Evaluation of Change in Stereopsis with Age in Normal Eyes

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ABSTRACT

BACKGROUND

Stereopsis is the ability to perceive the depth of field based on the disparity of the images formed by the two eyes; in other words, the fusion of the separated images on the Panum's area in order to form binocular single vision. Depth perception is very important in everyday life tasks such as driving, orientation in space while moving (e.g. descending a flight of stairs) and for fine-motor tasks involving hand eye coordination such as threading a needle. By reducing the amount of scanning necessary to extract spatial information, stereopsis facilitates comprehension of complex visual experiences. While stereopsis is a uniquely binocular phenomenon, there are many monocular clues which can provide information on depth including linear perceptive, shadows, texture and gradients. We wanted to study the change and variation of stereopsis with age in normal eyes.

METHODS

This prospective study was conducted on the participants attending the Outpatient Department of the Department of Ophthalmology of our hospital. A total of 80 subjects (patients/ their relatives) aged between 7 and 80 years, were included in the study. Informed consent was taken from all the participants. Subjects with strabismus, amblyopia, anisometropia (difference of ≥ 2.5D between both eyes), glaucoma, cataract and with age related macular degeneration and patients with history of eye surgery were excluded from the study. Stereopsis was assessed by TNO random dot stereotest (TNO Test). The participants read the test plates at a distance of 40 cm, wearing polaroid spectacles or red-green goggles, under proper illumination and after correction for any refractive error.

RESULTS

Data was entered in EpiData entry and analysed using EpiData analysis software v. 3.0. Significance was set at $p<0.05$. It was observed that the stereopsis remained stable till the age of 30 years. Thereafter there was a decline in the median values of stereopsis with increasing age and this decline became statistically significant after the age of 50 years ($p<0.0001$).

CONCLUSIONS

In our study, we found that the stereoacuity decreased as the age increased when assessed by TNO test. Stereopsis has an impact on vision related quality of life. Thus knowledge of the underlying population prevalence of physiological reduction of stereopsis with age can help in assessing its contribution to already reducing quality of life with increasing age.

KEYWORDS

Stereopsis, TNO Random Dot Stereotest (TNO test), Depth Perception, Stereoacuity

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BACKGROUND

Stereopsis was first described in 1838 by Charles Wheatstone, the inventor of the stereoscope. Stereopsis is the perception of depth achieved by the analysis of the relative disparity of images projected onto the two retinae; in other words, the fusion of the separated images on the Panum's area in order to form binocular single vision.[1] Depth perception is very important in everyday life tasks such as driving, orientation in space while moving (e.g. descending a flight of stairs) and for fine-motor tasks involving hand eye coordination such as threading a needle.[2] By reducing the amount of scanning necessary to extract spatial information, stereopsis facilitates comprehension of complex visual experiences. While stereopsis is a uniquely binocular phenomenon, there are many monocular clues which can provide information on depth including linear perceptive, shadows, texture and gradients. These clues provide indirect information on depth but don't offer the quality of stereopsis which is the only direct measurement of depth.[3]

It has been reported that stereopsis is absent at birth and begins to develop from 4 months of age. Stereoacuity does not improve significantly between 6 and 12 months, but it improves rapidly after 12 months.[4] Stereopsis results from the integration of two slightly dissimilar retinal images, which requires a degree of retinal disparity (along the horizontal but not vertical meridian). It is influenced by a number of factors which are relevant to clinical testing conditions, including contrast, illumination and colour.[2] Stereoacuity is the measure of the minimum perceivable horizontal disparity expressed in seconds of arc. While under ideal experimental conditions stereoacuity thresholds may reach 2-3 seconds of arc, but in clinical practice, values of around 30-40 seconds are regarded as normal. The distance over which stereopsis operates is probably up to 500 m and improves closer to until limited by accommodation.[5]

Humans have the remarkable ability to take the subtle differences between the two eye's views (binocular disparities) and use them to perceive depth and 3-D object shape.[6] Binocular Single Vision is the coordinated use of both the eyes, so that separate and slightly dissimilar images arising in each eye are perceived by the individual as a single image. There are three grades of binocular vision as given by Worth's classification.[7,8]

Grade I- Simultaneous macular perception is the most basic type of binocularity. It is the ability of the eyes to see two dissimilar objects simultaneously.
Grade II- Fusion is the power to superimpose two incomplete but similar images to form one complete image.
Grade III- Stereopsis is the highest type of binocularity wherein images from both the eyes are fused to give a sense of depth perception.

The tests of stereopsis may be qualitative or quantitative. Stereopsis is measured in seconds of arc. The qualitative tests are Lang's 2 pencil test and Synaptophore. The quantitative tests for Stereopsis are Randot stereotest, TNO Test and Lang's stereo test.[8] Stereopsis develops in early infancy between about 3 and 5 months of age and, depending on the test used, adult levels are not achieved until around 5-7 years.[9] There are very few reports on the changes of stereopsis with age. Earlier reports suggesting that stereopsis doesn't change with age were based on small sample size of older age group.[10] Majority of the studies showed a significant decrease in the prevalence of stereopsis with aging. However, even after extensive search of literature, we could not find any study evaluating stereopsis and effect of age on stereopsis in the Indian population. Hence we propose to conduct a study assessing the changes in stereopsis with age in our set of population.

We wanted to study the change and variation of stereopsis with age in normal eyes.

METHODS

This prospective study which was conducted on the participants attending the Outpatient Department of the Department of Ophthalmology of our hospital. A total of 80 subjects (patients/ their relatives) aged between 7 and 80 years, were included in the study. Informed consent was taken from all the participants.

Inclusion Criteria
Subjects without eye diseases mentioned in exclusion criteria.

Exclusion Criteria
1) Subjects with strabismus, amblyopia, anisometropia (difference of ≥2.5D between both eyes), glaucoma, cataract and age related macular degeneration.
2) History of eye surgery.

Detailed Procedure
The subjects were separated into 8 study groups. Each group comprised of 10 participants, with 5 males and 5 females per group. Following were the 8 study groups-

Group 1: 7 to 10 years.
Group 2: 11 to 20 years.
Group 3: 21 to 30 years.
Group 4: 31 to 40 years.
Group 5: 41 to 50 years.
Group 6: 51 to 60 years.
Group 7: 61 to 70 years.
Group 8: 71 to 80 years.

The subject underwent complete eye examination including visual acuity, refraction if required, cover uncover test, anterior segment examination and detailed fundus examination. Intraocular pressure was assessed using applanation tonometer. Automated perimetry was done wherever required. Before assessing the stereopsis, the visual acuity of all the subjects was adjusted at near and far distance by appropriate refraction. The stereopsis was assessed by TNO Test. It consists of seven plates (to be

viewed with red green spectacles) that carry figures that can be seen only when both eyes cooperate to give stereoscopic vision. Each test plate consists of a stereogram in which the half images have been superimposed and printed in roughly complementary colours. The first three plates (plate I-III) enable the examiner to quickly establish whether stereoscopic vision is present at all. The subjects who are able to read these three plates are said to pass the test. The fourth plate (plate IV) is used as a suppression test. The next three quantitative plates (plate V-VII) are used for the exact determination of stereoscopic sensitivity which is measured in seconds of arc. The participants read the test plates at a distance of 40 cm, wearing polaroid spectacles or red-green goggles, under proper illumination and after correction for any refractive error. The detailed data was recorded as per the proforma.

Plates of TNO Test

RESULTS

Data was entered in EpiData entry and analysed using EpiData analysis software v. 3.0. Frequency, proportion, mean, standard deviation was done as a part of descriptive study. Chi square test and student t-test were the tests of significance. Significance was set at $p<0.05$.

Age Distribution of Subjects

A total of 80 subjects, aged between 7-80 years, were enrolled in the study. The average age in the study was 40.15 years. The maximum and minimum age of the subject enrolled was 78 and 7 respectively. The subjects were equally distributed into 8 study groups according to the age. Each group comprised of 10 subjects (12.50%) as shown in Table-1.

Study Group	Frequency	%
7-10	10	12.50%
11-20	10	12.50%
21-30	10	12.50%
31-40	10	12.50%
41-50	10	12.50%
51-60	10	12.50%
61-70	10	12.50%
71-80	10	12.50%
Total	80	100%

Table 1. Age Distribution

Gender Distribution of Subjects

There were 40 males (50%) and 40 (50%) females enrolled in the study. The males and females were equally distributed among the study groups with each group having 5 males and 5 females (Table-2, Figure-1).

	Frequency	%
Females	40	50%
Males	40	50%
Total	80	100%

Table 2. Gender Distribution

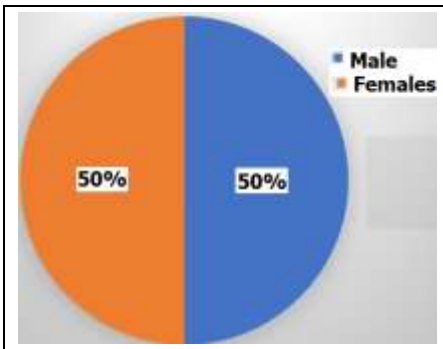

Figure 1. Gender Distribution

Change of Stereopsis with Age

All the 80 subjects were able to pass the test. The average stereopsis assessed by the TNO test in group 1 to group 8 was 54 (±40.74), 147 (±149.8), 63 (±22.14), 114 (±71.83), 183 (±173.46), 264 (±165.41), 408 (±115.93) and 396 (±139.14) respectively (Table-3). The range of stereopsis was 15-120 in group 1, 15-480 in group 2, 30-120 in group 3, 60-240 in group 4, 30-480 in group 5, 60-480 in group 6, 240-480 in group 7 and 120-480 in group 8 (Table-3).

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	
Stereopsis	**7-10**	**11-20**	**21-30**	**31-40**	**41-50**	**51-60**	**61-70**	**71-80**	**p**
Sample size	10	10	10	10	10	10	10	10	
Mean ± S.D.	54± 40.74	147± 149.8	63± 22.14	114± 71.83	183± 173.46	264± 165.41	408±1 15.93	396± 139.14	
Median	60	60	60	90	90	240	480	480	<0.0001
Min-Max	15-120	15-480	30-120	60-240	30-480	60-480	240-480	120-480	
Inter									
quartile									
Range	15-60	60-240	60-60	60-120	60-240	120-480	240-480	240-480	

Table 3

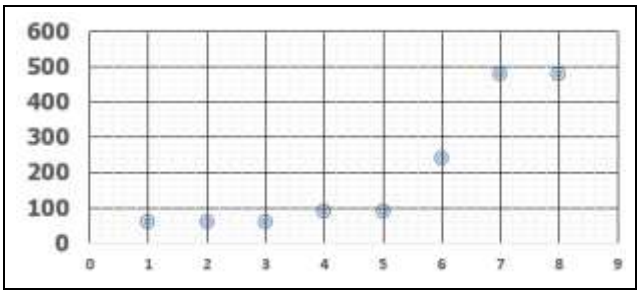

Figure 2. Median Value of Stereopsis

The median values of stereopsis in group 1 to group 8 were 60, 60, 60, 90, 90, 240, 480 and 480 (Figure-2). It was

observed that the stereopsis remained stable till the age of 30 years. Thereafter there was a decline in the median values of stereopsis with increasing age and this decline became statistically significant after the age of 50 years ($p<0.0001$).

Also, when compared to Group 1, a statistically significant reduction of stereopsis was observed in Groups 6, 7 and 8 ($p=0.001$, 0.0001 and 0.0001 respectively). After comparing the statistical values among various groups, it was observed that till the age of 50 years, the decline in stereopsis was not significant statistically but after 50 years, there was statistically significant ($p=0.0001$) reduction in stereopsis (Table-4).

	7-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80
7-10	-	0.153	0.345	0.03	0.034	0.001	0.0001	0.0001
11-20	0.153	-	0.392	0.81	0.528	0.077	0.002	0.003
21-30	0.345	0.392	-	0.036	0.087	0.001	0.0001	0.0001
31-40	0.03	0.81	0.036	-	0.719	0.03	0.0002	0.0005
41-50	0.034	0.528	0.087	0.719	-	0.196	0.006	0.009
51-60	0.001	0.077	0.001	0.03	0.196	-	0.042	0.071
61-70	0.0001	0.002	0.0001	0.0002	0.006	0.042	-	0.888
71-80	0.0001	0.003	0.0001	0.0005	0.009	0.071	0.888	-

Table 4. Statistical Values (p Values) of Stereopsis among Various Groups

DISCUSSION

Stereopsis is a pattern of the highest level of binocular vision, which refers to the ability to use the fovea of one eye and the macula of the other eye to perceive the depth of a subject in the fusion state of visualizing a subject, and thus to obtain binocular single vision.[11] On the retina, the fovea has high spatial resolution power, and, therefore, even if the images formed by the two eyes are slightly different, a single image is perceived and thus detailed high stereopsis is possible. In the peripheral visual field, as its receiving unit is large, only a large disparity of the images can be perceived, and its stereopsis is thus decreased. Stereopsis is presented as the ability to perceive a very small seconds of arc of the depth between two points. In normal individuals, the standard of stereopsis test has been applied with the classification of shorter than 50 seconds as normal stereoscopic acuity and between 60-3,000 seconds as partial stereoscopic acuity.

Various studies have reported the change of stereopsis according to age. In our study the stereopsis decreased as the age increased when assessed by TNO test. Particularly, in the groups older than 50 years, the decline in stereopsis was evident and statistically significant ($p=0.0001$). In the comparison with the group younger than 11 years, stereopsis was clearly reduced in the 50s, 60s and 70s. The findings observed in our study are comparable to similar studies done in the past.

Lee SY et al found decrease in stereopsis with increasing age. Compared to the stereoacuity of 7-10 year old group, the stereopsis test results were significantly decreased for the 6th, 7th and 8th decade groups.[1] Stephen BE also observed that the prevalence of defective stereopsis increased with age. The incidence of full stereopsis remains the same until the sixties, followed by an abrupt decrease by half in the seventies ($p = 0.0038$).[9] Wright LA et al studied the prevalence of stereopsis in elderly population. They found that over the age of 65 years, only 27% had full stereopsis and 29% had no stereopsis.[12] Zaroff CM et al also observed that 88% of the subjects below the age of 60 years had normal stereoacuity and this percentage decreased to 37% and 25% in the age group of 60-69 years and 70-79 years respectively.[13]

In our study the subjects had no ocular disorder like cataract, anisometropia, strabismus, glaucoma etc. Also visual acuity of all the subjects was adjusted at near and far distance before performing the TNO test. So the reduction of stereopsis was not associated with the decrease of visual acuity. These observations support the theory that the reduction of stereopsis with increasing age is due to the reduction of cerebral function with aging.

CONCLUSIONS

In our study, we concluded that the stereopsis remained stable till the age of 30 years. Thereafter there was a decline in the median values of stereopsis with increasing age and this decline became statistically significant after the age of 50 years ($p<0.0001$). We found that the stereoacuity decreased as the age increased when assessed by TNO test. The stereoacuity remained stable till 30 years of age and declined gradually thereafter. In the groups older than 50 years, the decline in stereopsis was evident and statistically significant ($p=0.0001$). This baseline knowledge of declining stereopsis with age has great clinical importance and interpreting diseases associated with decreased stereopsis in elderly population.

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