparities separately in exophoric and esophoric subjects are presented in Table 3.

<table>
<thead>
<tr>
<th>Near Phoria</th>
<th>Exophoria</th>
<th>Esophoria</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stereopsis</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td></td>
</tr>
<tr>
<td>TNO</td>
<td>Crossed disparity</td>
<td>81.3 ± 59.5</td>
<td>142.7 ± 137.8</td>
</tr>
<tr>
<td></td>
<td>Uncrossed disparity</td>
<td>91.9 ± 52.9</td>
<td>123.3 ± 77.2</td>
</tr>
<tr>
<td>Titmus</td>
<td>Crossed disparity</td>
<td>41.8 ± 5.1</td>
<td>43.5 ± 7.0</td>
</tr>
<tr>
<td></td>
<td>Uncrossed disparity</td>
<td>42.5 ± 7.7</td>
<td>41.2 ± 4.2</td>
</tr>
</tbody>
</table>

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

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 on either test.

Also, the Wilcoxon test did not show significant differences in stereopsis using crossed or uncrossed disparity with TNO (p=0.4) or Titmus (p=0.1) tests in esophoric subjects or with TNO (p=0.06) or Titmus (p=0.4) tests in exophoric subjects. The mean of stereopsis with exophoric and esophoric subjects separately in symptomatic and asymptomatic groups are presented in Table 4.

<table>
<thead>
<tr>
<th>Esophoria</th>
<th>Variables</th>
<th>Symptomatic</th>
<th>Asymptomatic</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TNO</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td></td>
</tr>
<tr>
<td>Crossed</td>
<td>160.0±80.7</td>
<td>126.5±77.0</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Uncrossed</td>
<td>148.0±71.2</td>
<td>100.3±77.5</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Titmus</td>
<td>Crossed</td>
<td>40.6±2.5</td>
<td>41.8±5.4</td>
<td>0.7</td>
</tr>
<tr>
<td>Uncrossed</td>
<td>47.3±8.8</td>
<td>40.0±0.0</td>
<td>0.02</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exophoria</th>
<th>TNO</th>
<th>Crossed</th>
<th>Asymptomatic</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossed</td>
<td>120.9±59.7</td>
<td>69.5±54.5</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Uncrossed</td>
<td>129.0±63.8</td>
<td>80.8±43.7</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Titmus</td>
<td>Crossed</td>
<td>46.0±7.8</td>
<td>40.5±2.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Uncrossed</td>
<td>51.2±12.9</td>
<td>40.0±0.0</td>
<td>&lt;0.001</td>
<td></td>
</tr>
</tbody>
</table>

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

The Mann-Whitney U test indicated that there were significant differences in mean stereopsis between symptomatic and asymptomatic subjects with crossed or uncrossed disparity in both esophoric or exophoric subjects with except with the Titmus test with uncrossed disparity in esophoric subjects.
We used Rate of Change (ROC) curves for determination of the amount of stereopsis for the best sensitivity and specificity for separating symptomatic from asymptomatic subjects (Figures 3 and 4).

![ROC curve for TNO test](image1.png)

**Figure 3:** The ROC for determination of the stereopsis cut-off point of TNO test

![ROC curve for Titmus test](image2.png)

**Figure 4:** The ROC for determination of the stereopsis cut-off point of Titmus test

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.
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. If this is done with Titmus, or local, stereopsis testing, patients should be tested to well below 50 arc seconds to determine which patients have symptoms. Note that there is only one Wirt circle Titmus target smaller than 50 arc seconds on the commonly-used Stereo Fly. One Wirt circle Titmus target smaller than 50 arc seconds.

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. Random Dot 2 offers Titmus targets with disparity as small as 12.5 arc seconds, but its global targets have a threshold of only 125 arc seconds. See Figure 5.

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. The only widely-available global stereopsis test with low thresholds is the Random Dot Preschool Stereoaucuity 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. See Figure 6.
Whether the Preschool Randot or other low-threshold global stereo-targets were used, we would predict that patients of any age with potential binocular-vision would not be able to see the targets in this lowest-threshold booklet.

In conclusion, low-threshold stereopsis testing is necessary to detect binocular-vision symptoms. The clinician should be aware that standard, high-threshold stereopsis test is mostly useful in the detection of small-angle strabismus, not binocular vision problems.

Acknowledgments

We thank the students who participated as subjects in this study.

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