ORIGINAL ARTICLE

THE EFFECT OF CLINICAL VISUAL STRESS ON STEREOACUITY MEASURED WITH THE TNO TEST

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We measured stereoacuity using TNO test on 25 patients without fixation disparity (FD) and compared the result with other 25 patients exhibited FD related to visual stress. All patients were presbyopes of ages ranging from 40 to 80 years, with visual acuity 6/6 or better in each eye, free from ocular diseases and generally healthy. The results showed statistically significant difference in the stereoacuities measured between the groups (Mann-Whitney U = 181.0, $p < 0.01$), suggesting that FD significantly reduced stereoacuity. Although the correlation between the magnitudes of FD and stereothreshold is statistically not significant (Spearman's $r_s = 0.33$, $p>0.01$), elimination of FD using prisms correction statistically improved stereoacuity (Wilcoxon's Z = 2.43, $p<0.01$). The findings conclude that visual stress manifested as FD causes deficit in stereoperformance measurable with the TNO test and can be improved by prism correction.

Key words : Visual stress, fixation disparity, stereopsis, stereoacuity, prism correction.

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Introduction

It has been reported (1) that visual stress producing fixation disparity (FD) induced by ophthalmic prisms in young adults decreases stereoacuity measured with the TNO test (2). The study also suggests that a TNO test may be used to detect the presence of stress on the visual system. This study confirms the use of TNO test to measure visual stress exhibiting FD.

The effects of naturally occurring FD on stereoacuity, using a motorised Howard-Dolman apparatus has been carried out (3). The changes in the subjects' stereoacuities with respect to the change in their forced vergence FD curves (4-7) was monitored following several weeks of wearing prismatic correction to nullify the disparity. The result showed no improvement in stereoacuity and the FD curves remained unchanged.

It should be noted that Howard-Dolman stereopsis test involves monocular cues like shadows and parallax difference of the test objects that allow perception of real depth without binocular vision (8). On the other hand, FD curves generated by prism stress confederate prism adaptation (9,10) to the vergence systems making the interpretation of the curves questionable (11).

Rustein (2) used optometry students all of whom were young adults, as subjects for his clinical experiment. Although the subjects recruited for his study all exhibited 'naturally occurring' FD, the author did not specify whether the FD was physiological or related to visual stress.

FD is a very small misalignment of visual axes occurring during binocular vision (12-14). It's presence can be physiological or related to stress on the vergence systems (7). A physiological FD is a naturally occurring vergence error (15,16) that acts as a simulus for vergence eye movements during normal binocular vision. The cue for an error of vergence is an intrinsic presence of retinal disparity of the right and the left retinal images occurring due to some 6 cm lateral separation of the right and the left eyes. Physiological FD is asymptomatic, has no detrimental effect to binocular vision and its presence is indeed required for vergence movements of the eyes.

FD due to visual stress, on the other hand, refers to misalignment of visual axes due to imbalances of the vergence and accommodation systems (7,17). Its presence is associated with an inability of the eyes to overcome heterophoria (18,19). Several extensive studies on FD and its relationship with heterophoria and symptoms of binocular decompensation had been conducted with findings suggesting that FD due visual stress can be differentiated from that of physiological FD by its magnitude, measurable by the value of prisms required to nullify the visual axes misalignments (7,11,20,21). FD refers to the residual misalignment of the visual axes that could not be compensated by the vergence systems during binocular vision. Its measurement involves partial dissociation of vision, that is, complete dissociation of the central field in association with binocular vision and fusion of the peripheral visual field. The visual axes misalignment measured in prism dioptre is known as associated heterophoria.

Associated heterophoria value of 1 prism dioptre and more in non-presbyopes with FD or, 2 prism dioptres and more in presbyopia, are indicators for the presence of visual stress (21). Values less than those suggest that the FDs are physiological. The occurrence of stress on the visual systems can be detected towards the end of a working day (22), when the demand on visual tasks becomes excessive (7) and in a poorly lighted work place (20). The condition becomes obvious in presbyopes, particularly those who require an update to the additional refractive correction for near vision (23). The visual systems of the presbyopes are susceptible to stress producing FD as demand to accommodative effort increases whilst amplitude accommodation decreases with age.

This study investigates threshold stereoacuities measured with the TNO test on subjects exhibiting clinical FD. All of the subjects were presbyopes who complained of symptoms of visual discomfort requiring an update to their near vision correction.

Table 1. Mean and SD of the subject’s age, with median and mode of the stereoacuities of Group 1. The mean and SD of the data is also included for reference purpose. The large SD from the result is not indication of intersubjects variations of the stereoacuities but more of the effects from the truncated scales of the measurement.

N = 25 Mean age = 55.88 years SD ±8.46	Stereoacuity (sec arc)
Median	60
Mode	60
Mean	84.00
SD	±94.87

Subject

Subjects for the study were presbyopes ages ranging from 40 to 80 years. They were grouped into Group 1 which comprises of presbyopes without FD and Group 2 that belongs to presbyopes with FD of 2 prism dioptre and more. A previous study claimed that people whose ages more than 55 years had Howard-Dolman stereoacuities lower by about 40% when compared to those below 40 years of age (24). The experiment for the Group 1 aimed to establish threshold stereopsis within the selected age group whilst the experiment for the Group 2 measures steteoacuities in the presence of FD and upon its elimination with optical correction.

Subjects for Group 1 were recruited from patients attending the Optometry Clinic at the University of Bradford, United Kingdom. Twenty five patients of ages ranging from 40 to 70 years participated in the study. Subjects for Group 2 were patients who came for private optometric examination at The Shakespeare Collinge and Stott, West Yorkshire, England, requiring an updating to their near vision correction.

Twenty five patients ages ranging from 49 to 80 years were identified to have FD measured as associated heterophoria value of 2 prism dioptres and more. All subjects had visual acuities of 6/6 or better in each eye and posed good ocular health taken from self report and funduscopy.

Materials and Methods

All subjects underwent comprehensive optometric eye examination and their refractive errors were optimally corrected. FD was measured using Mallett unit (25) for near vision whilst stereoacuity was measured using the TNO test (2).

The TNO test uses random-dots of anaglyphs pairs printed in red and green. Red and green spectacles are worn to experience a projection of stereoscopic perception. The test provides a series of test plates to measure stereopsis at retinal disparity levels of 480, 240, 120, 60, 30 and 15 seconds of arc when viewed at 40 cm viewing distance. A more detailed account of the TNO test was described previously (1).

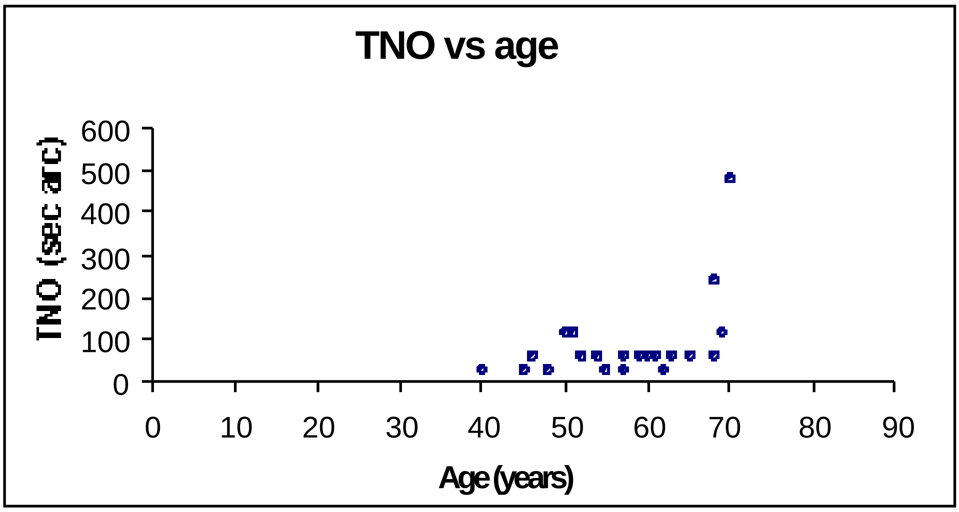
Throughout the experiments, the surface illumination of the TNO test plate was maintained at 570 lux whilst the room illumination was kept at about 180 lux (26).

Experiment 1 for Group 1

Twenty five subjects, mean age 55.88 standard deviation (SD) ±8.46 serve as control to verify baseline stereoacuity in presbyopes. Recruited subjects had their FDs measured first. Wearing the best near refractive correction, the patient was presented with a Mallet unit for near vision and was asked to read a few lines of the paragraphs on the face of the unit. This was aimed to stabilise peripheral fusion hence binocular vision. The FD was then measured, using minimum prism value, which give an appearance of alignment of the nonius lines. Only subjects without FD were selected for this experiment.

This was followed with measurement of the stereoacuity with the TNO. The patients wore the red ands green glasses on top of the new near

Figure 1. A scattergram showing the spread of the relationship between stereoacuity values in seconds of arc and the patients' ages from Group 1.



refractive correction. The TNO test plates were then introduced, one by one, and the threshold stereoacuity was determined.

Experiment 2 for Group 2

Twenty-five subjects mean age 64.44 SD ±8.51 were selected for the study. They underwent a normal routine optometric examination prior to any other test. Only patients with associated heterophoria value of 2 prism dioptres and more were recruited for the experiment.

The procedure described for Experiment 1 was repeated in Experiment 2. After measurement of threshold stereopsis was completed, the TNO test was repeated with minimum prism power that eliminated the FD being worn before the patients' eyes using Halberg clips. The power of the prism was equally divided between the eyes.

Results

Experiment 1

A test for normality shows that the stereoacuity data measured with TNO is positively skewed (degree of skewness 3.43), hence non-parametric statistical analysis is indicated. Table 1 shows the median and mode of the data representing the central tendency of the subjects' streoacuities. The mean and standard deviation (SD) of the data are also included for reference purposes.

The result shows that the stereoacuity values measured from the selected age group (40 years and over) are considerably lower than previously found in the young adult group (1). The median and mode of the threshold stereopsis of the young adults subjects ages ranging from 19 to 29 years shown from that study were both 30 sec arc respectively, with values of mean 48.50 and SD ±41.63 sec arc. On the other hand, the presbyopic group had the mean and mode stereoacuity of both 60 sec arc respectively, with the values of mean 84.00 and SD±94.97 sec arc.

It should be noted that the SDs of the stereopsis data were large. However, the large SDs are not indications for large intersubjects' variation of the data but more due to the effects of the truncated scales of the TNO test which were non-parametric, namely 480, 240, 120, 60, 30 and 15 sec arc.

A Spearman's rank correlation coefficient between stereothreshold and age of the patients in Group 1 shows values of $r_s = 0.48$, $p = 0.01$, ($\mu = 0.05$), N = 25. The result suggests a small significant correlation exists between age and stereoacuity over a relatively narrow age range of 40 to 70 years. Figure 1 depicts the spread of the points representing the stereoacuity and the patients' ages.

Experiment 2

Table 2 shows the mean and SD of the subjects, ages and FDs as the associated heterophoria values in prism dioptres. The medians and modes for stereoacuity measured without and with

Table 2. Means and SDs of the subjects' age and associated heterophoria, and medians and modes stereoacuity without and with prism correction of FD of the Group 2. The means and SDs of respected stereoacuities are also included for reference purposes. The large SD from the result is not indication of intersubjects variations of the stereoacuities but more of the effects from the truncated scales of the measurement.

N= 25 Mean age = 64.44 years SD ±8.51	Assoc. Phoria (prism dioptre)	TNO without prism (sec arc)	TNO with prism (sec arc)
Median	-3.00	60	60
Mode	-3.00	60	60
Mean	-3.52	103.20	84.00
SD	± 1.39	± 89.19	± 42.43

elimination of FD were shown. The means and SD for the stereoacuity results were also included for reference purposes.

The stereoacuity data without prism from Group 2 in Table 2 was compared with the stereoacuity data from Group 1 in Table 1. A Mann-Whitney U test shows values of U = 181, p<0.01, which suggests the clinically exhisting FD significantly reduces stereoperfomance.

Spearman's ranked correlation coefficient test between the associated exophoria data (which are parametric) and the stereoacuity (which are non-parametric) data shows values of $r_s = 0.33$, p>0.01. The value do not indicate a significant correlation between the magnitude of assocated heterophoria and the threshold stereopsis in this sample of subjects. Figure 2 depicts the spread of the threshold stereopsis in patients with FD taken from Group 2.

As is seen from the table above, although no change in the values of the medians and modes for stereoacuities measured without and with prismatic correction of FD, the Wilcoxon's signed ranked test shows values of Z = -2.43 and p<0.01. The result suggests that the threshold stereopsis significantly decreases (that is, increases in stereoacuity) upon alignment of the visual axes using prism correction.

Discussion

The result of this study confirms that patients who exhibit FDs have lower stereoacuities than those without FDs. Although in general, patients of ages of 40 and over have lower stereoacuity than the younger age group (1), those with FD appears to show further impediment in their stereo-performance.

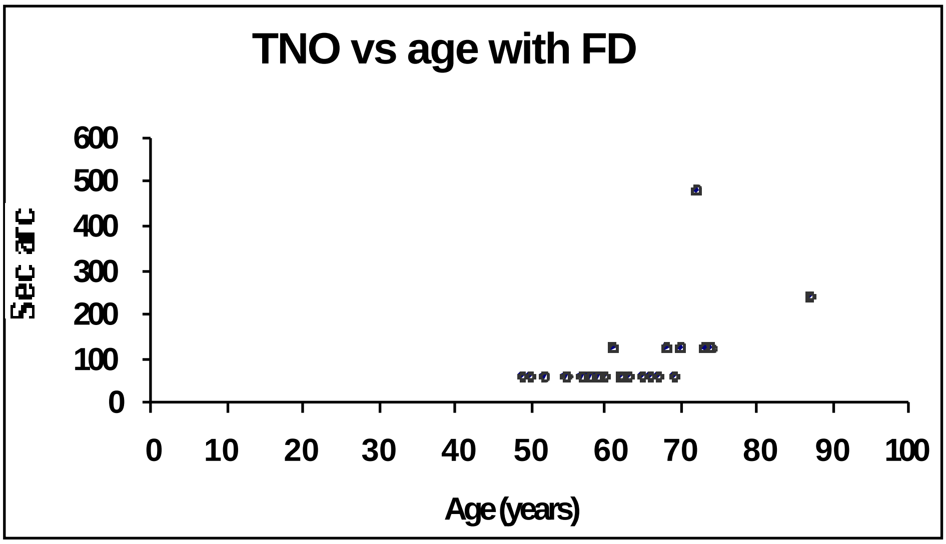
It should be noted, that all patients used for this study were selected from those whose visual acuities were 6/6 or better. However, measurement of visual acuity does not fully describe the quality of vision; rather, it measures no more than the smallest details resolvable by the central retina. The process of stereoscopic perception with random-dot stereograms like the TNO test involves complex interaction of the binocularly driven cells within the visual cortex (1,27), and not only of a perceived image at the retinal level.

A decrease in stereopsis performance due to age has been reported (24) to be due to some degenerative changes of the visual pathways particularly in people over 60 years of age (28). These are like the cortical substrate subserving binocularity of the visual cortex loses its cells (29,30), the cells which remain have fewer synapses (31) and with fewer receptor sites (32).

Visual deficit due to age has been accounted for the reduced in contrast sensitivity function (33,34) through reduction in retinal illumination due to miosis (33) and due to poor light absorption of the lens with age (35). The loss seen in the contrast sensitivity function primarily occurs at higher spatial frequencies rather than at low spatial frequencies (33,36). If perception for high spatial frequency is affected by age, it is therefore not surprising to find a high stereoscopic threshold in the subjects of this study. With the presence of FD, the stereoacuity seems to reduce further.

This study concludes that a TNO test

Figure 2. A scattergram showing the spread of the relationship between stereoacuity values in seconds of arc in the presence of FD and the patients' ages from Group 2.



employing random-dot stereograms is able to detect deficit in stereoscopic perception due to visual stress. The test has no monocular cues, free from correct guessing and no learning effects. The results of this study also showed that a temporary elimination of the FD might improve stereoacuity.

It is suspected that the reduction in the stereoperformance with FD as well as the improvement in stereoacuity with prism correction may be more pronounced than is shown. The limitation of the TNO measuring scale, for which the scale of measurement is large and truncated, for example, 480, 240, 120, 60, 30 and 15 seconds of arc, may have been a major contributory factor towards the inability to detect a small change of stereoacuity. It would be ideal in future to design a random-dot stereopsis test which has a linear scale, with small incremental changes and to test the device on young adult subjects showing visual stress producing FD.

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