Original Article

Role of improved distance and near visual acuity with low vision aids to enhance stereopsis in retinal diseases

Punita Kumari Sodhi, Akanksha Gautam, Nandini Sharma[1], Kamlesh Anand, Ramneeq Singh Sodhi[2]

Purpose: The purpose of this study was to examine role of improved distance and near best-corrected visual acuity (DBCVA and NBCVA) with use of magnification devices to enhance stereopsis in low vision (LV) subjects having retinal diseases. **Methods:** In a cross-sectional observational study without control, 84 subjects having LV due to retinal diseases were examined for an improvement of BCVA with use of magnifying low vision aids (LVAs) (2X for DBCVA and 3X for NBCVA). The stereopsis scores on titmus fly test were recorded with near refractive correction "on" and then with 3X magnification. The improvement in stereopsis for distance was however estimated through statistical correlation values. **Results:** The DBCVA ($P < 0.001$), NBCVA ($P < 0.001$) and stereopsis ($P < 0.001$) improved statistically significantly (SS) following magnifying LVA. There was no correlation between pre-LVA stereopsis and pre-LVA DBCVA ($r = 0.059$; $P = 0.444$;NSS) and post-LVA DBCVA ($r = 0.054$; $P = 0.487$;NSS); and no correlation between post-LVA stereopsis and pre-LVA DBCVA ($r = 0.042$; $P = 0.592$;NSS) and post-LVA DBCVA ($r = 0.08$; $P = 0.920$;NSS). There was no correlation between pre-LVA stereopsis and pre-LVA NBCVA ($r = 0.044$; $P = 0.572$;NSS) and no correlation between post-LVA stereopsis and pre-LVA NBCVA ($r = 0.108$; $P = 0.165$;NSS). But positive correlation between pre-LVA stereopsis and post-LVA NBCVA ($r = 0.347$; $P < 0.001$) and between post-LVA stereopsis and post-LVA NBCVA ($r = 0.445$; $P < 0.001$) was SS. **Conclusion:** The use of magnification as LVA improves both the BCVA and stereopsis. The increase in DBCVA with LVA improves the stereopsis for distance though it may not be SS while improvement in NBCVA with LVA enhances stereopsis for near objects in SS manner.

Access this article online

Website: www.ijo.in

DOI: 10.4103/ijo.IJO_3154_20

Quick Response Code:

Key words: Low vision, low vision aids, stereopsis, stereopsis in low vision, stereopsis tests, visual acuity

In addition to other disabilities like diminution of vision, altered color perception and defective contrast sensitivity, a low vision (LV) person has an impaired stereopsis, making it difficult for him to recognize edges of articles and a relative physical distance between objects.[1,2] Reduced stereoacuity also affects more complex visuomotor tasks including reading, writing, mathematics and spelling ability.[3,4] In retinal diseases, progressive photoreceptor and ganglion cell loss cause an incomplete Panum's area utilization, an incongruent retinal localization, defective cortical perception and an impaired stereo-depth.[5] A LV in one or both eyes can profoundly disturb fine balance of pre-existing binocularity and affect many activities of daily living (ADL).[6] The ADL are infrequently examined in LV assessments.[7] Resultantly, the aspect of stereopsis and its improvement with use of low vision aids (LVAs) has been rarely studied.[2] Tarita-Nistor *et al.* by comparing monocular and binocular acuities found that binocular interaction as a visual function is a separate entity from visual acuity itself.[8]

There are LVAs for improving distance and near VA but there is paucity of study on impact or benefit of these LVAs on stereopsis. As stereo-acuity is dependent on visual impulses being sent from both eyes, it is closely related to central visual acuity (VA), retinal sensitivity and fixation stability,[2,5] In this study, we found the role of improved distance and near VA with use of relevant LVAs to enhance stereopsis.[1]

Methods

A cross-sectional observational study, without control, was conducted at Department of Ophthalmology of our hospital on patients having LV due to retinal diseases. The study was approved by the institutional ethical committee and written informed consent was obtained from each participant. The subjects having LV due to corneal diseases or glaucoma were excluded on account of difference in affection from that in retinal diseases for creating LV, as corneal diseases interrupt appropriate light stimulus from reaching the photoreceptors preventing initiation of an ocular/visual stimulus and glaucoma damages mainly the retinal ganglion cells but has lesser effect on other layers of retina.[9] Additionally, subjects

Guru Nanak Eye Centre & Maulana Azad Medical College, [1]Department of Community Medicine, Maulana Azad Medical College, [2]Netaji Subhash University of Technology, New Delhi, India

Correspondence to: Prof. Punita Kumari Sodhi, Guru Nanak Eye Centre & Maulana Azad Medical College, C-7/164, S.D.A., P.O. Hauz Khas, New Delhi, India. E-mail: punitasodhi222@gmail.com

Received: 08-Oct-2020 Revision: 27-Jan-2021
Accepted: 07-Feb-2021 Published: 18-Jun-2021

Cite this article as: Sodhi PK, Gautam A, Sharma N, Anand K, Sodhi RS. Role of improved distance and near visual acuity with low vision aids to enhance stereopsis in retinal diseases. Indian J Ophthalmol 2021;69:1867-71.

having significant media opacity like cataract and vitreous hemorrhage; other co-existing ocular diseases like uveitis and optic atrophy; and central nervous system disease were also excluded.

The subjects were enquired for visual symptoms of defective near and distance vision, defective color vision and glare. The stereopsis was evaluated by enquiring for difficulty in grasping objects and perceiving their edges, or in doing daily activities like driving.

They were subjected to detailed ocular examination for baseline evaluation of visual functions including presence of squint. Following refraction, the monocular DBCVA was found on ETDRS distance acuity charts under uniform illumination for each eye separately. For monocular NBCVA, the subjects' near vision was tested for each eye separately using ETDRS N charts on text printed in high contrast, at reading distance of 40 cm, using optimal illumination, while wearing appropriate glasses.

A total of 84 subjects having DBCVA less than 20/63 (logMAR 0.48) and at least 20/200 (logMAR 1) in better eye were included in this study.[10] The stereopsis was tested utilizing Titmus fly test (Stereo Optical Co., Inc., Chicago) held at 40 cm ahead, with both eyes open. The crossed polaroid filters (1 pair of standard 3D viewers) were worn over the near refractive correction, if any. The patient was passed thorough all three aspects of test that is touching wings of housefly, seeing 9 sets of four circles and seeing three rows of five animals. The results for stereopsis test score was recorded from answer key.

A binocular telescopic head mounted lens system with power of 2 X was used for magnifying distant targets and improvement in DBCVA was recorded. A magnifying convex 3X lens, having diameter of 14 cm, was used as LVA for seeing improvement in NBCVA and subject viewed text through the magnifying lens with both eyes open.

The titmus fly test was repeated with use of magnifying lens of 3X held appropriately close to housefly/circles/animals and the subjects wearing appropriate near refractive correction viewed in a binocular condition. The primary outcome variable was an improvement/change in stereopsis.

Statistical method

On account of data being non-parameteric, median and an inter-quartile range for variables and SS of difference between pre-LVA and post-LVA was found using Wilcoxon sign rank test. Difference was accepted significant only when *P* value was less than 0.05. Correlation coefficients were calculated using Spearman correlation coefficient.

Results

In a cross-sectional observational study, without control, 84 subjects [*n* = 57 (67.85%) males and *n* = 27 (32.14%) females] with LV due to retinal diseases and having BCVA less than 20/63 (logMAR 0.48) and at least 20/200 (LogMAR 1) in better eye, were included in the study. The main causes of LV were dry age related macular degeneration (ARMD), wet ARMD, diabetic retinopathy, central serous retinopathy (CSR), heredo-macular degeneration, choroiditis, myopia, vascular occlusion, fundal coloboma and hypertensive retinopathy.

The mean age of our subjects was 48.25 ± 18.36 years. All the subjects had defective distance and near vision and experienced difficulty in doing daily activities. Out of 84 subjects, 35 (41.66%) subjects experienced glare. None of our subject had squint or eccentric fixation.

The ETDRS DBCVA for distance varied from 20/200 (logMAR 1.00) to 20/63 (logMAR 0.48). Following use of 2X telescope, the DBCVA improved and varied from 20/200 (LogMAR 1.00) to 20/25 (LogMAR 0.10). Thus, with use of telescopic magnification, the DBCVA improved from mean logMAR value of 0.68 ± 0.17 (median value = 0.70; IQL (0.48,0.78) at pre-LVA to a mean logMAR value of 0.53 ± 0.09 (median value = 0.48; IQL 0.48,0.60) at post-LVA, making the mean improvement in DBCVA of LogMAR 0.14 ± 0.14 (median value for improvement = - 0.12; IQL -0.22, 0.00) (*P* value < 0.001; SS) [Fig. 1 and Table 1].

The NBCVA varied from 20/400 (LogMAR 1.3) to 20/40 (LogMAR 0.3). Following use of 3X magnification along with near refractive correction, if any, the NBCVA improved and ranged from 20/250 (LogMAR 1.1) to 20/25 (LogMAR 0.1). Thus, with use of 3 X magnification, the NBCVA improved from mean logMAR value of 0.72 ± 0.25 (median value = 0.70; IQL 0.60, 0.90) at pre-LVA to a mean logMAR value of 0.35 ± 0.18 (median value = 0.30; IQL 0.30, 0.40) at post-LVA making the mean improvement of logMAR 0.37 ± 0.21 (median value for improvement = –0.30; IQL –0.50, –0.20) (*P* < 0.001; SS) [Fig. 2 and Table 1].

It would be to clarify that lower logMAR values implies better VA.

All the subjects were able to perform titmus fly test, after wearing near refractive correction, implying presence of binocular function. Pre-LVA, all the subjects were able to touch the wings of fly in air thus implying presence of gross stereopsis. The stereopsis score of 84 subjects at Pre- LVA ranged from 100-800 (338 ± 184.68) (median value = 400; IQL 200, 400) seconds of an arc (SOA). It improved to stereopsis score post- LVA (3 X magnification) ranging from 100-800 (252.8 ± 161.8)

Table 1: Improvement in BCVA and stereopsis following use of LVA

Parameter	Pre-LVA Mean±SD	Post-LVA Mean±SD	Mean (SD) of improvement	*P*
DBCVA	0.68±0.17	0.53±0.09	0.14±0.14	<0.001; SS
	Median=0.70 (0.48,0.78)	Median=0.48 (0.48,0.60)	Median = -0.12 (-0.22, 0.00)	
NBCVA	0.72±0.25	0.35±0.18	0.37±0.21	<0.001; SS
	Median=0.70 (0.60, 0.90)	Median=0.30 (0.30, 0.40)	Median = -0.30 (-0.50,-0.20)	
Stereopsis	338±184.68	252.8±161.8	85.11±132.55	<0.001; SS
	Median=400 (200,400)	Median=200 (100,400)	Median=0 (-200, 0)	

(median value = 200; IQL 100, 400) SOA. It would be to clarify that lower values implies better stereopsis. The mean difference between pre-LVA and post-LVA stereopsis value was 85.11 ± 132.55 SOA (median value for improvement = 0; IQL (–200, 0) and the change was SS ($P < 0.001$) [Fig. 3 and Table 1].

We indirectly measured an improvement in stereopsis at distance by finding correlation between pre-LVA and post-LVA stereopsis values with pre-LVA and post-LVA DBCVA. We additionally found this correlation for pre-LVA and post-LVA stereopsis values with pre-LVA and post-LVA NBCVA [Table 2].

Table 2 shows that there was no correlation between pre-LVA stereopsis and pre-LVA DBCVA ($r = 0.059$; $P = 0.444$;NSS) and post-LVA DBCVA ($r = 0.054$; $P = 0.487$;NSS); and no correlation between post-LVA stereopsis and pre-LVA DBCVA ($r = 0.042$; $P = 0.592$;NSS) and post-LVA DBCVA ($r = 0.08$; $P = 0.920$;NSS). There was no correlation between pre-LVA stereopsis and pre-LVA NBCVA ($r = 0.044$; $P = 0.572$;NSS) and no correlation between post-LVA stereopsis and pre-LVA NBCVA ($r = 0.108$; $P = 0.165$;NSS). However, the values of correlation coefficient "r" were positive implying that as the values of logMAR VA reduced, the values of stereopsis also reduced, thus both improved simultaneously and vice versa. But positive correlation between pre-LVA stereopsis and post-LVA NBCVA ($r = 0.347$; $P < 0.001$) and between post-LVA stereopsis and post-LVA NBCVA ($r = 0.445$; $P < 0.001$) was SS.

Discussion

Stereopsis is defined as an ability to gain information about the three dimensional structure of visual scenes by comparing information collected separately and simultaneously from different lines of sight to the same region of space. While visual pathway involves rods-cones, bipolar-amacrine cells and finally ganglion cells, stereopsis appears to be processed in the visual cortex. If eyes do not function together appropriately, stereopsis is diminished or lost.

The only suggested measures to improve stereopsis are to use corrective lenses for improving vision of affected eye, multifocal soft contact lens[11] and laser in-situ keratomileusis (LASIK). Other measures include eye rolling or circling exercises, unequal illumination in two eyes say by factor of 2 cycles per degree,[12] resting the dominant/better eye[13]; and visual stimulation by video games[14] and use of highly tactile, colored and raised foam or plastic dots with adhesive backing to mark appliances, dials, computers, and keyboards.

Improvement in DBCVA with telescope of appropriate power which does not compromise patient's field of vision and an improvement in NBCVA with use of magnifiers may enhance stereopsis for distance and near to some extent and help LV subject to execute tasks like driving, climbing down the stairs, fine motors skills and reading.[3,4] Magnification is a method of increasing the size of the image so that enough of

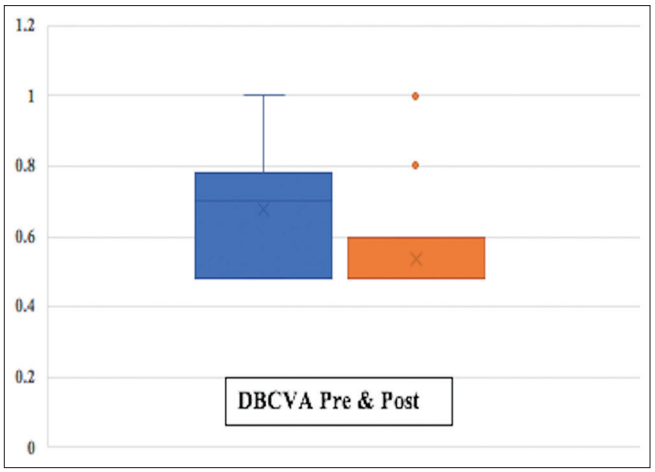

Figure 1: Values of DBCVA pre- and postmagnification

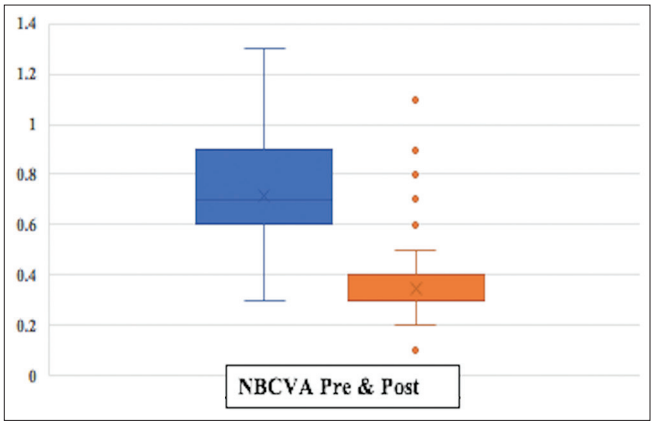

Figure 2: Values of NBCVA pre- and postmagnification

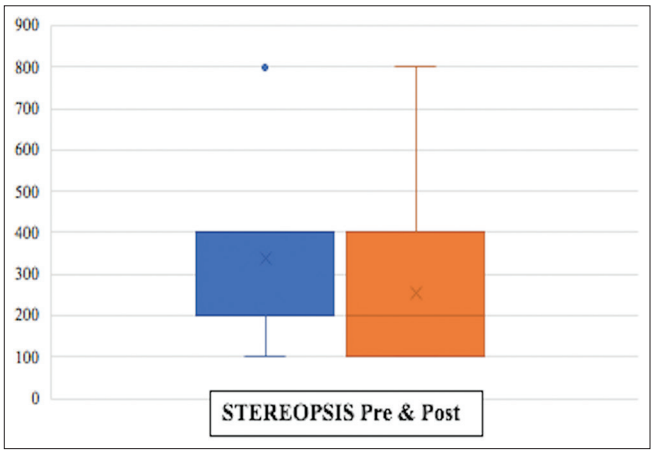

Figure 3: Values of Stereopsis pre- and postmagnification

Table 2: Correlation between pre-LVA and post-LVA stereopsis with pre-LVA and post-LVA DBCVA and NBCVA

Stereopsis score	Pre-LVA (Post-refraction)		Post-LVA (with refractive correction)	
	BCVA distance	BCVA near	BCVA distance	BCVA near
Pre- LVA	r=0.059, (P=0.444; NSS)	r=0.044, (P=0.572; NSS)	r=0.054, (P=0.487; NSS)	r=0.347, (P<0.001; SS)
Post-LVA (magnification)	r=0.042, (P=0.592; NSS)	r=0.108, (P=0.165; NSS)	r=0.08, (P=0.920; NSS)	r=0.445, (P<0.001; SS)

the retina is stimulated, ensuring an impulse to be sent through the optic nerve, allowing an object to be perceived. These stimulate binocular interaction, henceforth absent. Previous studies have utilized outcomes like reading speed, reading accuracy, reading comprehension, reading acuity, critical print size, fatigue-free duration[1] but evaluating improvement of stereopsis, as an outcome, with use of magnifiers, has not been done before. In addition to this, the visual function of stereopsis in LV subjects has been infrequently studied in the past.[1,5,11-14] While near and distance VA are measured for individual eyes, parameters like reading speed is measured with both eyes open, which allows a more functional assessment based on better seeing eye and excluding artefacts like an increase in nystagmus amplitude by covering one eye.[1] We also measured stereopsis in our subjects under binocular conditions.

The tests like titmus fly test, Frisby test, TNO random dot test, Lang test and Randot test have been used to measure stereopsis in LV subjects.[5,15] The LV subjects having retinal diseases generally manage to preserve the peripheral fusion, thus use of Titmus fly test seems suitable for detecting gross stereopsis in these subjects.[6] But stereopsis examination of LV subjects on this test has been reported infrequently.[5]

The advantages of Titmus fly test is that it allows for evaluation of both fine and gross stereo-vision, the latter one is more relevant in LV subjects.[6] Additionally, Titmus test is a quantitative test like TNO and Lang test, and unlike random dot stereogram and synaptophore, which are qualitative in nature. The test includes a fly for gross stereopsis (3000 seconds of an arc), graded circle test (800 to 40 seconds of arc) and animal test (400 to 100 seconds of arc). While Fricke and Siderov state that monocular cues of lateral displacement can taint the examination on Writ Circles,[16] Cooper and Warshowsky found that lateral displacement as a cue in the Titmus stereo-test is absent for animal test and for Writ Circles 4-9.[15,17] In order to reduce the chance of monocular cues contaminating the data, numbers 4 to 9 of the circle test were necessarily used by us.[15] Moreover, our subjects gave readings of 800, 400, 200 and 100 only which were deemed to be doubly checked from fly test and animal test in addition to Writ circles. Though false positive test (reporting perceived stereopsis, when not possible) is the only drawback with titmus fly test, Leske and Holmes found that false-positive results occurred with less frequency in Titmus Fly (6%) test than other tests including Titmus Animals (10%), Titmus Circles (35%), and the 800 seconds of arc (") level of the original Preschool Randot test (10%).[18]

There are presently two short comings. There is no LVA to exclusively improve stereopsis. Additionally, the stereo-tests are generally done at near range for example Titmus fly test, Lang test and TNO test are done at 40 cm,[19] and Frisby test is done at 30-80 cm.[2]

The limitation of this study is that we utilized different magnification for distance and near which may have confounded results. The reason for using 2X magnification for distance is that on increasing magnification, field of vision contracts and a higher magnification for distance is not recommended in practical situation. We utilized 2X magnification for distance and 3X magnification for near to place our subjects in practical situations, whereby higher magnification with somewhat reduced field is permissible for near, while slightly lower magnification with adequate field of vision is preferable for distance.

We indirectly measured an improvement in stereopsis, at distance, by finding correlation between pre-LVA and post-LVA (×3 magnification) stereopsis values with pre-LVA and post-LVA DBCVA. There was a negligible but *positive correlation* between stereopsis scores and DBCVA, both at pre-LVA and post- LVA, implying that subjects having better distance vision may also have a better stereopsis for distance. The values of correlation coefficient increased with use of LVA, as post-LVA stereopsis correlated better with post-LVA DBCVA and NBCVA than pre-LVA stereopsis with pre-LVA DBCVA and NBCVA. This agrees with previous findings of Vingolo *et al.* that stereopsis is linked to VA.[5] But SS correlation was found only between pre-LVA stereopsis and post-LVA NBCVA and between post-LVA stereopsis and post-LVA NBCVA, perhaps because titmus fly test is devised to be done at near i.e., 40 cm. Secondly, we used higher magnification for near than for distance.

In a study examining two groups having comparable BCVA of 0.04 ± 0.92 LogMAR in the RP (retinitis pigmentosa) group and 0.04 ± 1.0 logMAR in CG (control group), Vingolo *et al.* found that stereo-acuity (SA), except with Lang test, had lower values in CG i.e., better stereopsis in CG. The mean SA was 136.52 ± 26.5 arc sec in the RP group and 67.2 ± 11.5 arc sec in control group (CG) with Titmus stereotest; the SA was 391.39 ± 53.72 arc sec in RP group and 1150 ± 33.4 arc sec in CG with Lang test; and SA was 69.3 ± 14.39 arc sec in the RP group and 15.97 ± 3.7 arc sec in CG with TNO test. Vingolo *et al.* have not explained probable reason for different result with Lang test.[5] After conducting study with four standard clinical stereotests including Titmus, TNO, Frisby and Randot test, Heron *et al.* found that intertest correlations are poor, and in cases where the correlation is significant, no identifiable pattern emerges between testing procedures, age and stereotests.[15] Though the results for all three stereotests used in the study showed a significant correlation between SA and VA ($P = 0.0001$) in RP patients, but the authors added that RP subjects having macular involvement may have a split in visual fields exactly at fixation point and consequently they will have anomalous stereopsis despite having good VA.[5]

Cao and Markowitz measured SA in 27 LV subjects, having mean age of 84 ± 6 years, and BCVA ranging from 20/50–20/400 (6/15–6/120) using Frisby test and found that 59.3% (16/27) of the subjects were not able to see any SA plate, 25.9% (7/27) had SA of 340 SOA, 11.1% (3/27) had SA of 170 SOA and 3.7% (1/27) had SA of 85 SOA. The mean Overall Functional Visual Abilities (OFVA) score was significantly higher in those with stereopsis (2.25 ± 0.99) than those without stereopsis (1.50 ± 0.92) ($P = 0.028$), specifically for reading ($P = 0.010$) and visual motor skills ($P = 0.046$). The authors concluded that stereopsis should be considered as a component of LV rehabilitation and considered as an outcome measure in research and clinical practice. These authors did not find correlation between BCVA and stereopsis ($r = –0.1915$, $P \leq 0.573$) and mean DBCVA was not significantly different ($P = 0.44$) between those retaining stereopsis and those not retaining it.[2] We feel that difference in distance at which two tests were conducted by these authors, that is DBCVA with ETDRS at 1 m and Frisby test at 30 to 80 cm, is the most probable cause for not correlating.

The above two studies did not estimate SA separately at near and distance and did not find SA in their LV subjects following use of LVA.[2,5]

We found negligible positive correlation between DBCVA and stereo-acuity, implying that there is a possibility that an improvement in DBCVA will improve stereo-acuity for a distant target. We feel that greater magnification for distance i.e., higher power of telescope might have raised the values of correlation coefficient.

Stereopsis is a visual function which by definition is directly related to VA.[20] It is the level of VA in the poorer eye that limits the level of stereopsis, which can be achieved in a certain individual.[6,21] Fine stereopsis can be achieved therefore only in those LV subjects who have good VA and simultaneously present good macular function also in the poorer seeing eye, but with loss of the macular function, gross stereopsis is only that can be achieved.[22]

The presence of stereopsis provides a better quality of visual function in our everyday life[23] but practical benefits of stereopsis have been largely neglected.[24] During rehabilitation of a LV subject, an improvement in distance stereopsis can result in a greater ability to perceive surface slant, surface shape, front to back depth, 3D shapes and improvement in near stereopsis can facilitate reading, writing, math, and spelling ability and several motor skills.[3,25] Assessing various functional impacts of magnifiers is relevant to users and providers, as these are widely available LVA and wider impact of devices on quality of life is increasingly important.

Electronic magnifiers are equipped with flexible magnification enabling better visual acuity and facility for variation in quantity and type of light for a superior contrast. In addition to uniocular displays, these have binocular displays for presenting same image or different images to both eyes for increasing field of vision and stereopsis respectively.[26] For customization, digital sight enhancement algorithms have been incorporated.[27] Low-vision devices are complex and training on these is required to enable an individual to utilize his skills for gaining an improvement in best-corrected visual acuity, contrast sensitivity and field of vision which evoke binocularity and better inter-ocular interaction thus improving stereopsis.

Conclusion

The use of magnification as LVA improves both the BCVA and stereopsis. The increase in DBCVA with LVA improves the stereopsis for distance though it may not be SS while improvement in NBCVA with LVA enhances stereopsis for near objects in SS manner.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Barker L, Thomas R, Rubin G, Dahlmann-Noor A. Optical reading aids for children and young people with low vision. Cochrane Database Syst Rev 2015;CD010987. doi: 10.1002/14651858.CD010987.pub2.
2. Cao KY, Markowitz SN. Residual stereopsis in age-related macuar degeneration patients and its impact on vision related abilities: A pilot study. J Optom 2014;7:100–5.
3. O'Connor AR, Birch EE, Anderson S, Draper H; FSOS Research Group. The functional significance of stereopsis. Invest Ophthalmol Vis Sci 2010;51:2019-23.
4. Kulp MT, Schmidt PP. A pilot study. Depth perception and near stereoacuity: Is it related to academic performance in young children? Binocul Vis Strabismus Q 2002;17:129-34, discussion 133.
5. Vingolo EM, Limoli PG, Steigerwalt RDJ, Carlesimo SC, Salvatore S. Abnormal stereopsis and reduced retinal sensitivity in patients with retinitis pigmentosa. Int Ophthalmol 2020;40:179-84.
6. Markowitz SN. Principles of modern low vision rehabilitation. Can J Ophthalmol. 2006;42:289-312.
7. Windham BG, Griswold ME, Fried LP, Rubin GS, Xue QL, Carlson MC. Impaired vision and the ability to take medications. J Am Geriatr Soc 2005;53:1179-90.
8. Tarita-Nistor L, Gonzales EG, Markowitz SN, Steinbach MJ. Binocular interactions in patients with age-related macular degeneration: Acuity summation and rivalry. Vis Res 2006;46:2487–98.
9. Behtaj S, Öchsner A, Anissimov YG, Rybachuk M. Retinal tissue bioengineering, materials and methods for the treatment of glaucoma. Tissue Eng Regen Med 2020;17:253-69.
10. World Health Organization. International Statistical Classification of Diseases, Injuries and Causes of Death, tenth revision. Geneva, 1993.
11. Sha J, Tilia D, Kho D, Amrizal H, Diec J, Yeotikar N, *et al*. Visual performance of daily-disposable multifocal soft contact lenses: A randomized, double-blind clinical trial. Optom Vis Sci 2018;95:1096-104.
12. Reynaud A, Zhou J, Hess RF. Stereopsis and mean luminance. J Vis 2013;13:1.
13. Li RW, So K, Wu TH, Craven AP, Tran TT, Gustafson KM, *et al*. Monocular blur alters the tuning characteristics of stereopsis for spatial frequency and size. R Soc Open Sci 2016;3:160273. doi: 10.1098/rsos.160273.
14. Ratra D, Rakshit A, Ratra V. Visual rehabilitation using video game stimulation for Stargardt disease. Ther Adv Ophthalmol 2019;11:2515841419831158. doi: 10.1177/2515841419831158.
15. Heron G, Dholakia S, Collins DE, McLaughlan H. Stereoscopic threshold in children and adults. Am. J Optom Physiol Opt 1985;62:505-15.
16. Fricke TR, Siderov J. Stereopsis stereotests and their relation to vision screening and clinical practice. Clin Exp Optom 1997;80:165-72.
17. Cooper J, Warshowsky J. Lateral displacement as a response cue in the Titmus stereo test. Am J Optom Physiol Opt 1977;54:537-41.
18. Leske DA, Holmes JM. Maximum angle of horizontal strabismus consistent with true stereopsis. J AAPOS 2004;8:28-34.
19. Vancleef K, Read JCA, Herbert W, Goodship N, Woodhouse M, Serrano-Pedraza I. Overestimation of stereo thresholds by the TNO stereotest is not due to global stereopsis. Ophthalmic Physiol Opt 2017;37:507–20.
20. Burian HM. Stereopsis. Doc Ophthalmol 1951;5:169–71.
21. Colenbrander MC. The limits of stereoscopic vision. Ophthalmologica 1948;115:363-5.
22. Coutant BE, Westheimer G. Population distribution of stereoscopic ability. Ophthalmic Physiol Opt 1993;13:3-7.
23. Beauchamp GR, Black BC, Coats DK, Enzenauer RW, Hutchinson AK, Saunders RA, *et al*. The management of strabismus in adults, III: The effects on disability. J AAPOS 2005;9:455–9.
24. Fielder AR, Moseley MJ. Does stereopsis matter in humans? Eye 1996;10:233–8.
25. Norman JF, Norman HF, Craft AE, Walton CL, Bartholomew AN, Burton CL, *et al*. Stereopsis and aging. Vis Res 2008;48:2456-65.
26. Ehrlich JR, Ojeda LV, Wicker D, Day S, Howson A, Lakshminarayanan V, *et al*. Head-mounted display technology for low-vision rehabilitation and vision enhancement. Am J Ophthalmol 2017;176:26–32.
27. Crossland MD, Starke SD, Imielski P, Wolffsohn JS, Webster AR. Benefit of an electronic head-mounted low vision aid. Ophthalmic Physiol Opt 2019;39:422-31.