

Article ▶ Effect of Test Target Size on Phoria and Horizontal Fusional Vergence

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ABSTRACT

Background: A phoria is a latent deviation held in check by fusional vergence. This implies that fusional vergence measurement is important in assessing binocularity. It compensates for phoria and thus is very important in normal binocular function. The aim of this study was to evaluate differences between phoria and fusional vergence measures obtained using varying target sizes at distance and near fixation.

Method: A comparative analysis of measures of phoria and horizontal fusional vergence (blur, break, and recovery values) was obtained with randomization of target size and order of prism base. Eighty-four subjects were recruited. The following measurements were made: cover test, ocular motility test, near point of convergence test, amplitude of accommodation test, phoria, and fusional vergence using Von Graefe technique.

Results: The mean horizontal phoria values in prism diopters (Δ) for all subjects at distance fixation were: 2.04 ± 1.26 for a 6/6 target to 2.05 ± 1.42 for a 6/60 target. The mean horizontal phoria values in prism diopters for all subjects at near fixation were: 2.82 ± 1.64 for 6/6 to 2.67 ± 1.76 for 6/60. The mean horizontal fusional vergence ranges for all subjects at distance fixation were: BO 16.76 ± 4.20 to BI 10.10 ± 2.61 for a 6/9 sized target and BO 18.98 ± 4.47 to BI 12.30 ± 3.08 for a 6/60 sized target. The mean horizontal fusional vergence ranges in prism diopters for all subjects in this study at near fixation were: BO 16.56 ± 3.54 to BI 14.98 ± 3.23 for a 6/9 sized target and BO 18.26 ± 3.56 to BI 17.95 ± 3.86 for a 6/60 sized target. These results showed an increase in the horizontal fusional vergence values as the test target size increased at both distance and near fixation.

Conclusion: There was no significant difference in phoria measures obtained with the different-size targets. However, there was a significant difference between horizontal vergence measures obtained with the different-size targets. Smaller fusional vergence values were obtained with small target sizes compared with large target sizes.

Keywords: fusional vergence, phoria, test target, Von Graefe technique

Introduction

Heterophoria is defined as the tendency of the line of sight to deviate from the relative position necessary to maintain single binocular vision.¹ In other words, the phoria is the latent deviation of the eyes held in check by fusional vergence.² During bifoveal vision, the phoria is compensated for by fusional vergence. When assessing binocularity, measuring fusional vergence ranges provides important information.^{3,4}

The magnitude and type of fusional vergence needed for binocular vision depends on the size and direction of the phoria.⁵ Fusional vergence movement can be either positive (a movement of both eyes inward) or negative (a movement of both eyes outward). Vertical vergence movements involve one eye moving upward or downward with respect to the other in order to maintain single binocular vision.

Phoria creates demand for fusional vergence. The amount of fusional vergence required to avoid diplopia is called the fusional vergence demand. The amount of fusional vergence held in reserve is known as fusional vergence reserve. The total fusional range is an indication of how much the eyes can

converge or diverge to avoid diplopia due to retinal disparity before accommodative convergence or divergence comes into play.⁵ In order to achieve comfortable binocular vision, the fusional vergence reserve should be at least twice the demand.⁶ It has also been proposed that the visual system is capable of maintaining good performance as long as no more than two-thirds of the total amplitude is used.⁷

Many studies have been carried out to determine different phoria and fusional vergence parameters, including the normal fusional vergence range, the effect of age and/or gender, ocular dominance, test distance, measuring techniques for phoria and fusional vergence, and the relationship between the type of deviation and the measured fusional vergence. Many of the studies have stated the type of target used.⁸⁻¹³ These target sizes vary considerably from one study to the next, ranging from a small, detailed target (central stimulus) to a large target (peripheral stimulus) to columns of letters isolated from the Snellen chart. One aspect that does not appear to have been fully addressed in the literature is the size of the target that is used when measuring phoria and fusional vergence. This

prompted the current study, aimed at determining whether target size has a significant effect on the phoria and fusional vergence measurement.

Methods

Study Population

This study was carried out at the University of Benin Optometry teaching clinic, Benin City, Edo state, Nigeria. The study followed the tenets of the Declaration of Helsinki and was approved by the ethics committee of the University of Benin. Informed consent was obtained from all participants. Eighty-four participants, both male and female adults (18-30 years), were involved in this study. They were recruited using a convenient-sampling technique but were required to meet the inclusion criteria (best corrected visual acuity of 6/6 or better, refractive error within $\pm 5.00\text{DS}/\pm 2.00\text{DC}$, esophoria or exophoria within ± 10 prism diopters, and visually asymptomatic). Individuals with strabismus, abnormal ocular motility, eye disorders and pathology, history of eye surgery, amblyopia, and nystagmus were exempt from the study. Subjects were properly educated on the various test procedures.

Procedure and Data Analysis

The following tests were carried out: monocular and binocular visual acuity with and without correction using Snellen optotypes at distance (6m) and at near (40cm), cover test, ocular motility test, near point of convergence test, amplitude of accommodation test, and phoria and fusional vergence measurement using the Von Graefe technique. Effort was made to take accurate measurements, considering the test distance, test target, and illumination. Regarding the choice of target, each subject was requested to pick out a piece of paper to indicate the order of target use, which ranged from VA of 6/60 to 6/9. Previous studies have shown some variation in measurement as target size is altered.¹⁴ Subjects were allowed to rest for 1-2 minutes between each measurement, during which time they were instructed to gaze into the distance to minimize prism adaptation effects.¹⁵ Measurements were taken during one visit.

For the Von Graefe lateral phoria test at distance and near, the test targets were vertical rows of Snellen letters at distance and near (6m and 40cm, respectively) in a room with ambient illumination. With the subject's distance and/or near prescription placed in the phoropter and interpupillary distance set, the subject's attention was drawn to the target, and the eyes were dissociated with 6^Δ base-up in front of the left eye and 12^Δ base-in in front of the right eye. Two images were seen, one up and the other down, with the left eye seeing the lower image to the left and the right eye seeing the upper image to the right. The subject was then instructed to look at the lower image to the left and to report "yes" when the other image to the right was directly above it or appeared to be aligned as the base-in prism in front of the right eye was gradually reduced. If the two images were aligned with zero

prism, the subject was labelled as orthophoric. If the measuring prism indicated base-in at subjective alignment of the images, the subject was exophoric, and if base-out, the subject was esophoric. The magnitude was equivalent to the amount of prism power at the different distances at which alignment was reported. This procedure was carried out using each of the six targets.

A similar procedure was carried out for the Von Graefe vertical phoria test at distance (6m) and near (40cm). For this measurement, the test targets were horizontal rows of Snellen letters at distance and near, with the base-up prism as the measuring prism. A base-up alignment of the images with the measuring prism indicated that the subject had right hyperphoria or left hypophoria, while a base-down alignment indicated that the subject had left hyperphoria or right hypophoria. The magnitude was equivalent to the amount of prism power at the different distances at which alignment was reported.

The Von Graefe negative fusional test was done at both distance (6m) and near (40cm) using each of the six test targets oriented vertically. The subject's distance and/or near prescription was placed in the phoropter, and interpupillary distance was adjusted. The rotary prisms were placed before each eye and set up for horizontal power. The subject was instructed to fixate the target letters and to make an effort to keep them as focused as possible. Starting from zero, the base-in prism power before each eye was simultaneously increased. The subject was instructed to report "yes" the moment he noticed the letters become constantly blurred (blur point). To help the subject identify the blur point, blur was stimulated by adding +0.50D to the subject's eye or distance correction before starting the procedure. The first sustained blur was noted, and the prism power required was recorded. The subject was then asked to report the moment the column of letters doubled and the two images could not be reunited (break point), then when a single column was again observed (recovery point). The prism power at which the blur, break, and recovery occurred at the different distances was noted. For this procedure, the subject was not expected to report a blur point at distance. If the patient reported blur, it indicated that the subject was accommodating at distance or that the subjective finding was in error in the direction of insufficient plus or excessive minus power.⁵ The subjective end point was rechecked before repeating the procedure. A similar procedure was carried out for the Von Graefe positive fusional test for distance and near using base-out prism.

Data was analyzed using the SPSS program (version 21). A paired t-test was used to determine whether there was any significant difference in the measurements obtained using the different target sizes.

Results

On the cover test at distance, 30 subjects had esophoria, 45 had exophoria, and 9 had orthophoria. At near, 14 subjects

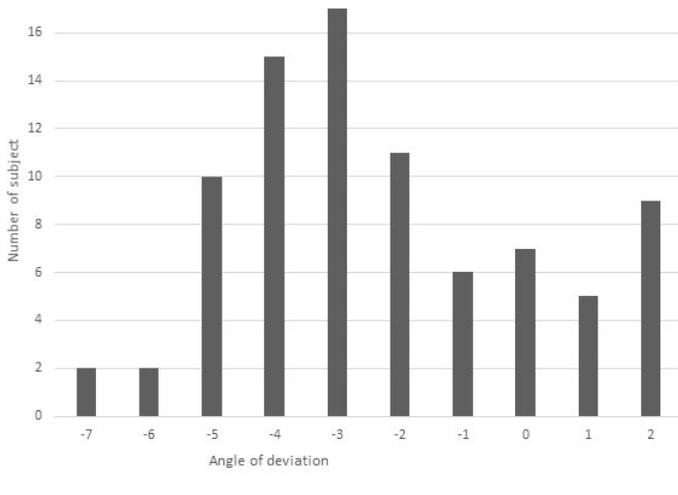


Figure 1. Angle of deviation at distance

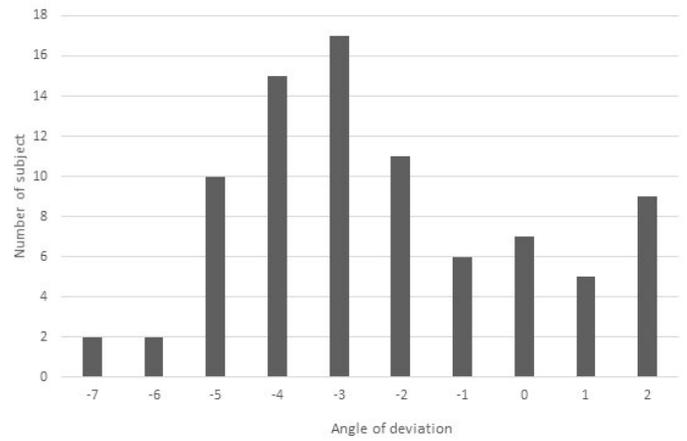


Figure 2. Angle of deviation at near

Table 1. Mean Horizontal and Vertical Phoria Values for Distance and Near Fixation According to Target Size

Target size	6/9	6/12	6/18	6/24	6/36	6/60
Horizontal						
Near	2.82±1.64	2.82±1.67	2.85±1.66	2.87±1.72	2.65±1.59	2.67±1.76
Distance	2.04±1.26	1.94±1.29	1.94±1.29	1.94±1.29	1.94±1.29	2.05±1.42
Vertical						
Near	0.90±0.82	0.90±0.82	1.02±1.06	1.06±1.25	1.05±1.24	0.96±1.06
Distance	1.11±0.84	1.02±0.79	1.10±0.82	1.11±0.78	1.12±0.83	1.17±0.85

Table 2. P-values for Base-In Findings, Base-Out Findings, and Phoria

		P-value							
		BI			BO			Phoria	
		blur	break	recovery	blur	break	recovery	vertical	horizontal
Pair 1	Near 6/9 - Near 6/12	1.000	.971	.943	.288	.246	.711	1.000	1.000
Pair 2	Near 6/9 - Near 6/18	.302	.215	.006	.292	.006	.058	.141	.708
Pair 3	Near 6/9 - Near 6/24	.121	.001	.004	.000	.000	.013	.139	.752
Pair 4	Near 6/9 - Near 6/36	.000	.000	.004	.000	.000	.018	.192	.154
Pair 5	Near 6/9 - Near 6/60	.000	.000	.000	.000	.000	.000	.469	.179
Pair 6	Distance 6/9 - Distance 6/12		.410	.506	.572	.030	.040	.090	.059
Pair 7	Distance 6/9 - Distance 6/18		.150	.011	.196	.047	.024	.765	.059
Pair 8	Distance 6/9 - Distance 6/24		.000	.000	.685	.003	.000	1.000	.059
Pair 9	Distance 6/9 - Distance 6/36		.000	.000	.000	.006	.000	.836	.059
Pair 10	Distance 6/9 - Distance 6/60		.000	.000	.000	.000	.000	.300	.897

had esophoria, 63 had exophoria, and 7 had orthophoria. The median prism cover test in prism diopters was -1Δ (-4 to $+5\Delta$) at distance fixation and -3Δ (-7 to $+2\Delta$) at near fixation (Figures 1 and 2).

Phoria

When comparing horizontal phoria measures obtained with 6/9-size targets with values obtained using the other targets (6/12, 6/18...6/60) at distance and near fixation, there was no significant difference for all comparisons ($p > 0.05$) by paired t-test (Tables 1 & 2).

Negative/Positive Fusional Vergence (Horizontal Fusional Vergence)

Table 2-4 show the findings related to the positive and negative fusional vergence testing. Out of the 50 possible findings, 33 were found to be significantly different. There was no statistical difference between the 6/9 BI to blur, break, and recovery and the 6/12 or 6/18 BI to blur, break, and recovery. There was a statistically significant difference with 6/24, 6/36, and 6/60 break, blur, and recovery values ($p < 0.05$). There was a statistically significant difference when comparison was made between 6/9 BO to break, recovery values and 6/18, 6/24, and 6/36 to break and recovery values. ($p < 0.05$).

Table 3. Mean Horizontal Fusional Vergence Values for Near Fixation in BO and BI Findings According to Target Size

Near fixation	Target size	6/9	6/12	6/18	6/24	6/36	6/60
BI	Blur	11.42±3.14	11.42±2.99	11.77±3.17	13.74±13.56	13.23±3.01	14.30±3.42
	Break	14.98±3.23	14.99±3.21	14.58±3.50	15.95±2.94	16.58±3.31	17.95±3.86
	Recovery	10.33±2.60	10.36±2.61	11.64±3.43	11.42±2.63	11.42±2.63	12.24±3.24
BO	Blur	13.39±3.31	13.54±3.25	13.54±3.19	13.94±3.25	14.71±3.25	15.42±3.85
	Break	16.56±3.54	16.82±3.37	17.17±3.30	17.57±3.37	17.73±3.24	18.26±3.56
	Recovery	11.48±2.80	11.42±2.69	11.87±2.65	12.05±2.66	12.05±2.61	12.86±2.64

Table 4. Mean Horizontal Fusional Vergence Values for Distance Fixation in BO and BI Findings According to Target Size

Distance fixation	Target size	6/9	6/12	6/18	6/24	6/36	6/60
BI	Blur						
	Break	10.10±2.61	10.30±2.52	10.30±2.61	10.83±2.51	11.92±2.83	12.30±3.08
	Recovery	6.00±2.20	6.07±2.05	6.32±2.06	6.63±2.15	7.20±2.48	8.21±3.00
BO	Blur	12.67±3.74	12.75±3.80	12.88±3.90	12.52±4.55	13.79±4.30	14.80±4.53
	Break	16.76±4.20	17.19±4.29	17.24±4.49	17.62±4.80	17.74±4.28	18.98±4.47
	Recovery	10.26±2.97	10.79±2.74	10.99±2.96	11.10±2.64	11.32±2.99	12.69±3.15

Discussion

The question as to whether target size may influence the measurement obtained for phoria and fusional vergence was critically investigated using different-size targets ranging from 6/9 (central stimulus) to 6/60 (peripheral stimulus). Deductions were made by comparing the values using statistical testing (paired t-test). The study showed that target size does not have a statistically significant effect on both horizontal and vertical phoria at distance and near. This was in accordance with Strong and Pace.¹⁶ They also reported no difference in phoria measurements obtained using chromatic targets. The results of the study showed that varying target size has a significant effect on horizontal fusional vergence at distance and near. The results also showed an increase in the horizontal fusional vergence values as the test target size increased at both distance and near fixation. Scobee and Green¹⁷ measured prism fusion vergence at both near (28 BO to 20 BI) and distance fixation (19 BO to 7 BI) but with an unknown target size. The near and distance ranges are comparable with the range in this study using 6/60 and 6/9-size targets. Tait⁸ measured prism fusion vergence with a 6/30 peripheral target at distance fixation and obtained an average range of 30 BO to 12 BI. This is comparable to the range in this study with similar target size. Wesson⁹ used a 1.40 target at near fixation and a 6/12 target at distance fixation and reported fusional vergence of 19 BO to 13 BI for near and 11 BO to 7 BI for distance. These values are slightly different from those found in this study with similar target sizes. Rosenfield et al.¹⁰ documented a range of 27 BO to 8 BI using a parafoveal target at distance. Narbheram and Firth¹¹ used a central target at both distance (33 BO to 9.7 BI) and near (57 BO to 18.5 BI). Their BO range was particularly high, which may relate to the subjects used in the study (orthoptic undergraduate students). The convergence

range can be improved with long-term adaptation,¹⁵ and this is likely to have influenced and enhanced the results of their study. Antona et al.¹³ used a 0.8 decimal equivalent to 6/36 letter size and reported fusional vergence ranges of 28.91 BO to 12.14 BI for near and 23.25 BO to 8.63 BI for distance. The BI values are similar to those obtained in this study for the 6/9-size target. The positive fusional vergence from Antonia's study is slightly larger and more comparable to that of the 6/60 (peripheral) values in the present study. Rowe¹⁸ documented ranges for near (25 BO to 10 BI) and distance (16 BO to 6 BI) using a 6/6-size target. When a 6/60-size target was used, the range at near was 35 BO to 12 BI and at distance was 25 BO to 6 BI. The BO range at near was slightly larger than obtained in this study. The BO range at distance and the BI ranges were not similar to those obtained in this study. It would appear from the current study and much of the literature that the early prism fusional vergence values from 1948 generally remain consistent.^{9,13,18} Where there are some discrepancies, these undoubtedly relate to varying methodology across studies: namely, biased/unbiased subjects, the underlying angle of deviation, target size, time allowed to fixate the target, and the order of testing. These factors will impact fusional vergence measures.

Conclusions/Recommendations

The results of this study demonstrate that target size has no significant effect on phoria measurement. Difference in fusional vergence values tends to increase with an increase in test target size. It is recommended that the patient fixate a target of size commensurate with his or her visual acuity (for example, a line above the best visual acuity of the worse eye) when measuring their angle of deviation and fusional vergence. If not, erroneous interpretation of the ability to control a deviation may occur.

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