DOI: 10.5455/msm.2025.37.37-42
Received: Feb 02 2025; Accepted: Mar 06, 2025

ORIGINAL PAPER Mater Sociomed. 2025; 37(1): 37-42

Depth Perception and Intraocular Differences in Visual Acuities Among Older Spectacle Wearers

Ivana Mravicic[1], Selma Lukacevic[1], Ante Barisic[1], Sudi Patel[1], Alma Biscevic[1,2], Melisa Ahmedbegovic-Pjano[2], Nikica Gabric[1]

[1]1Eye Clinic "Svjetlost", Zagreb, Medical School University of Rijeka, Croatia

[2]Specialty Eye Hospital Svjetlost, Sarajevo, Bosnia and Herzegovina

Corresponding author: Ivana Mravicic, Assoc Prof, PhD, MD, Eye Clinic "Svjetlost", Medical School University of Rijeka, Heinzelova 39, 10 000 Zagreb, Croatia, E-mail: ivana.mravicic@svjetlost.hr. ORCID ID: 0000-0001-7545-9922

ABSTRACT
Background: Falls impose a heavy financial burden on society, and the incidence is age-related. The correction of refractive errors has been mooted as a valuable procedure to prevent falls. However, depth perception, estimated by stereo acuity tests, is reduced in the older population and has been cited as contributing to the higher incidence of falls in the elderly. **Objective:** To explore the clinical relationship between age, interocular differences in the corrected distance and near logMAR visual acuities, refractive errors, axial (eyeball) lengths, pupil sizes, and higher-order ocular aberrations (HOAs) on clinical measures of stereoacuity and aniseikonia in asymptomatic presbyopic habitual spectacle wearers. **Methods**: Total amount of 91 subjects underwent clinical assessment of i) subjective refractive error, ii) stereoacuity at 6m and 40cm (Randot Stereotests), iii) aniseikonia at 6m (Awaya test along vertical and horizontal meridian) iv) higher order aberrations (Hartman-Shack aberrometer) v) eyeball length and pupil size (IOL master 700). The Pythagorean theorem was applied to each pair of aniseikonia values to calculate the resultant aniseikonia (AR). **Results:** Mean (±sd,95%CI) age of the subjects was 56.2years (±8.10,54.6-57.9). Root mean square (RMS) interocular differences (±sd,95%CI) in spherical refractive errors, axial lengths and pupil sizes were 0.66D(±0.93,0.47-0.85), 0.24mm (±0.33,0.17-0.31), 0.15mm (±0.11,0.12-0.17). The median (mode, interquartile range) values for AR were 2.8(1.0,1.3-4.0). Significant correlations ($p<.01$) were revealed between: a) log distance stereoacuity (y1), age (x1) and RMS difference in the corrected distance logMAR visual acuity (x2). b) log near stereoacuity (y2), RMS differences in the corrected distance (x2) and near visual acuities (x3). These key associations are best described by: $y1=0.011x1+1.101x2+1.553$ ($r^2=0.169$, n=91); $y2=1.715x2+1.883x3+1.725$ ($r^2 = 0.239$, n=91). **Conclusion**: Stereoacuity is age-related, influenced by interocular differences in the corrected visual acuities but not related to interocular differences in pupil sizes, HOAs or clinical measures of aniseikonia in older habitual spectacle wearers. Assessment of stereoacuity and aniseikonia, in older persons is useful when advising to prevent accidental mis-location and falls.

Keywords: Stereoacuity, visual acuity, aniseikonia, presbyopia, quality of life.

1. BACKGROUND

Falls impose a heavy financial burden on society, and the incidence is age-related (1-3). The correction of refractive errors has been mooted as a valuable procedure to prevent falls (3, 4). However, depth perception, estimated by stereo acuity tests, is reduced in the older population and has been cited as contributing to the higher incidence of falls in the elderly (3-8). A person relies on various cues besides stereoacuity to prevent falling over. Nevertheless, several factors have been cited for influencing stereoacuity, including aniseikonia and interocular differences in visual acuity (9-11). Aniseikonia describes the condition when the two retinal images are unequal in size and/or shape (12). Therefore, increasing the disparity between the retinal images should enhance aniseikonia and reduce stereoacuity. Interocular differences in the refractive errors and axial lengths augment this disparity and carry the potential to reduce stereoacuity (7-11). Inter-ocular differences of the more complex higher-order optical aberrations of the eyes (HOAs) have been cited as affecting aniseikonia (13). The magnitude of HOAs depends on pupil size, so interocular differences in HOAs and pupil sizes could also affect stereoacuity. HOAs, pupil sizes, and axial lengths are measured objectively; stereoacuity, aniseikonia, and visual acuities are measured subjectively, and refractive errors can be measured both objectively (by autorefractometry) and subjectively (by refraction).

Hence, interocular differences evaluated by objective tests may contribute to any association between the subjective measures of stereoacuity and age. If a correlation between stereoacuity and age occurs in asymptomatic older people in the absence of other interocular differences, then by process of elimination, the likely cause may be related to other perceptual factors.

2. OBJECTIVE

The aim of this study was to determine if there were detectable relationships between clinical measures of stereoacuity and age in habitual spectacle-wearing presbyopes free of any symptoms linked to binocular vision and to determine if the stereoacuity correlated with aniseikonia, interocular differences in refractive error, HOAs, pupil size, and visual acuities.

3. MATERIAL AND METHODS

Study Design

A partially masked, semi-randomized, case-by-case, clinical investigation, approved by the Ethics committee at the Specialty Eye Hospital Svjetlost in Zagreb. The tenets of the Helsinki agreement were followed throughout. All subjects provided signed consent after they were fully informed of the purpose of the study. All subjects were examined, where appropriate, by the same clinical team. The subjects were patients attending for routine eye examinations.

Inclusion Criteria

Subjects with significant distance refractive error (sphere and/or astigmatic correction outside the range ±0.50D), requiring a presbyopic correction, free of any signs or symptoms associated with binocular vision anomalies and corrected distance visual acuity of logMAR 0.3 or better.

Exclusion Criteria

Subjects with a history of ocular surgery, binocular vision anomalies, systemic conditions known to affect quality of mono- or binocular vision, corneal dystrophies, glaucoma, macular disease, retinopathy, orthoptic treatment, tropias, amblyopia, anisocoria, irregular pupils, anisometropia >2D sphere and/or astigmatism >1D, or corrected distance visual acuity worse than logMAR 0.3, were excluded.

Refraction

All subjects underwent subjective refraction, and astigmatism was assessed using a Jackson cross-cylinder. The best corrected logMAR visual acuity was measured using distance and near charts (CSO Visio Chart Mod. CVC 01, Firenze, Italy).

Stereoacuity

Stereoacuity, with the subject's best spectacle correction in place, was assessed at distance with a Randot Stereotest having a range from 20 to 640 arcsecs (") in steps of 20" [CSO, Visio Chart CVC03 v2.0.0, Firenze, Italy], then at 40cm with a binocular +2.50D near addition in place using a near Randot Stereotest with a range from 20 to 400" in steps of 20" [Precision Vision, Woodstock, USA]. These tests are stereograms constructed using a polarizing vectograph process resulting in a disparity between binocularly viewed targets. The just noticeable change in stereoacuity associated with these tests is 20" or more. The subject was asked to point out which target stood out as appearing either closer or further away from the rest, whilst wearing the test cross-polarized glasses. The test was halted once the subject made two consecutive errors. The stereoacuity value recorded was the value of the setting where the subject correctly identified the target (closer or further away) prior to making the two mistakes.

Aniseikonia

Aniseikonia was measured at 6m using the Awaya test (14) with the subject wearing customised red-green glasses over their spectacle correction. The subject was asked to look at two red and green vertically orientated semi-circles of different sizes, the size of one of the semi-circles was adjusted until the subject reported they both appeared to be the same size. The changes in size in this test are in steps of 1%, therefore the noticeable value of aniseikonia is 1% or more. The magnitude of aniseikonia was the size of the image viewed by the right eye as a percentage (larger or smaller) compared with the size of the image viewed by the left eye. The percentage value of any aniseikonia was recorded as positive when the semi-circle seen by the right eye was larger than the semi-circle seen by the left eye, and negative if it was smaller. The test is constructed to measure aniseikonia in the vertical meridian. The test was modified to measure aniseikonia along the vertical meridian then the horizontal meridian.

Axial Length and Pupil Diameter

The eyeball lengths and pupil diameters were measured using IOL master 700 (Carl Zeiss Meditec AG, Jena, Germany). The mean value of 6 consecutive readings, each separated by a blink, were recorded for the right eye then the left.

Abberometry

The ocular higher order aberrations (HOAs) were measured using an aberrometer based on Hartman-Shack principles (L80 wave+TM, Luneau SAS, Prunay-le-Gillon, France). The subject was dark adapted for at least ten minutes to allow the pupils to dilate naturally prior to measurement of HOAs. The specific HOAs recorded were coma, trefoil and spherical aberration for pupil diameters of 3mm and 5mm. Three consecutive

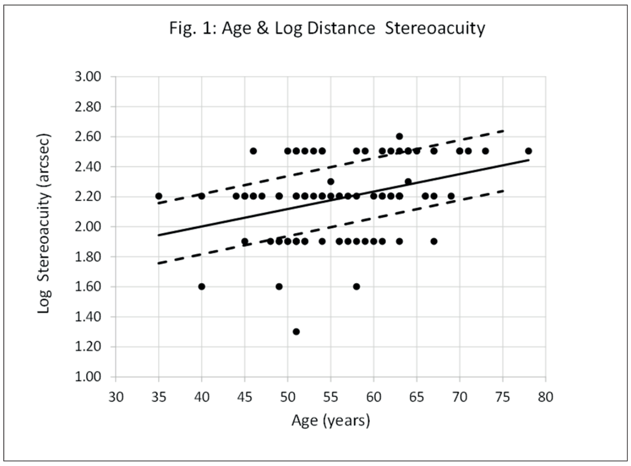

Figure 1 Age and log distance stereoacuity. The solid line represents the linear relationship between subject age (years) and log distance stereoacuity (arcsec). The equation of this line is, y = 0.012x + 1.537 (r2= 0.131, p<.01, n=91). The hatched lines represent the upper and lower 95% confidence limits of this line. There was no significant correlation between subject age and log near stereoacuity (p=.106).

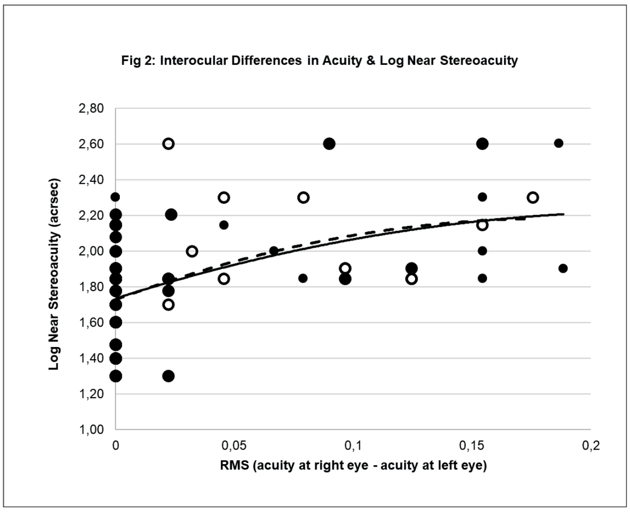

Figure 2 RMS interocular difference in the corrected visual acuities and near stereoacuity. Empty circles represent interocular differences in distance acuities and empty circles represent the differences in near acuities. The solid line represents the relationship between RMS interocular difference in the corrected distance visual acuity (x) and log near stereoacuity (y). The equation of this line is, y = 1.735+ 4.227x -9.152x2 (r^2 = 0.204, p<.01, n=91). The hatched line represents the relationship between RMS interocular difference in the corrected near visual acuity (x1) and log near stereoacuity (y). The equation of this line is, y = 1.727+ 4.951x1 -13.463x12 (r^2 = 0.204, p<.01, n=91). NB, larger filled circles represent cases where distance and near data points overlap.

readings, separated by a blink, were taken for the right eye then the left. For each eye, the average values for coma, trefoil and spherical aberration for 3mm and 5mm pupils were recorded for later analysis.

Data and Statistical Analysis

All data were stored on an Excel spreadsheet [Microsoft, Redmond, WA] prior to analysis.

Treatment of Refractive Data

Each spectacle prescription was reduced to the corresponding B, M, J0 and J45 vectors, in accordance with standard methods thoroughly described elsewhere (15, 16). The interocular differences in refractive errors (or anisometropia) are indicated by ΔB, ΔM, ΔJ0 and ΔJ45

Treatment of Aniseikonia Data

The vertical and horizontal measurements of aniseikonia can be used to draw the corresponding sides of a right-angled triangle and the length of the hypotenuse can be interpreted as a single figure representing the resultant aniseikonia experienced by the subject. The Pythagorean theorem was applied to individual pairs of vertical and horizontal measures of aniseikonia to derive the resultant aniseikonia perceived by the subject.

Data were assessed to determine the significance of any association, where appropriate, using either Spearman's rho [rs] or Pearson correlation coefficient [r], between:

1) Stereoacuity, at distance and near, and i) subject age; ii) aniseikonia; iii) anisometropia as indicated by the ΔB, ΔM, ΔJ0, and ΔJ45 difference vectors; iv) interocular differences in HOAs, eyeball lengths, pupil diameters or corrected visual acuities.

2) Aniseikonia and i) subject age, ii) anisometropia as indicated by the ΔB, ΔM, ΔJ0, and ΔJ45 difference vectors; iii) interocular differences in HOAs, eyeball lengths, pupil diameters or corrected visual acuities.

In addition, data would be subjected to multiple linear regression if stereoacuity and/or aniseikonia values were significantly associated with more than one factor. Data sets were assessed for normality using the Kolmogorov Smirnov test and subjected to non-parametric tests where appropriate. A comparison was considered statistically significant when p<.05. This was adjusted using Holm's modification of the basic Bonferroni correction (17).

	OD	OS	RMS Δ
Sphere	0.62(±2.50, 0.11-1.13)	0.62(±2.50, 0.11-1.13)	0.66(±0.93, 0.47-0.85)
Astigmatic power	0.87(±0.70, 0.73-1.01)	0.87(±0.70, 0.73-1.01)	0.17(±0.27, 0.11-0.23)
Astigmatic axis	101.5(±67.5, 87.7-115.4)	113.7(±61. 0,101.1-126.2)	36.7(±59.1, 24.4-49.0)
Axial length	23.27(±1.19, 23.03-23.51)	23.23(±1.22, 22.98-23.48)	0.24(±0.33, 0.17-0.31)
Pupil diameter	2.83(±0.46, 2.73-2.93)	2.84(±0.42, 2.75-2.93)	0.15(±0.11, 0.12-0.17)
CDVA	0.00,0.00 (0.00-0.02)	0.00,0.00 (0.00-0.02)	0.02(±0.05, 0.01-0.03)
CNVA	0.00,0.00 (0.00-0.05)	0.00,0.00 (0.00-0.00)	0.02(±0.04, 0.01-0.03)

Table 1 Breakdown of all refractive errors, axial lengths, corrected distance and near acuities (n=91). Mean (±sd, 95% CI) sphere and astigmatic powers values in diopters, astigmatic axis values in degrees, axial lengths and pupil diameters in mm. Median and mode (interquartile range) of corrected distance (CDVA) and near (CNVA) logMAR visual acuities are shown. None of the interocular differences were significant (where appropriate, either paired t-test or Wilcoxon signed rank test, p>.05). The root mean (±sd, 95% CI) square differences between right (OD) and left (OS) eyes are listed under RMS Δ.

Test	Me, Mo, IQ
Distance Stereoacuity	160, 160, (80-320)
Near Stereoacuity	70, 70, (40-80)
Aniseikonia Vertical	0.0, -1.0, (-1.0 to +1.0)
Aniseikonia Horizontal	0.0, 0.0, (-1.0 to +1.0)
Total Resultant Aniseikonia	2.8, 1.0, (1.3 to 4.0)

Table 2 Breakdown of stereoacuity and aniseikonia. Legend: Median (Me) and mode (Mo) values of distance and near stereoacuity (arcsec), vertical horizontal and resultant aniseikonia (%) values are shown with the corresponding interquartile ranges (IQ) in parentheses.

The variance inflation factors (VIF) for both x1 and x2 were 1.011.

The association between log near stereoacuity (y2), x2 and RMS interocular difference in the corrected logMAR near visual acuities (x3) is described by:

y2=1.715x2+1.883x3+1.725

(r^2=0.239,p<.01;r^2 for x2=0.200,p<.01;r^2 for x3=0.198,p<.01; n=91). (eq.2)

The variance inflation factors (VIF) for both x2 and x3 were 1.813.

4. RESULTS

Ninety-one subjects, 61 females and 30 males, were recruited during this study. The mean (±sd, 95% CI) age of the subjects was 56.2 years (±8.10, 54.6 to 57.9). Chief details of the refractive errors, the corrected visual acuities, stereoacuities (distance and near), aniseikonia (vertical, horizontal, and resultant), eyeball lengths, HOAs and results of vector analysis are shown in Tables 1-4. The ranges of distance sphere and astigmatic powers, in positive format, were -13.00DS to +5.00DS and 0.00DC to +4.00DC respectively.

	OD	OS	RMS ΔHOA
For 3mm pupil			
Coma	0.05(±0.05, 0.04-0.06)	0.05(±0.05,0.04-0.06)	0.04(±0.06,0.03-0.05)
Trefoil	0.05(±0.06,0.04-0.06)	0.05(±0.04,0.04-0.06)	0.03(±0.06,0.02-0.04)
Sph Aberr	0.01(±0.05, 0.00-0.02)	0.01(±0.04,0.00-0.02)	0.02(±0.04,0.01-0.03)
For 5mm pupil			
Coma	0.11(±0.11,0.09-0.13)	0.12(±0.08,0.10-0.14)	0.08(±0.10,0.06-0.10)
Trefoil	0.10(±0.10,0.08-0.12)	0.10(±0.07,0.10-0.12)	0.06(±0.10,0.04-0.08)
Sph Aberr	0.04(±0.07,0.03-0.06)	0.03(±0.07,0.02-0.04)	0.04(±0.05.02-0.05)

Table 3 Breakdown of higher order abberations Legend: Mean (±sd, 95% CI) values of the three higher order aberrations (HOA in units of μm) for right (OD) and left (OS) eyes, and root mean square interocular differences are listed under RMS Δ HOA. RMS ΔHOA = √ [(value of HOA at right eye – value of HOA at left eye)2]. Sph Aberr is the abbreviation for spherical aberration. Apparent interocular differences of mean coma, trefoil and spherical aberration were not significant (paired t-test, p>.05 for 3mm & 5mm pupil sizes).

	OD	OS	RMS Δ
M	0.55(±2.87,-0.22 to 1.32)	0.85(±2.63,0.14 to 1.56)	0.88(±1.04,0.59 to 1.17)
J_0	0.08(±0.42,-0.04 to 0.19)	0.05(±0.50,-0.08 to 0.18)	0.15(±0.13,0.12 to 0.19)
J_{45}	0.04(±0.26,-0.03 to 0.11)	0.01(±0.28,-0.0 to 0.09)	0.22(±0.34,0.13 to 0.31)
B	2.27(±1.88,1.76 to 2.78)	2.54(±2.03,1.99 to 3.09)	1.08(±1.30,0.73 to 1.43)

Table 4 Cases where astigmatism was present (n=53). Legend: Vectorial representations of refractive errors in the cases where astigmatism was present Mean (±sd, 95% CI) values of M, J0, J0 and B for right (OD) and left (OS) eyes, and the root mean square interocular differences (RMS Δ) of M, J0, J0 and B are shown. Apparent interocular differences of mean M, J0, J45 and B values were not significant (paired t-test, p>.05).

Stereoacuity

Figure 1 shows there was a significant association between age and log distance stereoacuity acuity (Spearman Rank rs = 0.372, p<.01), but not between age and near stereoacuity acuity (Spearman Rank rs = 0.169, p=.106). The least squares regression line describing the relationship between age and log distance stereoacuity acuity is shown in Figure 1.

Stereoacuity (both distance and near) and aniseikonia were not associated with any descriptors of anisometropia, root mean square (RMS) interocular differences in axial lengths, pupil diameters or HOAs (p>0.05). Application of the Holm's sequential Bonferroni procedure (13) revealed significant correlations between,

a) log distance stereoacuity and age (p<0.01), the RMS interocular difference in the corrected logMAR distance visual acuities (Spearman Rank rs = 0.246, p=.036),

b) log near stereoacuity and RMS interocular difference in the corrected logMAR distance (Spearman Rank rs = 0.400, p<.01), and near visual acuities (Spearman Rank rs = 0.421, p<0.01).

Multiple-linear regression revealed the association between log distance stereoacuity (y1), age (x1) and RMS interocular difference in the corrected logMAR distance visual acuities (x2) is described by:

y1=0.011x1+1.101x2+1.553

(r^2=0.169,p<.01;r^2 for x1=0.131,p<.01;r^2 for x2=0.054,p=.026;n=91). (eq.1)

Figure 2 shows the best fit least squares single regression lines describing the relationships between, y2 & x2, and y2 & x3. These are described by:

y2 = 1.735 + 4.227x2 - 9.152x22 (r^2 = 0.204, p<.01, n=91) (eq.3)

y2 = 1.728 + 4.951x3 - 13.463x32 (r^2 = 0.204, p<.01, n=91) (eq.4)

Aniseikonia

Linear regression analysis did not reveal any meaningful associations between aniseikonia and age, any descriptors of anisometropia, interocular differences in eyeball lengths, pupil diameters or HOAs.

5. DISCUSSION

The association between distance stereoacuity and age, as shown in Figure 1, supports previous findings (5-8). Tables 1,3 and 4 show there were no significant inter-ocular differences in the refractive errors, axial lengths, pupil diameters, CDVA, CNV, HOAs and descriptors of anisometropia. Furthermore, the RMS interocular differences in the objectively derived measurements were not associated with either stereoacuity or aniseikonia. These objective measurements cannot predict stereoacuity in asymptomatic older subjects. Table 2 shows the interquartile ranges of aniseikonia were similar to the ±2% range of repeatability of the Awaya test for aniseikonia (18, 19). Thus, the aniseikonia of the subjects included in this study should have negligible influence on the measurement of stereoacuity.

The measurement of stereoacuity can be instrument dependent (20). This is not unusual considering the outcomes of subjective tests depend on factors such as prevailing test conditions, intricacies of instrument design, subject alertness, duration of the test, the process used to elicit responses from subjects and ambient factors (19, 21, 22). Yet, stereoacuity was confirmed to be significantly associated with the interocular differences in the corrected visual acuities.

The mean pupil sizes vary between 2.6mm and 3.5mm in presbyopes when reading under well-lit conditions (23). Table 1 shows the pupil diameters of the subjects assessed during the study fell within this range and none of the subjects had any obvious signs of anisocoria or irregular pupil shapes.

Near stereoacuity was influenced by interocular differences in both corrected distance and near visual acuities. Figure 2 shows there was a gradual decline in near stereoacuity as the gap between right and left eye corrected acuities widened. This further supports previous findings though these other reports were more centered on interocular differences in retinal blur rather than visual acuity (7, 8, 10, 11). This depends on our understanding and definition of blur. Interocular differences in low contrast acuity, or contrast sensitivity curves, could be considered as indicative of interocular differences in blur may also be associated with stereoacuity. A drawback of this investigation is that neither low contrast acuity measurements nor contrast sensitivity assessments were considered from the outset. Horwood (24) claimed that 'Blur is the subjective awareness that the edges of a high contrast image are indistinct.' Differences in high contrast acuity can be considered as differences in blur. Therefore, it is reasonable to interpret the associations between stereoacuity and interocular differences in acuity as indicative of the relationship between stereoacuity and interocular differences in blur.

One of the axioms governing regression analysis is the dependant variable (x) is standardized, that is, controlled. Clearly, Figures 1 and 2 show there maybe trends between stereoacuity, age and interocular differences in the corrected visual acuities, and the corresponding rs values confirm the significance of some of these trends.

Hence, it is practical to apply linear regression analysis to determine some form of valuation that signifies the relevance of any combination of trends.

The value of r2 in eq.1 implies that age and interocular differences in the corrected distance visual acuities contribute towards 17% of the variance in distance stereoacuity, and the value of r2 in eq.2 suggests the interocular differences in the corrected visual acuities account for about 24% of the variance in near stereoacuity. A rise of interocular differences in the corrected visual acuities reduces the clinical measurement of stereoacuity, but other factors are also affecting this measurement.

For eqs 1 and 2, the variance inflation factors (VIF) for age and interocular differences in CDVA and CNVA were all below 2.0. The likelihood of a multicollinearity problem affecting the estimation of distance and near log stereoacuities using age and the interocular differences in CDVA and CNVA is negligible (25). Thus, age and the interocular differences in CDVA and CNVA can be considered as independent variables when estimating distance and near log stereoacuities.

Eq.1 predicts distance stereoacuity values of 98.5" and 270" at ages of 40 and 80 years when the interocular difference in the distance corrected visual acuities is zero. Distance depth perception is approximately halved over a span of 400 years. This change is not related to any of the ocular factors considered in the study.

6. CONCLUSION

These values increase respectively to 210" and 580" for a difference in corrected visual acuities of 0.3 (≈20/40). Eq. 2 predicts near stereoacuity of 53" when the interocular difference in corrected distance and near visual acuities are zero. The near stereoacuity deteriorates to 637" when interocular differences in the corrected distance and near visual acuities are 0.3. Such differences in the perception of depth may predispose aged individual to mislocate objects in visual space and, in extreme cases, misstep leading to falls.

- **Patient Consent Form:** All participants were informed about subject of the study.
- **Authors conribution:** The all authors were involved in all steps of preparation this article. Final proofreading was made by the first author.
- **Conflict of interest:** The authors declare no conflict of interests.
- **Financial support and sponsorship:** This study was self-financed.

REFERENCES

1. Heinrich S, Rapp K, Rissmann U, Becker C, König HH. Cost of falls in old age: a systematic review. Osteoporos Int. 2010 Jun; 21(6): 891-902. doi: 10.1007/s00198-009-1100-1. Epub 2009 Nov 19. PMID: 19924496.
2. James SL, Lucchesi LR, Bisignano C, et al The global burden of falls: global, regional and national estimates of morbidity and mortality from the Global Burden of Disease Study 2017. Inj Prev. 2020 Oct; 26(Supp 1): i3-i11. doi: 10.1136/injuryprev-2019-043286. Epub 2020 Jan 15. PMID: 31941758; PMCID: PMC7571347.
3. Saftari LN, Kwon OS. Ageing vision and falls: a review. J Physiol Anthropol. 2018 Apr 23; 37(1): 11. doi: 10.1186/s40101-018-0170-1. PMID: 29685171; PMCID: PMC5913798.
4. Mehta J, Czanner G, Harding S, Newsham D, Robinson J. Visual risk factors for falls in older adults: a case-

control study. BMC Geriatr. 2022 Feb 17; 22(1): 134. doi: 10.1186/s12877-022-02784-3. PMID: 35177024; PMCID: PMC8855581.
5. Garnham L, Sloper JJ. Effect of age on adult stereoacuity as measured by different types of stereotest. Br J Ophthalmol 2006; 90(1): 91-95. doi: 10.1136/bjo.2005.077719. PMID: 16361675; PMCID: PMC1856927.
6. Lee SY, Koo NK. Change of stereoacuity with aging in normal eyes. Korean J Ophthalmol 2005; 19(2): 136-139. doi: 10.3341/kjo.2005.19.2.136. PMID: 15988931.
7. Costa MF, Moreira SM, Hamer RD, Ventura DF. Effects of age and optical blur on real depth stereoacuity. Ophthalmic Physiol Opt 2010; 30(5): 660-666. doi: 10.1111/j.1475-1313.2010.00750.x. PMID: 20883352.
8. Schmidt PP. Sensitivity of random dot stereoacuity and Snellen acuity to optical blur. Optom Vis Sci. 1994; 71(7): 466-471.
9. Menon V, Bansal A, Prakash P. Randot stereoacuity at various binocular combinations of Snellen acuity. Indian J Ophthalmol. 1997; 45(3): 169-171.
10. Lovasik JV, Szymkiw M. Effects of aniseikonia, anisometropia, accommodation, retinal illuminance, and pupil size on stereopsis. Invest Ophthalmol Vis Sci. 1985; 26: 741-750.
11. Atchison DA, Schmid KL, Haley EC, et al. Comparison of blur and magnification effects on stereopsis: overall and meridional, monocularly- and binocularly-induced. Ophthalmic Physiol Opt. 2020; 40(5): 660-668.
12. Borish IM. Anisometropia and Aniseikonia. In: Clinical Refraction. 3rd ed. Professional Press Inc Chicago; 1970: p270.
13. Jiménez JR, Castro JJ, Jiménez R, Hita E. Interocular differences in higher-order aberrations on binocular visual performance. Optom Vis Sci. 2008 Mar; 85(3): 174-179. doi: 10.1097/OPX.0b013e31816445a7.
14. Awaya S, Sugawara M, Horibe F, et al. The new aniseikonia tests and its clinical applications. Nippon Ganka Gakkai Zasshi. 1982; 86: 217-222.
15. Thibos LN, Wheeler W, Horner D. Power vectors: an application of Fourier analysis to the description and statistical analysis of refractive error. Optom Vis Sci. 1997; 74(6): 367-375.
16. Thibos LN, Horner D. Power vector analysis of the optical outcome of refractive surgery. J Cataract Refract Surg. 2001; 27(1): 80-85.
17. Holm, S. (1979). A simple sequentially rejective multiple test procedure. Scandinavian Journal of Statistics. 1979; 6(2): 65–70.
18. Antona B, Barra F, Barrio A, et al. Validity and repeatability of a new test for aniseikonia. Invest Ophthalmol Vis Sci. 2001; 48(1): 58-62.
19. Rutstein RP, Corliss DA, Fullard RJ. Comparison of aniseikonia as measured by the aniseikonia inspector and the space eikonometer. Optom Vis Sci. 2006; 83(11): 836-842.
20. Zhang Y, Meng B, Wu H. Evaluating the Mechanism by Which the TNO Stereo Test Overestimates Stereo Thresholds. J Ophthalmol. 2021; 18; 2021: 6665638.
21. Larson WL, Lachance A. Stereoscopic acuity with induced refractive errors. Am J Optom Physiol Opt. 1983; 60(6): 509-513.
22. García-Pérez MA, Peli E. Aniseikonia Tests: The Role of Viewing Mode, Response Bias, and Size-Color Illusions. Transl Vis Sci Technol. 2015; 11; 4(3): 9.
23. Koch DD, Samuelson SW, Haft EA, et al. Pupillary size and responsiveness. Implications for selection of a bifocal intraocular lens. Ophthalmology. 1991 Jul; 98(7): 1030-1035.
24. Horwood AM. When Does Blur Matter? A Narrative Review and Commentary. J Binocul Vis Ocul Motil. 2022 Apr-Jun; 72(2): 57-68. Epub 2022 Feb 14. PMID: 35157555.
25. Allison P. Multiple Regression: A Primer. Thousand Oaks: Pine Forge Press; 1999: 142.