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The effect of induced blur monocularly and binocularly on stereoacuity

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Background: Stereopsis plays a significant role in our visual system because it allows perception of depth to perform day-to-day activities.

Aim: The aim of this study was to determine the severity and proportions of monocular versus binocular-induced blur on stereoacuity using the Randot® Stereo Test (RST) at near (40 cm).

Setting: Data were collected at the optometry clinic of the University of Johannesburg.

Methods: The study used a cross-sectional, experimental and prospective design with a quantitative approach. Forty university students between the ages of 18 years and 25 years were invited to participate in this study. Blur was induced monocularly and binocularly through 1 dioptre (D) to 3 D lenses and stereoacuity was measured using the RST at near (40 cm).

Results: Stereoacuity measured with the added 1 D to 3 D lenses monocularly and binocularly resulted in reduced stereopsis, which was worse monocularly, found not to be significant (p = 0.17) with the addition of the 1 D lens(es) monocularly and binocularly. Significant reductions in stereoacuity were found with the addition of 2 D (p = 0.00) and 3 D (p = 0.00) monocularly and binocularly, respectively.

Conclusion: The effect of induced optical blur monocularly on stereoacuity impacted significantly compared with induced binocular blur. However, the different accommodative amplitudes could have affected monocularly and binocularly induced stereoacuity for some participants.

Contribution: The study is clinical and focuses on the effect of induced blur monocularly and binocularly on stereoacuity. Key insights are that the effect of induced optical blur monocularly impacted significantly on stereoacuity compared with induced blur binocularly.

Keywords: stereoacuity; isometropia; anisometropia; depth perception; induced blur; retinal disparity; optical blur.

Introduction

Stereopsis is a perceptual phenomenon at the centre of scientific observations after the stereoscope was invented in 1838 by Wheatstone.[1] Our brain uses two-dimensional images from both the left and right eyes, to enable the description of three-dimensional structures. Therefore, this process makes it possible to detect depth as a visual experience using the technique of stereopsis.[2] Differential focusing, image overlap, motion parallax, perspective and shading are some of the monocular cues to depth, while the vergence position of the eyes and binocular disparity are the two exclusive binocular cues to depth. Stereopsis enhances the ability to discriminate depth differences.[3,4]

The ophthalmic and binocular visual integration systems rely heavily on stereoacuity, viewed as the resolving capacity of the visual system.[5] Stereoacuity enables the matching of reality and perception, required for survival and learning in our environments. Binocular vision not only provides binocular depth perception but it also improves performance on tasks such as discrimination, resolution and detection.[4,5] Besides the above-mentioned fundamental tasks, binocular vision enables effective performance of complex visual tasks such as reading, eye–hand coordination and detecting camouflaged objects even in the absence of depth.[5,6] O'Connor discovered that subjects with normal stereoacuity performed better on motor skills tasks than subjects with poor stereoacuity. The study also demonstrated that normal stereoacuity is required for everyday tasks such as pouring water into a jug, inserting a needle into a bead and reading.[6]

One of the cues people utilise to perceive depth is retinal disparity, which is determined by the binocular depth perception, or stereopsis. There are two types of stereopsis: local and global, which vary in the amount of retinal area covered.[7] In this study, the random dot test (RDT) will be used to assess overall stereoacuities. The term 'binocular disparity' describes the variation in image locations and forms between two eyes, induced by the vantage points through which the eyes view the world.[8] Stereoacuity, contrast sensitivity and visual acuity (VA) are only a few of the many visual characteristics that constitute vision.[9] Our lives are growing more dependent on stereoacuity and binocularity because of the demand for 3-D awareness of our motor skills ability.[10] Most of the images we see are best understood through binocularity and stereoacuity. In addition, stereoacuity is necessary for depth perception to carry out many daily tasks and correctly perceive moving objects.[11]

Blur, amblyopia or strabismus interfere with stereoacuity. Anisometropia is one of the prominent visual anomalies causing amblyopia and strabismus in children. The loss of binocular function in people with anisometropia is universally acknowledged.[10,11] Binocularity is anticipated to be more negatively impacted by higher degrees of anisometropia than by lower degrees of anisometropia.[12] Research conducted supports that an uncorrected anisometropic refractive error (RE) can lead to foveal suppression and result in reduced binocular depth perception.[13,14] Furthermore, after producing anisometropia or aniseikonia in adults with healthy binocular vision, experimental studies have documented a significant decrease in stereopsis, although the degree of stereopsis and the severity of anisometropia was found to not significantly correlate.[15]

In a study by Oguz and Oguz[13] on 21 healthy adults ranging in age from 22 years to 34 years, they induced unilateral anisometropia for different types of REs, namely myopia, hyperopia or astigmatism (90/45 degrees). In their study, it was found that a dioptre of induced spherical anisometropia reduced stereoacuity by an average of 57–59 arcseconds (″), while induced cylindrical anisometropia reduced stereoacuity by 51″ – 56″.[12] The findings of the study conducted by Dadeya et al.,[14] which investigated the effect of induced spherical and cylindrical anisometropia, also showed a significant reduction of stereoacuity. Furthermore, the effect of induced blur using the cylindrical and spherical lenses (i.e., positive or negative) was found to lead to the deterioration of stereoacuity, with hypermetropic astigmatism leading to more adverse effects than myopic astigmatism.[13]

According to a study conducted by Hoosen et al.[15] induced binocular blur was found to have reduced proportional to the power of the convex test lens. They concluded that monocularly reduced vision should be considered when screening uncorrected and corrected emmetropes for eligibility of a driver's license. However, a VA of 6/9 or better in at least one eye is the requirement for drivers to qualify for vehicle licenses in South Africa.[16] The determination of the proportional decrease of induced stereoacuity monocularly and binocularly is likely to provide information related to its severity, which could contribute to the reduction of motor vehicle accidents. However, there are still ongoing debates related to reduced vision monocularly or binocularly and their severity on stereoacuity.[17]

Wajuihian and Hasraj,[18,19] in their study investigated the relationship between stereoacuity, refractive status, accommodative and vergence anomalies of South African school children with a mean age 15.89 ± 1.58 years and concluded that accommodative and convergence dysfunctions affected stereoacuity. Furthermore, participants with anisometropia were found to have significantly reduced mean stereoacuities compared to those with emmetropia. Therefore, they concluded that REs, accommodative or vergence anomalies are likely to contribute to the reduction of mean stereoacuity. As a result, they suggested that the Randot® Stereo Test (RST) could be used to identify those with REs, accommodative or vergence anomalies and further supported stereoacuity measurements as a useful tool to screen for binocular anomalies.[18,19] However, the aim of this study was to determine the severity and amount of stereoacuity of induced blur monocularly and binocularly using the RST at near (40 cm).

Methods

The research study was based on cross-sectional and experimental designs with a quantitative approach. A total of 40 participants were invited from university students, aged between 18 years and 26 years, with males (n = 30) and females (n = 10) from different ethnic groups. Recruitment of participants was carried out through social media platforms such as Facebook, Instagram and by word of mouth. The collection of data adhered to the ethics requirements of privacy, confidentiality and anonymity. Code names were allocated to participants to maintain anonymity, the data were collected in an eye testing cubicle by the researcher on the participant, in the absence of any other person and confidentiality was maintained by saving the collected data in a password-coded document only accessible to the researcher and supervisor. Before the commencement of data collection, purposively selected participants were handed the information and consent letter to sign. After signing the consent forms, their visual status was screened to ensure they met the inclusion criteria.

The inclusion criteria for participating in the study was VA of 6/6 or better monocularly and binocularly with or without habitual RE corrected. Participants with REs between ±1 dioptre (D) were invited to participate in the study. Excluded from the study were those with a history of strabismus, ocular pathologies, REs worse than ±1 D and minors. Tests used to screen for eligibility of participants were a comprehensive case history, determination of REs objectively using the autorefractor, cover test (CT) and investigation of ocular health status using the slit lamp and a fundus camera to rule out ocular pathologies. Eligible participants were allocated code names for the purpose of anonymity. Confidentiality was upheld by storing all collected data in a password-encrypted document only accessible to the researcher. Four separate stations were used to collect data. At the first station, the demographic data of participants were collected with one research assistant conducting vision screening to check the VA, and autorefractor and CT were conducted. Baseline stereo acuity was measured (through habitual prescription) and with 1 D-induced monocular and binocular stereoacuities. Three measurements for the baseline and 1 D, 2 D and 3 D-induced monocular and binocular stereoacuities were taken with the average for each category recorded. The final evaluation was of induced monocular and binocular stereoacuities using 2 D and 3 D lenses measured separately. Loose lenses were used with a trial frame to induce optical blur. Stereoacuity was measured at 40 cm as research shows no stereoacuity differences at a distance (5.18 m) and near (40 cm) under normal viewing conditions.[20] A pair of 3 D polarising spectacles were used to allow minimisation of monocular cues.

The RST used had targets with disparities of 400″, 200″, 160″, 100″, 63″, 50″, 40″, 32″, 25″ and 20″ with the highest values representing reduced stereoacuities and lower values demonstrating good stereoacuities. For participants unable to appreciate the difference at maximum disparity 400″, their stereoacuity was recorded as null and they were given an arbitrary value of 600″ for statistical purposes.[9] Consistency was upheld by data collectors with the RST chart held parallel and perpendicular to the participants' line of sight to eliminate monocular cues. No squinting or movements of the stereoacuity booklet for a better view of targets was allowed. The illumination in the testing rooms was not measured but it was kept at the same level by using the same fluorescent lamp throughout the process of data collection to maintain accuracy. Furthermore, the test cubicles where data were collected were completely insulated from ambient light. Participants were instructed to identify stereoscopic circles, and the identified maximum stereo circle was recorded as their stereoacuity.

Data analysis

The results of this study were evaluated for similarities and differences to check for normality of data distribution, medians, means, kurtosis and skewness including standard deviations of measured stereoacuities. Quantitative data were collected and analysed using Microsoft Excel. Data analysis also included graphical methods of box and whisker plots. Spearman's correlation test was used to test the association between stereo acuities of monocularly versus binocularly induced blur compared with baseline stereopsis. Inferential statistics such as *t*-tests and *r*-values were determined to clarify the significance and strength of differences in stereoacuity outcomes compared with baseline, induced blur monocularly and binocularly using the lenses. The criteria used for ranking of results using the RST at near are shown in Table 1.

Ethical considerations

Ethical clearance to conduct this study was obtained from the University of Johannesburg, Faculty of Health Sciences Research Ethics Committee (reference no.: REC-1406-2022).

TABLE 1: Ranking of results for stereoacuity testing in seconds of arc relevant to a paediatric population.

Rank	Description	Stereoacuity (Random Dot E) (seconds of arc)
5	Very strong	≤ 3 0″
4	Strong	31″ – 50″
3	Adequate	51″ – 100″
2	Weak	101″ – 600″
1	Very weak	> 600″

Source: Reproduced from Griffin JR, Grisham JD. Binocular anomalies: Diagnosis and vision therapy. Boston: Butterworth Heinemann Medical, 2002; p. 65

Results

Forty participants with ages ranging from 18 years to 25 years had interpupillary distances (IPD) measured, near point of convergence (NPC), VA, CT and objective REs using the autorefractor for screening purposes. Vision screening tests were used to ensure that those selected to participate in the study had no binocular vision anomalies (strabismus and heterophoria), high REs and poor vision both at distance and near. The collected data were not analysed in terms of gender, age and/or race as the sample was relatively small. The focus of the study was to investigate the effect of induced blur with 1 D, 2 D and 3 D lenses, monocularly (simulating anisometropia) and binocularly (simulating isometropia) on stereoacuity compared with the baseline.

Descriptive statistics for all variables

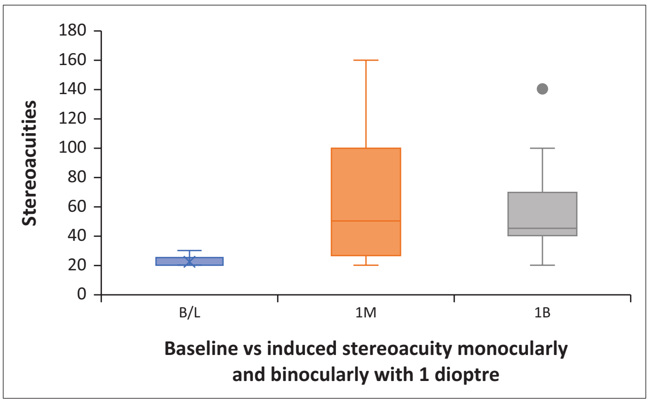
Table 2 shows descriptive statistics of analysed stereoacuities data on baseline and induced blur monocularly and binocularly using 1 D, 2 D and 3 D lenses. Baseline near stereoacuity data collected were spread between 20″ and 30″ with the mode and median of 20″. Therefore, showing that all participants had stereoacuity that fell within the normal ranges. However, the data collected showed high positive skewness of 1.14, with majority of participants found to have 20″ and a mean of 23 ± 4″. The minimum and maximum stereoacuity values were 20″ and 30″, respectively (Table 2). The standard deviation of the baseline stereoacuity was found to be 4″, indicating that the collected data were clustered around the mean.

The means for monocularly induced blur stereoacuities for 1 D, 2 D and 3 D lenses were found to be 67 ± 57″, 192 ± 164″ and 410.6 ± 202″, respectively. The mean of binocularly induced blur stereoacuities was found to be 57 ± 28″, 85.8 ± 70″ and 200 ± 155″, respectively, compared with those for induced blur monocularly. The standard deviation for stereoacuities increased with induced blur monocularly compared with binocularly. Thus, showing a large amount of variation of measured stereoacuities from the mean as the strength of convex lenses was increased. However, the distribution of data for stereoacuities measured through induced blur monocularly and binocularly was found to be positively skewed. The skewness for stereoacuities measured through 2 D lenses monocularly and binocularly were found to be high > 1. A positive kurtosis of 10.1 showing a leptokurtic distribution, indicated more extreme values than the

TABLE 2: Descriptive statistics for baseline stereoacuity versus induced blur monocularly and binocularly through 1 D, 2 D and 3 D lenses on participants (N = 40).

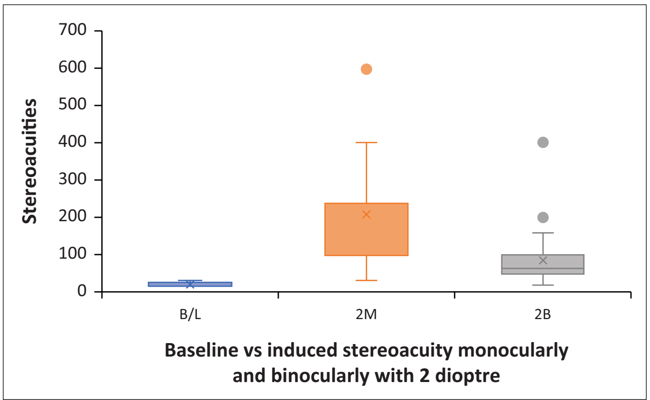
Clinical Measures	Means	Medians	Minima	Maxima	Skewness	Kurtosis
Baseline stereoacuity	23 ± 4	20	20	30	1.14	-1.9
Stereoacuity monocularly with +1.00	68 ± 57	50	20	140	0.86	-0.37
Stereoacuity binocularly with +1.00	57 ± 28	45	20	120	0.93	0.46
Stereoacuity monocularly with +2.00	192 ± 164	163	32	600	1.39	0.87
Stereoacuity binocularly with +2.00	85.8 ± 70	69	20	400	2.77	10.1
Stereoacuity monocularly with +3.00	410.6 ± 202	400	63	600	0.39	-1.57
Stereoacuity binocularly with +3.00	200 ± 155	160	25	600	0.74	-0.68

D, dioptre.



B/L, baseline; 1M, stereoacuity monocularly; 1B, stereoacuity binocularly.

FIGURE 1: Baseline stereoacuities compared with induced blur monocularly and binocularly using 1 dioptre lenses.



B/L, baseline; 2M, stereoacuity monocularly; 2B, stereoacuity binocularly.

FIGURE 2: Baseline stereoacuities compared with induced blur monocularly and binocularly using 2 dioptre lenses.

expected normal probability through induced blur using 2 D lenses binocularly. However, fewer outliers were observed with a low kurtosis of 0.39 for monocular-induced stereoacuities through a 3 D lens.

Baseline stereoacuities compared with induced blur monocularly and binocular using 1 dioptre lenses

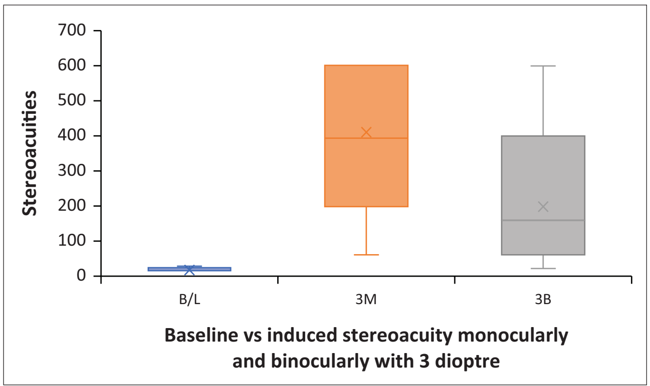
All participants were found to have very strong baseline stereoacuity ≤ 30″ (Figure 1). However, 12.5% (n = 5) participants demonstrated outliers of 160″ for stereoacuities with 1 D lens inducing blur monocularly. The outliers for binocularly induced blur with 1 D lenses were found to be 2.5% (n = 1) also indicating that one participant had weak stereoacuity (Figure 1). Stereoacuity data measured with added 1 D monocularly and binocularly showed positive skewness as demonstrated in Table 2. It is further demonstrated by the shorter whisker on the lower end of the box, confirming probability distribution deviating from symmetrical normal distribution of data collected (Figure 1). The addition of 1 D monocularly, demonstrated radically reduced stereoacuity compared with binocularly induced blur. However, the p-value was found to be > 0.05 (p = 0.17).

Baseline stereoacuities compared with induced blur monocularly and binocularly using 2 dioptre lenses

Stereoacuity levels were found to be reduced in proportion to the degree of induced blur monocularly and binocularly in all participants with added 2 D lenses (Figure 2). However, a majority (57.5%) were found to have good stereo acuities (≤ 50″), with 42.5% reporting adequate stereoacuities (50″ to 100″) for monocularly induced blur. Fewer participants (32.5%) were found to have good stereoacuities (≤ 50″) for binocularly induced blur, with 20% found to have adequate stereoacuities (50″ to 100″) and 17% with weak stereoacuities (101″ to 600″), thus the leptokurtic findings of 10.1, for stereoacuities measured binocularly through 2 D lenses. Furthermore, stereoacuity scores for 2 D lenses inducing blur monocularly were found to be very far from the mean compared with binocularly induced blur (192 ± 164 vs 85.8 ± 70), respectively (Table 1). The finding indicates a very high amount of variability worse with 2 D added monocularly than binocularly. Figure 2 shows positive skewness with the shorter whisker on the lower end of the box for monocularly induced blur stereoacuities compared to those induced binocularly. Thus, showing a probability distribution deviating from the symmetrical normal distribution of data collected. Nonetheless, the stereoacuities of monocularly versus binocularly induced blur with 2 D were found to be significant with the p > 0.05 (p = 0.00). However, the *r-value* indicated a weak correlation (r = 0.45) between stereoacuities measured with blur induced monocularly and binocularly with 2 D lenses.

Baseline stereoacuities compared with induced blur monocularly and binocular using 3 dioptre lenses

Reduced stereoacuity with an average of 200 ± 95″ with 3 D lenses inducing monocular blur was found (Table 1). Adequate stereoacuities (51″ – 100″) were found in 7.5% and a majority (92.5%) had very weak stereoacuities (101″ – 600″). Compared with induced blur binocularly, 5% were found to have very strong stereoacuities (≤30″), 12.5% had adequate stereoacuities



B/L, baseline; 3M, stereoacuity monocularly; 3B, stereoacuity binocularly.

FIGURE 3: Baseline stereoacuities compared with induced blur monocularly and binocularly using 3 dioptre lenses.

(51″ – 100″) and 82.5% were found to have weak to very weak > 100″ to 600″ (Figure 3). Therefore, this demonstrates that the addition of 3D monocularly and binocularly reduced stereoacuity significantly (p = 0.00). However, the correlation between monocularly and binocularly induced stereoacuities was found to be weak with r = 0.22. Interestingly, 10% of the study participants had stereoacuities similar to their baseline despite the inducement of binocular blur with 3 D lenses. However, the very same participants to the contrary showed decreased stereopsis of 600″ monocularly.

Discussion

The findings of this study were found to be consistent with those of other studies that measured the effect of reduced vision monocularly (simulating anisometropia) on stereoacuity and concluded that the reduction of stereopsis increased proportionately to the increased power of plus lenses.[12,13,14,15,16,17] Even though the other studies measured stereoacuity using local targets (RST), the final findings are consistent with those of this study. However, in this study, the focus was not only on induced blur monocularly (simulating anisometropia) but also on comparing it with binocularly induced blur (simulating isometropia).

The results of this study were further found to be consistent with those of the study conducted by Yang et al.,[21] who found complete loss of stereopsis in patients with spherical hypermetropia > 3 D. Although their study participants had different types of REs including astigmatism, myopia and hyperopia. Contrary to the findings of this study in which myopic blur shift was induced using 1 D, 2 D and 3 D lenses, and other REs such as astigmatism including hyperopic blur shift were not considered.

In this study, inducing blur with 1 D lens resulted in a significant reduction in stereoacuity. However, the association between the induced blur monocularly and binocularly with 1 D and baseline stereoacuity was found to be not significant (p = 0.17). Contrary to the findings of the study conducted by Brooks et al.,[22] in which inducing of blur using 1 D lenses was found to have caused a significant reduction in stereoacuity. However, this could be attributed to the age of their participants between 26 years and 59 years and a TNO Stereo Test (TST) was used to measure the stereoacuities. Poor amplitudes of accommodation could have contributed to their study findings because accommodation dysfunctions were also found to impact on stereoacuities.[19,20]

Even though in this study significant associations (p = 0.00) between induced blur monocularly and binocularly using the 2 D and 3 D lenses were found, their correlation was found to be weak with r = 0.45 and 0.22, respectively. Contrary to the findings of the study conducted by Yang et al.,[21] which found a significant correlation between different groups of spherical errors and stereoacuity measured and thus concluded that high hyperopia (> 3 D) severely reduced stereoacuity. Nevertheless, Yang et al.'s[21] study was conducted on participants with real REs that were not induced compared with this study.

The findings of a study conducted by Singh et al.,[23] which investigated the effects of induced monocular blur with 3 D on surgical tasks in a simulated environment were found to be consistent with those of our study. Therefore, they concluded that induced blur monocularly was associated with a significant reduction of stereopsis in surgical task scores. A significant positive correlation between the level of stereoacuity, measured using Stereo Test (TNO) and Randot® Stereo Test (RTS) versus the surgical task scores was found. Consistent with the findings of our study, which found a weak correlation of r = 0.51 when 1 D was used to induce blur monocularly and binocularly, even though it was found to be significant with 2 D and 3 D lenses. However, the differences between our study and that of Singh et al.[23] could be that our study was not conducted in a simulated environment.

In this study, addition of higher plus lenses (1 D, 2 D and 3 D) monocularly resulted in significantly reduced mean stereoacuity compared with when added binocularly. This led to the conclusion that there is some clinical significance between the two stereoacuity measurements with plus lenses added monocularly and binocularly.

Limitations of the study

One limitation of this study is that the screening tests did not include the evaluation of the accommodative amplitudes. Some participants could have had low amplitudes compared with the others, thus the discrepancy in the measurements of stereoacuities because they were only measured at near. The screening tests for visual anomalies only considered the autorefractor results and subjective refraction determining the true status of the REs could give a true reflection of our findings.

Conclusion

The effect of induced optical blur monocularly impacted to a greater extent on stereoacuity compared with binocular-induced blur.

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Competing interests

The author declares that she has no financial or personal relationships that may have inappropriately influenced her in writing this article.

Author's contributions

T.I.M. contributed towards the conceptualisation, methodology, write-up, and analysis of the collected data for the research article.

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Data availability

The data that support the findings of this study are available on request from the corresponding author, T.I.M.

Disclaimer

The views and opinions expressed in this article are those of the author and do not reflect the official policy or position any affiliated agency of the author.

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