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Changes in visual acuity as a function of defocus induced by positive lenses

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Abstract

(i) Purpose: To assess changes in visual acuity (VA) as a function of induced defocus by plus lenses till 5 D, in the Indian population using a computerized automatic measurement of VA. (ii) Methods: The study was done on 15 student volunteers. A complete optometric evaluation was done. Refractive errors did not exceed +/-1.00 DS, ± 0.50 DC, and were correctable to 6/6, N6. Subjects had no history of ocular diseases, binocular vision anomalies, and systemic diseases and were not on medications affecting pupil sizes or accommodation. With best correction, distance VA was tested and recorded automatically using LCD projected Freiburg Visual Acuity Test chart (FrACT3.8.0e software) placed at 6m, with Tumbling 'E'. Plus lenses were added in front of the right eye alone, in steps of -0.50 DS, starting from -0.50 DS to -5.00 DS. An informal consent was obtained.The VA readings were automatically generated. The data was analyzed using the Statview Statistical Software (SAS Institute Inc.) by Repeated Measures ANOVA. (iii) Results: VA decreases with plus lens-induced defocus in 0.5 D steps till -5 D, overall (p-value <0.0001). Although there is a steady linear decrease in acuity upto -2 DS, beyond this the rate of decrease in acuity slows down and plateaus. (iv) Conclusion: With increase in myopic defocus, induced by plus lenses, VA reduces, albeit, non-linearly especially for higher amounts of defocus. Spectacle magnification as an artefact needs to be verified.

1. Introduction

Visual acuity (VA) is an important parameter and many researchers and clinicians are interested in the relation between VA and refractive state. Peters (1961) investigated the relation between VA and uncompensated ocular defocus using charts of iso-oxyopia (lines of equal acuity). Radhakrishanan et. al. (2004) found linear decrease in visual acuity with positive lens-induced defocus, similar in non-myopes and myopes. However, they did not randomize the letters of the chart and hence the letters in the chart were familiar to the subjects for each lens change. In the present study, we are re-examining the effect of positive-induced defocus using a computerized logMAR chart that will estimate VA using Forced-choice testing.

2. Primary Objective

We aimed at assessing changes in Visual acuity as a function of induced defocus by positive lenses, in the Indian population using a forced-choice computerized automatic measurement of VA using the Freiburg Visual Acuity Test (FrACT, version 3.8). The results thus obtained will give an insight into VA changes in varying amounts of myopia.

3. Methodology

3.1. Subject Selection

The study was done on fifteen student volunteers (9 females and 6 males), of the Optometry department of Sri Jayendra Saraswathi Institute of Medical Sciences and research (JIMS, a unit of Sankara Eye Hospital, Pammal, Chennai). Their ages ranged between 18 to 25 years [mean±standard deviation (s.d.), 21.1± 1.98]. A complete optometric evaluation was done, which included vision, refraction, slit-lamp examination, extra-ocular muscles, cover tests, pupillary evaluation and fundus examination (see Appendix 1 for case-sheet). The volunteers were deemed eligible based on the below eligibility criteria.

3.2. Inclusion Criteria

- Emmetrope and corrected ametropes with refractive errors not exceeding Sph: +/-1.00 DS and Cyl: ± 0.50 DC,
- Best corrected visual acuity (BCVA) of 6/6, N6,
- No history of ocular diseases, binocular vision anomalies and systemic diseases.
- Subjects should not be on medications that may affect pupil sizes or accommodation or light tolerance.

3.3. Exclusion Criteria

- History of ocular diseases and systemic diseases
- Binocular vision abnormalities

3.4. Data Collection

With the best correction, the distance VA was tested and recorded automatically using a LCD projected Freiburg Visual Acuity Test chart (FrACT3.8.0e software) placed at 6m. The FrACT provides more reliable data, because of its ability to shuffle letter 'E' in different direction to avoid the subject from memorizing the chart details and uses a forced-choice method to assess VA. Plus lenses were then added in front of the right eye alone, in steps of -0.50 DS, starting from -0.50 DS to -5.00 DS. The VA readings of the subjects were automatically generated in an excel spreadsheet and recorded as decimal acuity and LogMAR acuity, for analysis.

An informal consent was obtained, after explaining the study to all the study participants.

3.5. Data Analysis

The data was analysed using the Statview Statistical Software (SAS Institute Inc.). Repeated Measures ANOVA and Fisher's protected least significant difference (Fisher's PLSD) post-hoc tests were used to analyze the data.

4. Results

All the eyes were correctable to 6/6 and the refractive error of the subjects ranged between 0 to -0.75 DS (mean± standard deviation (s.d.), -0.24±0.27 D). Fig. 1 shows the histogram of refractive error distribution of the study subjects.

A comparison of decimal visual acuity changes with positive lens-induced defocus in 0.50 D steps till -5.00 D, showed highly significant decrease overall (Repeated-measures analysis of variance [ANOVA]:$F_{14,\ 10}$ = 28.65; p-value <0.0001). Thus, as the amount of induced myopic defocus was increased, the decimal visual acuity tends to detoriate. For example, with -0.50 DS of induced myopic defocus, the mean visual acuity in decimal was 1.042, whereas with -2.00 DS of induced myopic defocus, the mean decimal visual acuity was 0.225.

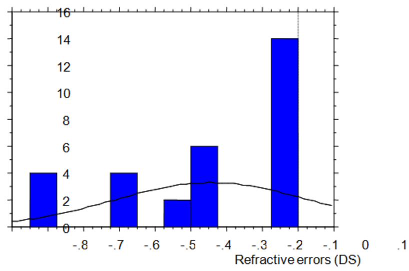

Figure 1. *Distribution of refractive errors in the right eyes of the thirty study participants.*

Although there is a steady linear decrease in decimal acuity upto -1.50 DS, beyond this the rate of decrease in acuity slows down till -5.00DS (fig. 2a). The table 1 summarizes the decimal visual acuity and LogMAR visual acuity (mean±s.d.) for the induced myopic defocus. The table 2 presents results of the Fisher's PLSD post-hoc test for individual comparisons.

Regression analysis fits a polynomial function of third-order to the decimal visual acuity data, R^2=0.807, p-value<0.0001 (fig. 3a).

With regards to the LogMAR visual acuity which is predominantly used for statistical analysis, similar trends of decrease in visual acuity, suggested by more positive values of LogMAR with increased myopic defocus is seen (Repeated-measures analysis of variance [ANOVA]:$F_{14,\ 10}$ = 234.756; p-value <0.0001) (see figs. 2b, 3b & Tables 1, 2) Regression analysis with LogMAR VA data fits a polynomial of the second order, R^2=0.833, p-value<0.0001 (fig. 3b).

Table 1. *Decimal visual acuity and LogMAR visual acuity with induced myopic defocus (0.0 to -5.0 DS, in 0.50 D steps): Acuity decreases as myopic defocus is increased. Mean± s.d. presented.*

Induced Myopic defocus (DS)	Decimal visual acuity (Mean ± s.d.)	LogMAR visual acuity (Mean ± s.d.)
0.0	1.33±0.51	-0.08±0.21
-0.5	1.04±0.32	-0.10±0.35
-1.0	0.68±0.24	0.20±0.14
-1.5	0.37±0.14	0.47±0.18
-2.0	0.23±0.10	0.69±0.19
-2.5	0.17±0.06	0.80±0.17
-3.0	0.13±0.06	0.93±0.16
-3.5	0.11±0.10	1.01±0.24
-4.0	0.09±0.03	1.08±0.16
-4.5	0.08±0.04	1.14±0.21
-5.0	0.06±0.02	1.23±0.12

Table 2. *Pair-wise comparisons of decimal visual acuity for differing amounts of induced myopic defocus, ranging from 0.0 to -0.5 DS. Fisher's PLSD post-hoc analysis used. Grey shaded cells show comparisons of LogMAR VA while the clear cells show comparisons of decimal VA. Significant differences are represented by symbols (**** indicate p-values <0.0001, ***indicate p-value <0.001, ** indicate p-value<0.01 and * indicate p-value<0.05, while NS implies the comparisons are not statistically significant at a level of 0.05.*

Induced Myopic defocus (DS)	0.0	-0.5	-1.0	-1.5	-2.0	-2.5	-3.0	-3.5	-4.0	-4.5	-5.0
0.0	-	NS	****	****	****	****	****	****	****	****	****
-0.5	****	-	****	****	****	****	****	****	****	****	****
-1.0	****	****	-	***	****	****	****	****	****	****	****
-1.5	****	****	****	-	**	****	****	****	****	****	****
-2.0	****	****	****	NS	-	NS	***	****	****	****	****
-2.5	****	****	****	**	NS	-	NS	**	****	****	****
-3.0	****	****	****	**	NS	NS	-	NS	*	**	****
-3.5	****	****	****	***	NS	NS	NS	-	NS	NS	**
-4.0	****	****	****	***	NS	NS	NS	NS	-	NS	*
-4.5	****	****	****	***	NS	NS	NS	NS	NS	-	NS
-5.0	****	****	****	****	*	NS	NS	NS	NS	NS	-

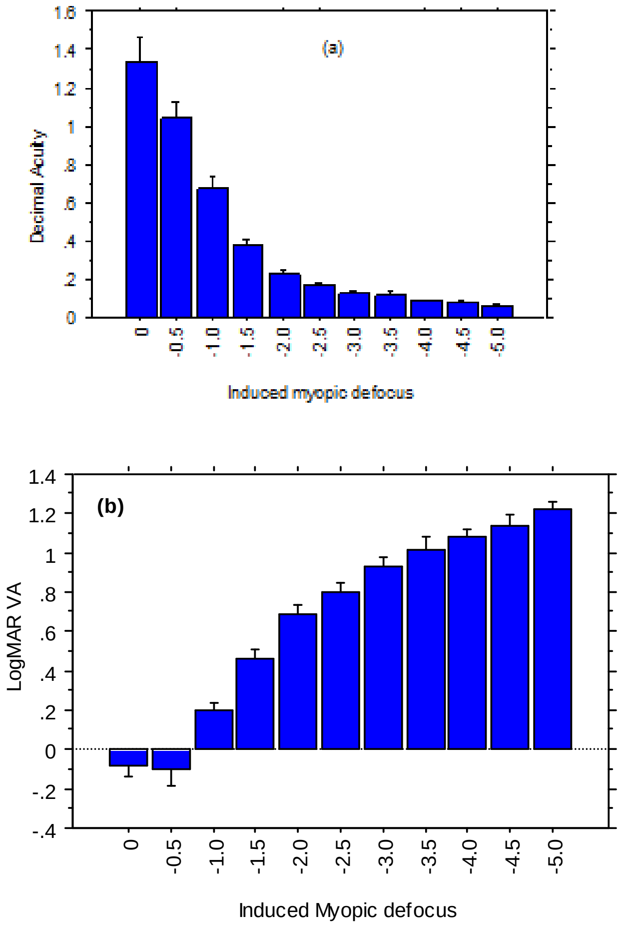

Figure 2. *The bar graphs (a, b) represent decimal VA and LogMAR VA as a function of induced myopic defocus, respectively. Mean± standard errors of mean (s.e.m.) plotted.*

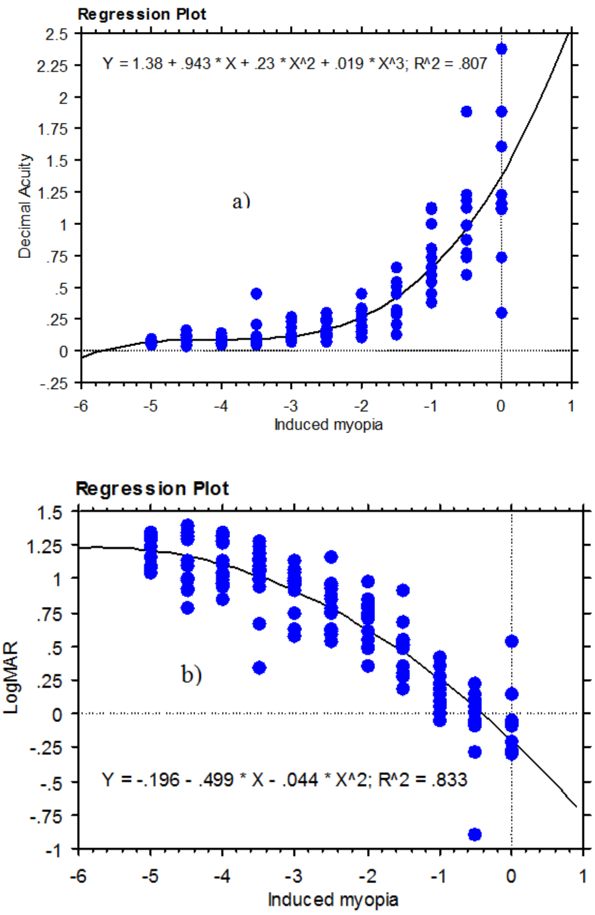

Figure 3. *The regression plot (a) shows decimal VA as a third order polynomial function of induced myopic defocus. The regression plot (b) shows LogMAR VA as a second order polynomial function of induced myopic defocus.*

5. Discussion

Our study shows that with the induction of positive lenses in front of the eye inducing myopic defocus results in a loss in visual acuity. However in our study, we do not find a linear response but a polynomial relationship. This is in contrast to the earlier work of Radhakrishnan et al. (2004). The reason for this difference could be explained by the difference in the testing methods; in our study an automatic forced-choice method was used. The earlier study used the conventional manual testing procedure, which does not eliminate the learning effect on the visual acuity, despite the researchers' effort to reduce it by randomising the introduction of the plus lenses.

In our study, we did not randomize the order of lenses because the FrACT is a very reliable procedure free from learning effects on visual acuity. Despite this, the subjects could have become tired to the repeated testing in our study. Moreover, the probability of guessing the direction of the Tumbling E was only 25% due to the fewer choice of directions i.e. 4. Nevertheless, these factors should have made the VA worse with higher powers, which is opposite to what we have observed.

The non-linearity response of VA seen in our study can be further attributed to the greater amounts of defocus introduced, upto -5.00 D in our study, in contrast to -3.00 D in the earlier study. Our work also supports a linear response only for lower powers. Although some of our study subjects had minor amounts -0.75 DS of myopia, they were considered emmetropes for the sake of the study; this may not completely explain the differences in the results as previous work has shown that plus-lens induced defocus does not vary for emmetropes or myopes.

The earlier study assessed vision under cycloplegia with a 6mm artificial pupil. Even though we did not control accommodation by cycloplegia and control pupil sizes, care was taken to prevent accommodation by placing the next plus lens before removing the previous lens. 6mm is definitely a large pupil size that can introduces aberrations as a factor. It is worth repeating the present study under cycloplegia or introducing the lenses in a descending order, starting from higher plus values, to prevent the subjects from accommodating. Pupil sizes may be assessed and visual acuity changes with artificial pupil sizes of 3mm may be studied.

The previous work has also re-calculated VA after adjusting for spectacle magnification effects. The present data may also be reanalysed using this adjustment factor.

Future work needs to be done to study higher defocus powers using the FrACT test, with better control of accommodation. The work can be extended to corrected myopes greater than -1.00 DS. It will be interesting to study VA changes with minus lens- induced hyperopic defocus, to verify earlier work that myopes show less VA loss with minus lenses than emmetropes.

6. Conclusion

Our study shows that with the increase in degree of myopic defocus, induced by plus lenses gradually results in decrease in visual acuity, albeit, non-linearly especially for higher amounts of defocus.

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