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Comparative Study of the Effect of Experimentally Induced Anisometropia on the Stereoacuity of Teenagers

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Abstract

Purpose: *To examine the effect of experimental anisometropia on steroacuity in teenagers using Titmus Stereo Fly Test.*

Methods: *Fifty-six teenage volunteers (ages ranging from 16-19 years) participated in the present study. Placing trial lenses over the dominant eye (from -3.50D to +1D), two different anisometropia types (including myopia and hyperopia), were induced. Steroacuity was measured using the Titmus Stereo Fly Test.*

Results: *In all the anisometropia types, there was a decline in stereopsis as anisometropia increased (p<0.05). The greatest impairment in stereoacuity was due to compound myopic anisometropia, -1.00DS and -3.50DS, +1.00DS and +3.50DS, and +2.00Ds and -2.00DS giving 3552 arc seconds in Titmus circles.*

Conclusion: *Anisometropia reduces stereopsis and compound myopic anisometropia gives the most noticeable change. The impairment had no gender correlation.*

Keywords: *Stereoacuity, anisometropia, stereopsis.*

INTRODUCTION

Stereoacuity can be defined as the discrimination of differences in depth on the basis of binocular disparity. In other words, stereoacuity can be defined as the measurement of stereopsis. Essentially, stereoacuity is the smallest detectable disparity of retinal images (1). It could be as low as three seconds of arc with a high contrast and sharp-edgedstimuli in the central zone, but conventionally in a normal person with good binocular vision, stereoacuity is forty seconds of arc. Stereopsis is the perception of depth based on horizontal, relative and retinal disparity. Retinal disparity is the difference in position of images on the left and right retina measured in visual angle units of degree, minutes or seconds of arc (1,2,3).

Stereopsis, which is the third grade of vision, could be the characteristically vivid qualitative impression of a 3D structure that is observed when real (or stimulated 3D) scenes are viewed binocularly. It is associated with a compelling perception of solidity or 3-dimensionality, a clear sense of space between objects and a phenomenal sense of realism. These visual characteristics are conventionally thought to be a result of the different views of an object afforded by binocular vision (disparity) or self-motion (motion parallax) (1).

The perception of depth depends on the combination of several factors such as:

- Retinal disparity
- Motion parallax
- Shading cues
- Inter-position cues (overlap of objects)
- Size or perspective
- Blur

Anisometropia is a condition in which the two eyes have unequal refractive power; that are in different states of myopia (near-sightedness) or hyperopia (far-sightedness). The unequal refractive state causes unequal rotations thus leading to diplopia and asthenopia. The higher the amount of ametropia, the more often anisometropia occurs. The name is from the Greek components: an – "not", so – "same", metro – "measure", and ops – "eye".

Very few people are born with identical power in the two eyes, but the brain manages to compensate the differences, thereby making it unnoticed. However, when a person has anisometropia, the difference in vision between the two eyes is significant and will interfere with normal binocular vision (about 1D difference or more). Sometimes anisometropia can be present at birth, although it won't become apparent until later in life most times.

There are three types of anisometropia namely:

- Simple anisometropia: This is when one eye is affected while the other eye has no refractive error.
- Compound anisometropia: This is when both eyes are myopic or hyperopic both with a significant difference of about 1diopter between both eyes.
- Mixed anisometropia: This is when both eyes have appreciable refractive errors with one eye being myopic and the other hyperopic. This can also be called Antimetropia.

Symptoms of anisometropia are:

- Amblyopia
- Strabismus (crossed eyes)
- Diplopia
- Eyestrain
- Headaches
- Nausea
- Light sensitivity
- Tiredness
- Dizziness

Anisometropia could result from defects in the eye at birth as well as uneven size of the two eyes (axial length). Anisometropia present at birth could be transient and may disappear as the eyes emmetropize (1,2,3). Ogle, (1950), reported that clinically significant degrees of anisometropia are axial in nature (4).

Schapero et al. (1968), classified anisometropia into anisometropic astigmatism, simple hyperopic anisometropia, simple myopic anisometropia and antimetropia. Since both eyes are not accommodating equally, an uncorrected anisometrope has the problem of never having sharply focused images on both retinas at the same time (1,5).

Blum et al. (1959) and Hirsch, (1967) found the prevalence of anisometropia of 1.00D or more to vary from 2-6 percent, being lowest at age 5 and increasing during the school year. In Hirsch's study, some of the children who had equal refraction in both eyes (isometropia) on entering school developed anisometropia during the school years, whereas others had anisometropia when entering school but eventually became isometropic and still some were found to be anisometropic on entering school and remained anisometropic (2,6,7).

Majority of patients in school children population are affiliated with the disturbance of binocular vision due to anisometropia. Lack of information on where this problem occurs most frequently results to a difficult diagnosis of the problem. An example is a complaint of diplopia by a patient. If this symptom is elicited by a patient who belongs to a target population where the anisometropia is high, the clinic will immediately think about the ruling out of anisometropia before going further for another diagnosis(1,2,3).

Anisometropia is one of the etiological factors in the pathogenesis of amblyopia as well as a contributing factor to decrease stereoacuity. The precise mechanism by which anisometropia causes a decrease in stereoacuity is not clear. It has been suggested that foveal suppression in the defocused eye is the cause of decreased stereopsis. This decreased stereopsis whether it is secondary to loss of visual acuity or loss of bifoveal fixation is not known (1,2). According to Von Noordeen and Campos (2002), anisometropia can result in the defocus of retinal images in one eye, including reduction of retinal image size (aniseikonia), contrast and clarity (1). So, for a person who is anisometropic, the signal from one eye which is sent to the brain to be analyzed cannot be harmonized with that of the other.

There may be active suppression of the fovea to overcome the secondary interaction between the eye with the better vision and that with lesser vision. It has been suggested that an onset of blurred vision early in life as a result of anisometropia may provoke a particular pattern of functional loss. However, the quantitative relationship between the degree of anisometropia and functional loss has not been fully explored(1,2,3). Anisometropia is clinically important because it is one of the most frequent cases of vision loss in infants and children. Poor stereoacuity causes impairment particularly in visual feedback control of movements leading to significantly longer and less accurate movements (8).

Buckley et al. (2010) and Helbostad et al. (2009) suggested that the effect of losing stereopsis extends beyond hand movements. In addition, adaptation to changes in terrain (e.g. steps) are significantly less accurate without stereopsis in normal sighted people viewing monocularly, people with amblyopia and people with reduced stereoacuity. Impaired stereopsis may also negatively affect the everyday activity in children (9,10). The aim of this study is to determine the effect of anisometropia on the stereoacuity of teenagers.

Objectives

- To determine if anisometropia has a significant effect on loss in stereoacuity so as to bring it to the awareness of optometrists and the general public that persons with anisometropia are likely to have an impaired stereopsis.
- To determine the nature of effect of anisometropia on the stereoacuity of teenagers.
- To determine the influence of gender on the stereoacuity of anisometropes.

This study is confined to teenagers in Abia state university, Uturu, Abia state within the ages of 16-19 years. The visual acuity of the patients (subjects) was gotten and only emmetropes or artificial emmetropes with a visual acuity of 6/5 and free of any ocular pathological conditions were used for this study.

Materials and Methods

The study was of minimal risk as well as the consent of all the participants were sought for without any violence or compulsion. The identities of the participant were kept anonymous as requested. Moreover, approval for this research was obtained from the Research and Ethics Committee of the department.

This study was carried out as a prospective study. A vision screening exercise was carried out in Abia State University, Uturu which involved:

- Case history
- Visual acuity testing (both at far and near)
- Penlight examination
- Ophthalmoscopy
- Refraction (when necessary)

The Stereoacuity of the subjects was then measured both before and after induction of anisometropia and recorded respectively.A total of 56 subjects were used for this study. These subjects were emmetropes or artificial emmetropes who had no significant existing pathological condition.A Randomized sampling technique was used. The following criteria were considered to determine the eligibility of the subjects used for this study:

1. Subjects were in good ocular and systemic health condition.
2. Subjects were emmetropes or artificial emmetropes.
3. Subjects were teenagers (i.e. 16-19 years of age).

Materials/Instruments

- Snellen's Visual Acuity Chart
- Pen torch
- Ophthalmoscope
- Retinoscope
- Trial Lens Set
- Titmus Stereo Fly Test

The Ophthalmoscope, Snellen Chart, Pentorch, Trial Lens Set and the Titmus Stereo Fly have all been approved by the World Council of Optometry (W.C.O.) and the Optometry and Dispensing Opticians Registration Board of Nigeria (ODORBN).

Out of the students' population of the Abia State University, Uturu, only the students aged 16-19 years were used for the study. The vision screening was carried out in this order:

Case history

The individual's name, age, sex, occupation, address, hobbies, chief complaint, ocular history, medical history, family ocular historyand family medical history were recorded accordingly. Allergies of the individuals were also recorded.

Visual Acuity test

Both the monocular and binocular distant and near visual acuity were measured respectively using standard illuminated optotypes at the appropriate measuring distance. For the distant visual acuity, the snellenoptotype was placed at 6m while the reduced/near Snellen chart was placed at the distance of 40cm.

Pen torch examination

External examination was done to check the external structures for any significant ocular abnormality.

Ophthalmoscopy

This was used in detection of any pathology or disease of the eyes by viewing the inner part of the patient's right eye with the right eye of the examiner; his right hand was used for holding the instrument when viewing the right eye of the patient and vice-versa. The retinal background or fundus was properly viewed. The refractive error of the researcher was compensated in the lens battery of the ophthalmoscope.

Anisometropia induction with trial lenses

Emmetropes or artificial emmetropes who do not have any ocular pathology were selected and used at this stage. 56 subjects were used and divided into three groups with twenty subjects each. Simple anisometropia, compound anisometropia and mixed anisometropia were induced respectively in the three groups in this manner:

GROUP 1: Simple Anisometropia:

- Simple myopic anisometropia with +1.00D and +2.00D was induced in 8 subjects.
- Simple hyperopic anisometropia with -1.00D and -2.00D was induced in 8 subjects (i.e. lenses placed on only one eye).

GROUP 2: Compound Anisometropia

- Compound myopic anisometropia was induced with plus lenses in both eyes with a difference of 1.00D, 1.50D, 2.00D and 2.50D between both eyes. This was done on 16 subjects (i.e. +1.00D on OD and +2.00D on OS, +1.00D on OD and +2.50D on OS, +1.00D on OD and +3.00D on OS and +1.00D on OD and +3.50D on OS).
- Compound hyperopic anisometropia was induced with minus lenses in both eyes with a difference of 1.00D, 1.50D, 2.00D and 2.50D between both eyes. This was done on 16 subjects (i.e. -1.00D on OD and -2.00D on OS, -1.00D on OD and -2.50D on OS, -1.00D on OD and -3.00D on OS and -1.00D on OD and -3.50D on OS).

GROUP 3: Mixed Anisometropia

- Myopia of 1D (with a +1.00D lens) and hyperopia of 1D (with a -1.00D lens) was induced in 4 subjects and myopia of 2D and hyperopia of 2D was induced on the remaining 4 subjects.

Stereoacuity testing

The stereoacuity of the subjects were tested before and after induction of anisometropia with the Titmus Stereo Fly test. The procedure undertaken was thus:

a. A well-lit, glare free area was used.

b. The polarizing lens was placed over the trial frame with lenses in the lens cell (for induction of anisometropia).

c. Test booklet was opened and folded so that only page 1 can be viewed by the test subject.

- The fly is used for this test as it is both universally recognized and understood by all age groups.
- When both eyes are functioning properly, the fly should appear to be a 3-dimensional image protruding from the page.
- If both eyes are not functioning properly, the fly will appear as a flat 1-dimensional image.

d. Subjects were asked to pinch the wings of the fly. Subjects who were able to perform the test and had a 3-dimensional view proceeded to the second part of the test; page 2.

e. The subjects were asked to look at the 10 boxes each containing 4 circles.

f. Only one circle in each box will appear to be floating or different from the others. Repeat this step for boxes 2-10.

g. When one was missed, the preceding box was retested to ensure that the test subject can achieve this level and was not just guessing.

h. The level of stereopsis for the circle in the last box chosen correctly was recorded.

Data Analysis Technique

Tables and graphs were used in representing the findings from the degree of stereoacuity impairment with induced anisometropia.. Tables were needed to summarize masses of raw data for the purpose of drawing conclusions and writing the report.Paired sample t-test and One-way ANOVA were used for statistical analysis.

Results, Analysis and Interpretation of Data

Data Presentation and Interpretation

The following data results were obtained on the effect of induced anisometropia on the stereoacuity of teenagers and analyzed using the One-Way ANOVA and paired sample t-test. 56 subjects between the ages of 16-19 years were used. The mean and standard deviation were calculated.

All analysis was conducted at $\propto= 0.05\propto= 0.05$ using the Statistical Package for Social Scientists version 23.

Table 1. *Paired Samples Test of stereoacuity before and after induction of Anisometropia*

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Stereoacuity After Induction On Anisometropia - Stereoacuity Before Induction Of Anisometropia	548.929	962.771	128.656	291.097	806.760	4.267	55	.000079

The Descriptive Statistics table is shown below:

Table 2 shows a paired samples statistic between stereoacuity before induction of anisometropia and after induction of anisometropia.

Table 2. *Paired Samples Statistics of stereoacuity before and after induction of Anisometropia*

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Stereoacuity After Induction Of Anisometropia	588,93	56	962.771	128.656
	Stereoacuity Before Induction Of Anisometropia	40.00	56	.000	.000

Table 3. *Paired Samples Statistics of gender influence on Stereoacuity*

Lovene's Test For Equality of Variance						T-test for Equality of Means				
		F	Sig.	T	df	Sig(2-Tailed)	Mean Difference	Std. Error Difference	95%Confidence Interval of the Difference	
									Lower	Upper
Stereoacuity After Induction Of Anisometropia	Equal Variance Assumed	.017	.898	.107	54.000	.915	28.137	263.897	-500.945	557.219
	Equal Variance Not Assumed			.107	47.794	.915	28.137	263.420	501.563	557.837

The independent samples t-test used to investigate if gender could influence stereoacuity between males and females returned with a very high p-value of 0.915 which is almost 1.0. Therefore, we do not have evidence against the null hypothesis. Consequently, we accept the null hypothesis. This is represented in table 3.

Table 4. *Gender group Statistics*

	Gender of Subjects	N	Mean	Std. Deviation	Std. Error Mean
STEREOACUITY AFTER INDUCTION OF ANISOMETROPIA	Male	33	600.48	975.470	169.807
	Female	23	572.35	965.802	201.807

After the inducement of anisometropia, the mean stereoacuity for males was 600.48 arc seconds with a standard deviation of 975.470 arc seconds while that of females was 572.35 arc seconds and 965.802 arc seconds respectively.

Table 5. *Anova For Stereoacuity After Induction Of Anisometropia*

	Sum of Squares	df	Mean Squares	F	Sig.
Between Groups	4517282.514	3	1505760.838	1.685	.182
Within Groups	46463773.200	52	893534.100		
Total	50981055.7	55			

A one-way ANOVA test was done to check for significant difference in stereoacuity after inducement of anisometropia amongst the different powers used with Lens on OD. A p-value of 0.182 shows no significant difference. The same was done for lens on OS which showed significant difference with a p-value of 0.001 as seen in Table 6. Consequently

Table 6. *Anova For Significant Difference In Stereoacuity Among The Different Lens Combinations*

	Sum Of Squares	df	Mean Squares	F	Sig.
Between Groups	24231019.714	13	1863924.593	2.927	.004
Within Groups	26750036.000	42	636905.619		
Total	50981055.714	55			

A p-value of 0.004 shows that there is significant difference in stereoacuity amongst the different lens combinations.

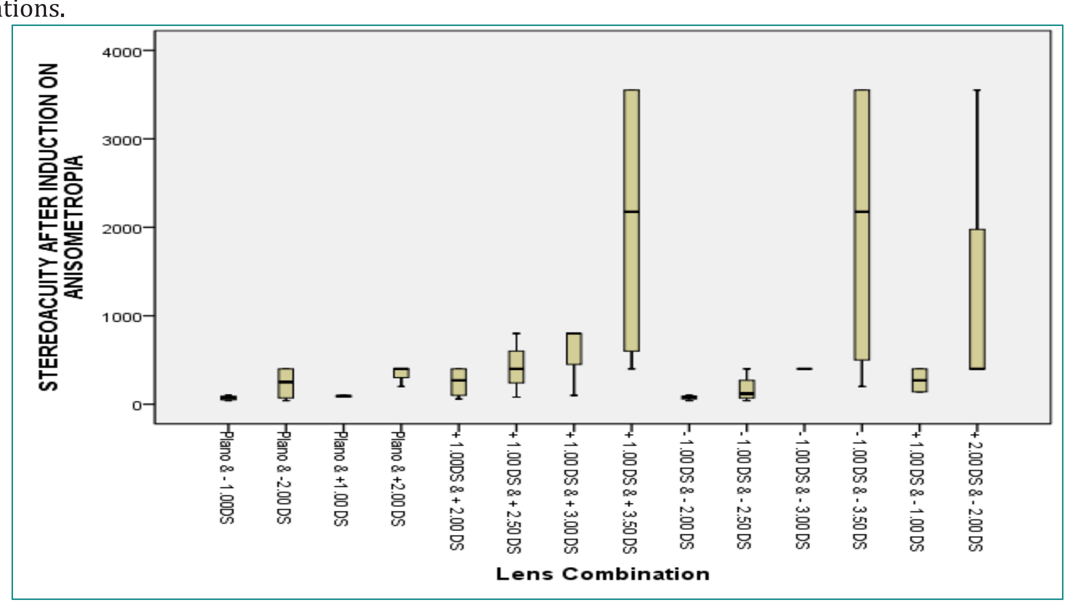

Figure 1. *Box plot of lens combinations*

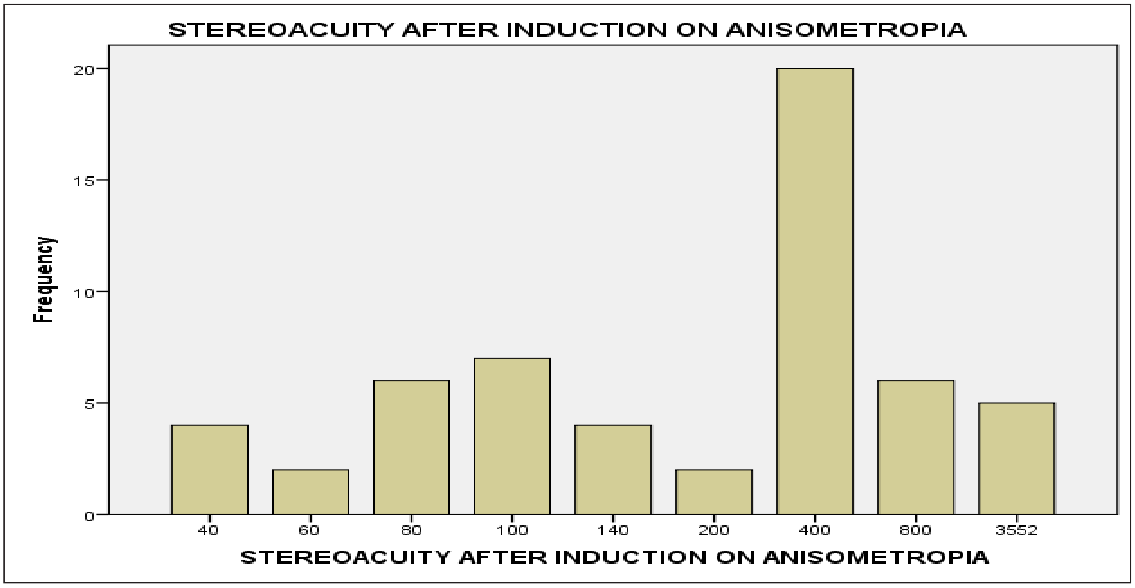

Figure 2. *Frequency of stereoacuity after induction of Anisometropia.*

Table 7. *Frequency table showingstereoacuity after induction of Anisometropia. Stereoacuity After Induction of Anisometropia*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	40	4	7.1	7.1	7.1
	60	2	3.6	3.6	10.7
	80	6	10.7	10.7	21.4
	100	7	12.5	12.5	33.9
	140	4	7.1	7.1	41.1
	200	2	3.6	3.6	44.6
	400	20	35.7	35.7	80.4
	800	6	10.7	10.7	91.1
	3552	5	8.9	8.9	100.0
	Total	56	100.0	100.0	

Conclusion

The paired samples t-test used to check for significant difference between stereoacuity before and after inducement of anisometropia returned a p-value of 0.000079 which is less 0.05. This provides enough strong evidence against the null hypothesis and one can conclude that indeed, anisometropia has statistical significant effect on stereoacuity.The independent samples t-test used to investigate if gender could influence stereoacuity between males and females returned with a very high p-value of 0.915. Almost 1. Therefore, we do not have evidence against the null hypothesis. Consequently, we accept the null hypothesis.

Discussion of Findings

This research was aimed at determining the effect of different magnitudes of experimental anisometropia on the stereoacuity of teenagers (between the ages of 16- 19 years).

The analysis represented in table 1 provides a strong evidence that anisometropia has a significant effect on stereoacuity having a significance of 0.000079.

An analysis done to compare the degree of impairment of stereoacuity by anisometropoia between males and females shows that there was no significant difference between the sexes. This was represented in table 3.

Table 6 represents an analysis which shows that there was a significant difference in stereoacuity impairment amongst the different lens combinations.

The result of this study showed that there was an increase in impairment of stereoacuity as the magnitude of anisometropia was increased and isometropic subjects had better stereopsis anisometropic subjects which is in accord with a research carried out by Habiba and Hussain, (2017), in which isometropic patients had better stereopsis as compared to anisometropic patients when measured the Lang and Frisby stereo tests (11). This research is also in accordance with that carried out by Dadeya, et al. (2001) and Nabie et al., 2019

(12, 13).

Myopic anisometropes had a greater impairment than hyperopic anisometropes. The highest degree of impairment was discovered to be among the compound myopic anisometropes of 2.50DS difference between both eyes having a mean of 2076 arc seconds followed by hyperopic anisometropes of 2.50DS difference between both eyes having a mean of 2026 arc seconds(12, 13). A high level of impairment was also recorded among the mixed anisometropes having +2.00DS on OD and -2.00DS on OS. Dennis, et al. (2012), using the Randot circles test discovered that anisohyperopes had a better stereoacuity than anisomyopes even with fairly small degrees of myopia in the weak eyes which showed a very poor stereopsis (14).

Simple hyperopic anisometropia of 1D had a better stereoacuity (i.e. lesser impairment) than simple myopic anisometropes of 1D. This tells that monocular blur have a much lesser effect on stereoacuity than binocular blur. It is believed to be due to a better visual function retained by isometropes when compared to anisometropes. For instance, by viewing at very close distance an isometrope (myopic) would have periods of clear vision. In contrast to myopic anisometropes a hyperopic anisometrope will generally accommodate to obtain a clear retinal image in the less hyperopic eye and the fellow eye will always be out of focus with an attendant degradation of high spatial frequencies in the retinal image (12, 13).

In the study carried out by Habiba and Hussain(2017), it was discovered that by wearing of anisometropic glasses, the stereopsis level was clinically close to normal and the glasses did not have effect on the binocular vision in spite of the severity of the anisometropia. This tells that early correction and management of anisometropia with the appropriate lenses no matter the severity or magnitude would prevent the onset of amblyopia as well as preserve binocular function(i.estereoacuity) to a large extent (11).

The research of Weakley, (2001) however contradicts this study which says that myopic anisometropia has a greater impairment on stereoacuity than hyperopic anisometropia. Weakley's study was carried out on 361 anisometropes and 50 non-anisometropes and he discovered that hyperopic anisometropia had a greater impairment on stereoacuity than myopic anisometropia. This contrast could be due to certain variation and differences such as ''Race'' of which strictly negroes specifically Nigerians were used in this study,''age''(Weakley used children between the ages of approximately 3-14.5 years whereas those used for this study were teenagers between the ages of 16-19 years), ''Location" and "a difference in the type of stereoacuity chart used for both studies" (15).

It should be noted that difference between the refractive conditions of both eyes is very significant because it can bring about impediments to academic achievements and choice of career. The unequal refraction of the same visual signal might result in sending different information to the brain; this would also impair the abilities to perceive depth and judge distance. The consequences thus add neuro-psychological load in attempting to make a single cortical image from two dissimilar image patterns which can again mutilate good performance.

Conclusion from this Study

The effect of both simple and compound myopic anisometropia was of a greater magnitude than simple and compound hyperopic anisometropia with isometropia causing a lesser impairment (i.e. simple anisometropia) than anisometropia (compound anisometropia).

This study supports existing guidelines for the observation of anisometropia and characterizes the association between the type of anisometropia and degree of anisometropia with the incidence of impairment of stereoacuity (i.e subnormal binocularity).

Contribution to Knowledge

This study gives an insight to the relationship between the degree of anisometropia and magnitude of staereoacuity impairment pointing out that compound myopic anisometropia of 2D difference and above between both eyes has a greater effect on impairing steroacuitythan does compound hyperopic anisometropia of 2D difference and above between both eyes among teenage Nigerians ageg 16-19 years.

This is quite different from previous researches done which says the reverse; thus, the researcher could say that due to this peculiar difference between her findings and those of past literatures that race, location, age and variation in stereoacuity charts used for testing might play a role in quantifying the effect of anisometropia on stereoacuity.

Limitation of Study

Like in all human endeavors, problems are bound and are indeed known to occur which tends to impede the absolute success and realization of any goal. Some of the considerations which limited the absolute authority of this study include:

- Errors due to latent refractive errors and malingering among the students.
- Errors due to the subjective method of determining the age of subjects used for the study.
- Difficulty in getting the stereoacuity chart used for the study.

Suggestion for Further Study

Due to the variation and difference between the findings of this study and that of past researches, further investigations need to be carried out on the negro race to establish this variance. A much larger population is advised to be used in further study as well as a different age group. This would give an insight into the possibility of age being a factor in this variation.

Recommendation

- Regular eye examinations and vision screening of teenagers should be encouraged in the society so as to provide early detection and proper management of anisometropic cases as this could be a detriment to their daily living due to their impaired ability to perceive depth and judge distance.
- Parents and guardians should be encouraged to provide corrective lenses for their wards not considering the cost but the advantages to be derived from this measure in the nearer future as amblyopia would be averted and choice of careers would not be limited to this young and promising population.
- There is a need to make visual screening certificate a prerequisite for admission into our schools. This will help in early detection of anisometropia and minimize it's progression as well as onset of amblyopia.

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