The Effects of Experimentally Induced Anisometropia on Stereopsis

Halit Oguz, MD, and Velissin Oguz, MD

ABSTRACT

**Purpose:** To determine the effects of experimentally induced anisometropia on stereopsis in healthy adults to assess the potentially detrimental effects of uncorrected anisometropia on the development of stereoacuity during childhood.

**Methods:** Twenty-one healthy adult volunteers ranging in age from 22-34 years (mean: 27 years) and free of ocular disease participated in the study. Four different types of anisometropia (unilateral myopia, unilateral hyperopia, or unilateral astigmatism [90° or 45°]) were induced in random order by placing trial lenses over the right eye in 1 diopter (D) increments ranging from 1-3 D. Stereoaucity was measured using the Titmus stereotest with patients placing the cross-polarizing stereoaucity glasses over their lenses or trial frames.

**Results:** Stereoaucity levels were reduced in proportion to the degree of anisometropia in all patients. One diopter of spherical anisometropia reduced stereoaucity to an average 57-59 arc seconds; 1 D of cylindrical anisometropia reduced stereoaucity to an average 51-56 arc seconds. Three diopters of anisometropia, regardless of type, produced a marked reduction of stereoaucity in all patients.

**Conclusions:** Low levels of anisometropia, both spherical and astigmatic, can have potentially significant adverse effects on high-grade binocular interaction in adults. Foveal suppression, which is directly related to the degree of anisometropia, may be responsible for the loss of stereopsis. The data suggest the effects of anisometropia on stereopsis should be considered in the empiric correction of anisometropic refractive errors in children.


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**INTRODUCTION**

Anisometropia is considered a causal factor in the pathogenesis of amblyopia and strabismus in the developing human eye. It is estimated that as many as 6%-38% of all cases of amblyopia are caused by anisometropia without strabismus, whereas approx-
imately 12%-18% of children with strabismus also have anisometropia.\textsuperscript{1,2} However, data on the prevalence of anisometropia and its complications in children are rare and conflicting. Although it is generally agreed that anisometropic refractive errors should be corrected in patients with established amblyopia or strabismus to ensure optimal visual development and maturation, the exact levels of anisometropia and age at which corrections should be undertaken in otherwise healthy children remain to be determined.

Amblyopia may be defined as a unilateral or bilateral decrease in visual acuity caused by deprivation of form vision, abnormal binocular interaction, or both, for which no organic cause can be detected.\textsuperscript{3} This definition clearly implicates amblyopia as the functional consequence of abnormal visual experience during early developmental plasticity; it does not encompass any abnormalities in binocular vision that also may exist. Normal neural development of binocular cortical cells requires clear and equal retinal images during the critical period of visual development. Research shows that unilateral image blur during the early period of visual development results in loss of binocular function such as fusion and stereopsis.\textsuperscript{4} Thus, it is important to consider the associated effects on binocular vision when establishing guidelines for the empiric management of potentially amblyogenic problems.

Stereo vision is the unique quality of binocular vision that enables depth perception in visual space. It arises from the horizontal retinal image disparity between the two foveas or other corresponding retinal points; differing amounts of such disparity give rise to differing sensations of depth.\textsuperscript{5}

It has been suggested\textsuperscript{6} that empiric correction should be considered for the following anisometric refractive errors: astigmatism >1.5 diopters (D), hyperopia of >1.5 D, and myopia of >3 D. Due to a lack of clinical evidence in support of these recommendations, the potential effects of uncorrected anisometropia on stereopsis were investigated.

In this prospective study, the stereovision levels of experimentally induced anisometropia in binocularly healthy adults were measured. We speculated that the sensory consequences induced by monocular blur in this group might mimic those experienced by the anisometropic young child with an equivalent amount of monocular blur. Although these two populations clearly are not identical, this approach may yield insights into the relationship between anisometropia and stereopsis, as well as identify levels of stereopsis possible in individuals affected by various degrees of anisometropia.

**MATERIALS AND METHODS**

Twenty-one healthy adult volunteers ranging in age from 22-34 years (mean: 27 years) and free of ocular disease participated in the study. The patients were composed primarily of staff members working at Harran University, School of Medicine in Turkey. Informed consent was obtained from each patient before examination. Requirements for participation in the study were: 20/20 best-corrected Snellen visual acuity for each eye in both distance and near, no shift of either eye occurred on cover test for distance or near, stereopsis was 40 arc seconds or better as measured by the polarized Titmus stereotest (Stereo Optical, Chicago, Ill), and volunteers had no history of strabismus or amblyopia. Patients were excluded if they had a heterophoria >4 prism diopters (Δ) while wearing full refractive correction at either a 6-m or 33-cm fixation distance.

During the examination, all patients wore full refractive correction, which was checked before the experiment using the fogging technique to ensure that excessive minus power was not present. In patients who met the inclusion criteria without the need for glasses, trial frames were used to create anisometropia, with the experimental lens placed over the right eye. In patients wearing glasses, the experimental trial lenses were placed in trial frames over the right eye. Cycloplegic retinoscopy was not performed because it was assumed from the preliminary sensory and motor testing and from the non-cycloplegic refraction with fogging that any latent refractive errors would be of small magnitude and not clinically significant.

Four different types of anisometropia were induced in random order by placing the following trial lenses, in 1-D increments ranging from 1-3 D, over the right eye. These were: unilateral myopia (+1, +2, and +3 lenses), unilateral hyperopia (-1, -2, and -3 lenses), unilateral against-the-rule astigmatism (+1, +2, and +3 cylinder, axis 90°), and unilateral oblique astigmatism (+1, +2, and +3 cylinder, axis 45°).

Testing was carried out under normal room lighting conditions. Stereovision was measured
using the Titmus stereotest with patients placing the cross-polarizing stereocuity glasses over their corrective lenses or trial frames. Each patient was instructed before and during the test to identify only those circles that appeared axially displaced and not simply blurred or horizontally shifted. Thus, the effect of memory and monocular clues could be largely eliminated. Each patient’s highest level of stereocuity was recorded in arc seconds of disparity. Stereopereception of the Titmus fly only, and none of the circles, was recorded as a stereocuity of 3000 arc seconds. The statistical analysis was performed using a paired t test to evaluate the differences in stereocuity test results between different levels of anisometropia; P < .05 was considered statistically significant.

RESULTS

Levels of stereocuity were reduced in proportion to the degree of anisometropia (Figure). One diopter of spherical anisometropia reduced stereocuity an average of 57-59 arc seconds. Of the 21 patients, 5 maintained 40 arc seconds of stereocuity with -1 D of spherical anisometropia and 3 maintained 40 arc seconds of stereocuity with +1 D of spherical anisometropia. In contrast, 1 D of cylindrical anisometropia reduced stereocuity to an average of 51 arc seconds for unilateral against-the-rule astigmatism and 56 arc seconds for unilateral oblique astigmatism, with two patients maintaining 40 arc seconds, respectively. Three diopters of anisometropia, regardless of type, produced a marked reduction in stereocuity for all patients. This decrease in stereocuity, which occurred with each diopter increment in anisometropia, regardless of type, was statistically significant (P < .001) for all patients.

DISCUSSION

Although anisometropia is one of the leading causes of amblyopia, the mechanism of anisometropic amblyopia is poorly understood. von Noorden8 suggests that active inhibition of the fovea may eliminate sensory interference caused by superimposition of a focused and a defocused image. Data on the prevalence of anisometropia and its complications in children are both rare and conflicting, with reported incidences ranging from 4.7%2-7.5%9 of children, depending on the population studied and the criteria used. It has been demonstrated previously that anisometropia can cause amblyopia as well as a disruption of binocularity.5 However, the levels of anisometropia that warrant correction in young children and the age at which such correction should be initiated to prevent abnormal visual maturation remain unclear. The answer to this question is critical in preventing and managing amblyopia because ample data support the notion that binocular vision has a discrete neural substrate10 with its own critical period10,11 and requirements for normal development.

To gain insight into this issue, we attempted to determine the levels at which anisometropia would interfere with high-grade binocular vision in adults. Although the exact extrapolation of such data to children is not justified, we believe anisometropia in adults is optically identical to anisometropia in children. We also assume the optical effect of the induced anisometropia promotes the degradation of stereocuity in our adult patients. Although these data do not allow us to make definitive conclusions regarding children, it seems reasonable to speculate that visually immature children with similar levels of uncorrected anisometropia may experience limitations in binocular testing. To relate our study results to children, it is also important to recognize the fact that refractive errors in children, including anisometropia, are in a dynamic state of development throughout the first several years of life,9,12 and this must be considered when determining whether empiric optical correction is warranted in a particular case.
The present study is significant for several reasons. Much of the previous investigation in this area has focused solely on spherical anisometropia\textsuperscript{3} or unilateral atropine penalization,\textsuperscript{13} relating the degree of anisometropia, blur, or resulting visual acuity to stereopsis. In this study, both spherical and astigmatic anisometropic refractive error were investigated and correlated each with stereopsis.

It has been suggested that bifoveal fixation is required to achieve 40 arc seconds of stereocuity or better.\textsuperscript{14} For the purposes of this study, 40 arc seconds of stereopsis on the Titmus stereotest was considered to be indicative of high-grade stereocuity—a level that should be attainable in healthy individuals. This study indicates that as little as 1 D of anisometropia, whether it is unilateral myopia, unilateral hyperopia, unilateral against-the-rule astigmatism, or unilateral oblique astigmatism, has the potential to degrade stereopsis to subnormal levels in visually mature adults. This is in agreement with the findings of Lovasik and Szymkiew\textsuperscript{15} and Brooks et al.\textsuperscript{16} Lovasik and Szymkiew\textsuperscript{15} found a clinically acceptable level of 40 arc seconds of stereocuity could be maintained in some patients with 0.5 D anisometropia on the Titmus test and 1 D of anisometropia on the Randot test. Furthermore, Brooks et al\textsuperscript{16} showed a clinically acceptable level of 40 arc seconds of stereocuity could be maintained in some patients with 1 D of anisometropia on the Titmus test. In these studies,\textsuperscript{15,16} as in ours, considerable variation in susceptibility between individuals was noted. Some of the variability noted in our study may have been due to the use of the Titmus stereotest, as opposed to random dot stereograms.

The Titmus stereotest was used due to its ease of presentation, with the understanding that it may not be sensitive enough to make quantitative measurements of stereocuity or sufficient to detect small differences in stereocuity. The test cannot completely exclude monocular clues or the use of memory to identify correct targets, which can result in falsely high measured stereocuity levels. As described above, we attempted to minimize this problem by carefully instructing patients to identify axially displaced circles only. Data from other investigators show similar reductions in stereopsis using random dot stereograms\textsuperscript{15}; the reduction in stereocuity in our study was highly significant for virtually all increases in anisometropia, suggesting the use of the Titmus stereotest did not bias the results of our study. Although, the precise mechanisms by which anisometropia leads a decrease in stereocuity are not clear, it has been suggested foveal suppression in the defocused eye is the cause of decreased stereopsis. However, other factors, such as contrast and density of fusional detail, may play an important role as well.\textsuperscript{17}

Our data suggest different optical forms of anisometropia differ in their tendency to degrade stereopsis. Spherical anisometropia (unilateral myopia and unilateral hyperopia) was more effective than astigmatic (unilateral against-the-rule astigmatism and unilateral oblique astigmatism) anisometropia in causing deterioration in stereopsis. We speculate this phenomenon may be due to the global blur induced by the spherical lenses as compared with the meridional blur caused by the cylindrical lenses. There were no significant differences in sensory outcome between unilateral against-the-rule astigmatism and unilateral oblique astigmatism.

**CONCLUSION**

Low levels of anisometropia, both spherical and astigmatic, can have a significant adverse effect on high-grade binocular interaction. The mechanisms underlying the loss of stereopsis seem to involve foveal suppression, the extent of which is directly related to the degree of anisometropia. Our results suggest the effects of anisometropia on stereopsis should be considered in the empiric correction of anisometropic refractive errors in children, although our data are not directly applicable to that population. This study may help the development of guidelines in the future.

**REFERENCES**