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An evaluation of the relationship between interpupillary distance and near phoria

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An evaluation of the relationship between interpupillary distance and near phoria

Abstract
This study was undertaken to determine if an individual with an extremely large or small interpupillary distance (PD) predisposed them to manifesting a similarly extreme near phoria. It was hypothesized that large PDs are more likely to be associated with higher exophoria than the norm and that small PDs would be associated with larger esophoria than the norm. The subject population was obtained from the patient records at the primary care clinic of Pacific University College of Optometry in Forest Grove, Oregon. Selected subjects were placed in either a large or small PD group and the distribution of their near phorias was analyzed. The large PD group had a mean near phoria of 4.3° exophoria and the small PD group's was 2.9° exophoria. This difference was not statistical significant (p=0.1249). The results of this study suggests that an extreme PD, either large or small, does not predispose an individual to an excessive near phoria in a particular direction.

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AN EVALUATION OF THE RELATIONSHIP BETWEEN INTERPUPILLARY DISTANCE AND NEAR PHORIA

BY

WILLIAM R. HALL AND ANTHONY W. BERGSTROM

A thesis submitted to the faculty of the
College of Optometry
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About the Authors

William R. Hall

William R. Hall was born in Kansas City, Mo. and grew up in Ilion, New York. He received a Bachelor of Science degree in Forestry from the SUNY College of Environmental Science and Forestry in 1977. Subsequently, he received a Bachelor of Science degree in Civil Engineering at the University of Utah in 1982. Mr. Hall worked as a civil/structural engineer for 10 years and was a licensed professional engineer in the state of New Mexico. He is currently a Doctor of Optometry candidate scheduled for graduation May, 1996.

Following graduation, Mr. Hall intends to become licensed to practice Optometry in New Mexico and to apply himself in a private practice.

Anthony W. Bergstrom

Anthony W. Bergstrom did his undergraduate work at Southern Oregon State University and Oregon State University, receiving his Bachelor of Science in Biology. He will receive his Doctorate of Optometry in May of 1996 and plans to join his wife in private practice in White Salmon, Washington immediately following graduation. He and his wife Deborah, their son Scott, and a new baby due in July, will make their home there as well.
ABSTRACT

This study was undertaken to determine if an individual with an extremely large or small interpupillary distance (PD) predisposed them to manifesting a similarly extreme near phoria. It was hypothesized that large PDs are more likely to be associated with higher exophoria than the norm and that small PDs would be associated with larger esophoria than the norm. The subject population was obtained from the patient records at the primary care clinic of Pacific University College of Optometry in Forest Grove, Oregon. Selected subjects were placed in either a large or small PD group and the distribution of their near phorias was analyzed. The large PD group had a mean near phoria of 4.3° exophoria and the small PD group’s was 2.9° exophoria. This difference was not statistical significant (p=0.1249). The results of this study suggest that an extreme PD, either large or small, does not predispose an individual to an excessive near phoria in a particular direction.

Key Words: interpupillary distance, near phoria.
Acknowledgments

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Most of all, we wish to thank our family members who have lived through this experience as much as the authors.
INTRODUCTION

Binocular vision dysfunctions at near are a common condition encountered by optometrists. There diagnosis can be perplexing and time consuming. Generally, it must be determined if the problem is vergence-based or accommodative-based. Relative to vergence-based dysfunctions, the source of the problem is often a phoric posture which strains the limits of fusional convergence. The fusional convergence effort required depends upon how the phoric posture compares with the total convergence demand of the fixated object. The convergence demand for a given fixation distance is a function of the interpupillary distance (PD). This raises the question as to whether knowing the patient's PD would aid the clinician in diagnosing a vergence-based binocular dysfunction.

The interpupillary distance (PD) is defined as the distance between the centers of rotation of the eyes.¹ For a given fixation distance, the convergence demand, the total angular excursion of the eyes necessary for bifixation, varies directly with the PD. The demand is quantified, in prism diopters (°), by multiplying the dioptric equivalent of the fixation distance by the PD in cm.² For a fixation distance of 40 cm., the convergence demand for a person with a 70 mm PD would be 17.5° and that for one with a 50 mm PD would be 12.5°. The significance of this difference, as to whether a binocular problem occurs, depends on the phoric posture of the individual and their fusional ranges.

A given convergence demand may result in a vergence-based binocular problem when the difference between it and the phoric posture exceeds the compensatory capabilities of the individual. A phoria describes the positioning of the visual axes under fusion-free conditions.³ Relative to a distant object it is a measure of how much the lines of sight deviate from parallelism. However, for a point closer than 6 meters it defines the degree to which the visual axes bifixate while fusion is inhibited. The phoria represents the amount
of fusion-free convergence which has occurred and it may; fall upon, lead ahead or lag behind the fixation point. If fusion is allowed, a convergent or divergent movement may be required to correct for any misalignment. Borish describes it as a "... position of functional rest..." and that it "... reveals the amount of fusional convergence needed to secure binocular single vision".1

The convergent rotation represented by the phoric posture is a manifestation of several innervational in-puts to the ocular muscles. These are tonic, accommodative, and psychic.1 The summation of these in-puts may cause the phoric posture to match, lead, or lag the fixation point, termed orthophoria, esophoria, and exophoria respectively. If the angular rotation caused by these in-puts were equal among individuals whose PDs differed, phorias would differ, as well as, the fusional vergence effort required for bifixation. Therefore, would PD values at the extremes of the population range result in excessive phorias which taxed the individual's ability to compensate?

The question posed assumes, rather simplistically, that there would possibly be a common amount of fusion-free convergence movement manifested by everyone and that the PD alone would determine the phoric posture. There are too many diverse neuralgic and anatomical factors, as well as, environmental factors, which summate to determine an individuals convergence behavior. However, a few investigators have searched for, or implied, a connection between the interpupillary distance and the binocular status.

A study done in Zaire investigating the incidence of strabismus among black Zairian people found that exodeviations were the most common form of strabismus in a population where large interpupillary distances are common.4 Duke-Elder states that a wide PD is a possible factor in the etiology of convergence insufficiency.5 Ditmars investigated the relationship between PD and far phorias, acquiring findings which suggested a tendency toward increasing
exophoria with increasing PD and an increase in esophoria with decreasing PD. He declined to consider near phorias because of their greater variability and the influence of factors such as psychic convergence.

This study was done to expand upon Ditmar's research and to determine if a relationship between the interpupillary distance and the near phoria does in fact exist. The study investigates the validity of the hypothesis that PD values at the extreme ends of the population range are associated with phorias above or below the phoria norms. Specifically, that large PDs are more likely to be associated with higher exophoria than the norm and that small PDs would be associated with larger esophoria than the norm.
METHODS

The subjects were selected from the patient records at the primary care clinic of Pacific University College of Optometry (PUCO) in Forest Grove, Oregon. The records were randomly searched until at least 200 patients who met the following entry criteria were located:

1. Subjects must have a surname which, as best as could be determined, indicated a Caucasian ethnic background.
2. Subjects must be male.
3. Subjects must be between the ages of 18 and 35.
4. Subjects must not be strabismic at any distance.
5. Subject’s refraction must be within plus or minus 1.00 diopter of their habitual correction.

A total of 201 subjects were obtained for inclusion in this study. For these patients, an interpupillary distance at far measurement, a far phoria measurement, and a near phoria measurement were recorded from the examination form. Only the most current examination results were used.

The methods of examination and testing were those used by the third and fourth year optometry students. Binocular status is determined by the unilateral cover test at six meters and 40 cm. The far PD is acquired by using the millimeter ruler procedure for measuring the binocular interpupillary distance between corneal reflections. The horizontal von Graefe technique at near point is used to measure the near phoria. Two phoria values are typically elicited from the patient, one from an initial base-in setting of the risley prism and another from a base-out setting. An average of these two phoria values was then recorded.

The statistical analyses performed in this study are directed towards determining if there is a different distribution of phorias between subjects with a large PD and those with a small PD.
normal PD range was assumed to be the subject population's mean PD plus or minus one standard deviation. A large PD was then defined as being larger than this range and a small PD one that was smaller. An unpaired, 1-tailed t-test with a 95% level of significance was performed to determine if the phoria distributions for these two groups of subjects is significantly different.
RESULTS

Descriptive statistics for the entire subject population are summarized in Table 1. A total of 201 male subjects between the ages of 18 and 35 years formed the subject population of this study.

Given a mean far interpupillary distance of 62.7 mm and a standard deviation of 3.0 mm for this population, a large PD was defined as equal to or greater than 66.0 mm (rounded up to the nearest mm) and a small PD as equal to or less than 59.0 mm (rounded down to the nearest mm). The descriptive statistics for these two PD groups are summarized in Table 2.

The mean near phoria for the large and the small PD groups were 4.3° of exophoria and 2.9° of exophoria respectively. Thus, the large PD group exhibited a larger mean exophoria of 1.4°. An unpaired, one-tailed t-test with a 95% level of significance revealed no significant difference between the means of the near phorias of the large and the small PD groups (p=0.1249).

The distribution of the near phorias in the large and the small PD groups is better appreciated as presented in Figure 1. The bar chart in Figure 1 illustrates the distribution of near phorias within three PD groups representing the entire subject population (Large, Normal, and Small). These groups were defined as previously described. Additionally, within each PD group the near phoria is categorized as High Exophoria, Normal Phoria, or High Esophoria. These categories are derived from the subject population's near phoria mean and standard deviation as follows:

1. High Exophoria: phoria < (mean phoria - 1 SD)
2. Normal Phoria: (mean phoria - 1 SD) <= phoria <= (mean phoria + 1 SD)
3. High Esophoria: (mean phoria + 1 SD) < phoria
Based upon the study hypothesis, the authors expected to find a greater frequency of high exophores at near in the large PD group versus the small PD group. Likewise, it was anticipated that the frequency of the high esophores would be greater in the small PD group.

So as to compare the results of this study with the results published by Ditmars, additional statistics regarding the subject population were determined. The mean far phoria for the subject population is $0.2^\circ$ exophoria ($SD=2.9^\circ$). A Pearson r correlation test comparing interpupillary distance and far phoria determined that $r=0.095$. Like-wise, a correlation comparison of interpupillary distance and near phoria determined that $r=0.13$. 
TABLE 1: Summary of Subject Population Statistics.

<table>
<thead>
<tr>
<th>n</th>
<th>Age (^a)</th>
<th>Far Interpupillary Distance (mm) (^b)</th>
<th>Near Phoria (Prism Diopters) (^c,d)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean(SD)</td>
<td>range</td>
<td>mean(SD)</td>
</tr>
<tr>
<td>201</td>
<td>25.0 (4.8)</td>
<td>18.0-35.0</td>
<td>62.7 (3.0)</td>
</tr>
<tr>
<td></td>
<td>-3.6 (5.3)</td>
<td>-25.0-+11.5</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) rounded to nearest 0.1 yr.  
\(^b\) rounded to nearest 0.1 mm  
\(^c\) (-) denotes exophoria; (+) denotes esophoria  
\(^d\) rounded to nearest 0.1 prism diopter

TABLE 2: Summary of Statistics for Large & Small PD Subjects.\(^1\)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Far Interpupillary Distance (mm) (^b)</th>
<th>Near Phoria (Prism Diopters) (^c,d)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>mean(SD)</td>
<td>range</td>
</tr>
<tr>
<td>Large PD (PD=&gt;66mm)</td>
<td>39</td>
<td>67.2 (1.2)</td>
<td>66.0-70.0</td>
</tr>
<tr>
<td>Small PD (PD&lt;=59mm)</td>
<td>32</td>
<td>58.4 (0.9)</td>
<td>56.0-59.0</td>
</tr>
</tbody>
</table>

\(^1\) See Table 1 for footnotes b, c, & d
FIGURE 1: Distribution of Subject Population by PD and Near Phoria Categories (n= 201).
The findings of this study show that the mean near phoria for the large PD group of subjects was greater in exophoria than that for the small PD group as hypothesized. However, the statistical significance of this difference \((p=0.1249)\) was not such that it's occurring as a random event could be ruled out. The study data as illustrated in Figure 1 also suggests that an extreme PD, either high or low, does not predispose an individual to an excessive near phoria in a particular direction.

The validity of these conclusions is impacted by two aspects of this study. The first is associated with how the subjects were selected for the study. The entry criteria used was developed so that a homogeneous subject population was obtained. It was intended that the influence of factors such as race, gender, age, and refractive status on PD and near phoria would be controlled in the subject population.

The interpupillary distance is known to vary among different races and genders.\(^7,8\) Gender was easily controlled because only those patient records with a gender notation were considered. Ensuring that all subjects were Caucasian was more difficult since race assessment based on a surname was often subjective. Even among Caucasians, there is evidence indicating a difference in average PDs between American and European Caucasians.\(^8\) The differentiation between Caucasian and Black races by surname is considered to be the least certain. However, black patients present very infrequently at the PUCO clinic. Thus, the subject population homogeneity may be compromised by intermixing of races, but the likelihood is small.

The subject's age, as their gender, was determined with certainty based on record entries. However, the age range specified was thought to represent a period of life when PDs, near phorias and
refractive status were stable. However, one study showed that PDs changed at a rate of 0.66 mm per year up until age 20 and thereafter at a rate of 0.045 mm per year.9 Several authors report a tendency for increasing exophoria at near with increasing age.1 Refractive status is fairly stable during these years, but there is evidence that even this may shift some.3 This variable was somewhat controlled by specifying a maximum refractive change over the habitual prescription. It was intended to make observations on a visually stable population of patients who were not in the process of adapting to ocular changes. Perhaps a narrower age range, possibly between the ages of 20 and 30 years, should have been specified.

But, even with the age range used, the mean age of the subject population is 25.0 years with over two-thirds falling between the ages of 20 and 30 years. Thus, PDs, phorias, and refractive status should be stable in the subject population.

A visual characteristic of the subject population not considered was the maximum amount of ametropia allowed. It may have been prudent to have included a limit on ametropia, if not for any possible influence of a high refraction on the near phoria, at least for considerations of prism effectivity during a von Graefe technique. Large values of ametropia, however, represent a very small fraction of the population as a whole.

A second aspect of this study which might impact the validity of the conclusions is that the PD and phoria measurements were taken by numerous third and fourth year Optometry students. It could be reasoned that results obtained by these "practicing" clinicians might be less than accurate. This concern is lessened by the fact that the mean PD and near phoria calculated for the subject population are in close agreement with the results of more "seasoned" researchers as discussed later in this section. Additionally, with so many different individuals involved, it may be assumed that individual measurement errors would be canceled out.
Given the above considerations, the authors feel that the study results are valid and that the subject variables were well controlled. One final consideration that influences the validity of the study results is the numbers of subjects included in the large and small PD groups. It is generally stated that for statistical validity a sample must be equal to or greater than twenty. The large PD group contained 39 subjects and the small PD group contained 32 subjects. Thus, the conclusions derived from this study should be applicable to the general population represented by the subject population.

The mean PD of 62.7 mm (SD=3.0) for the subject population are representative of those obtained by other researchers in comparable populations. Pryor reported a mean PD of 62.0 mm (SD=3.5) for a male Caucasian (American) population from ages 17 to 22 years. Hofstetter cites the results of a study conducted by Hertzberg, based upon 4,057 white males from ages 20 to 35, which reported a mean PD of 63.3 mm (SD=3.64). Numerous other studies cite average PD values for male populations which exceed that of this study, but they fail to define the gender or age range of their subjects.

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The near phoria mean of 3.6° exophoria (SD=5.3°) for the subject population also compares favorably with results obtained by others. Morgan, comparing expecteds of different investigators, calculated a mean induced near phoria of 3.0° exophoria (SD=5.0°). Scobee and Green reported that, at 40 cm., the near phoria mean was 3.0° exophoria (SD=5.2°) using a von Graefe test. However, Shepard determined the expected near phoria to be 5.0° exophoria (SD=5.0°). None of these results were reported for any particular race, gender, or age groups.

The study hypothesis proposed that a difference in the distribution of near phorias existed between a group of individuals defined as having a large PD versus those having a small PD. The study results showed the large PD group to have a mean near phoria that was 1.4° more exophoric than the small PD group. This is in the
direction hypothesized. However, this difference was not statistically significant \((p=0.1249)\). This difference must also be viewed in light of the reliability of the von Graefe technique for measuring phorias which Flom and Kerk considers to be about \(3.0^\circ\).\(^{12}\) Thus, the mean near phoria for these two PD groups as a measure of phoria distribution does not substantiate the study hypothesis.

More specifically, the study hypothesis made the assumption that the frequency of high exophores would be greater in the large PD group and that the small PD group would contain more high esophores. Figure 1 illustrates that this is not true for the study population. Both the large and the small PD groups contain the same number of high exophores and high esophores. Again, the study hypothesis is not substantiated.

Relative to Ditmars' work, the results for this study did not parallel his results. First, the mean PD value for his male patients was 65.44 mm. Secondly, the mean far phoria for his subjects was \(0.30^\circ\) esophoria as opposed to \(0.2^\circ\) exophoria for this study. Finally, his calculated correlation coefficient between PD and far phoria was \(+0.54\) versus \(+0.095\) for this study. The correlation coefficient found in this study between PD and near phoria was also low. Thus, the results of this study do not substantiate Ditmars' work as well.

This study was conducted with the hopes of providing the clinician with another tool for diagnosing a vergence-based binocular dysfunction. It was thought that a patient's interpupillary distance, when abnormally large or small, might predispose them to a phoric posture that taxed their fusional convergence reserves. A difference in the mean near phoria was found to exist between two extreme PD groups, but, the difference was not statistically significant, was possibly within the measurement reliability for the von Graefe technique, and was probably not even clinically significant. Also, it would seem that an individual with an extreme PD is equally likely to manifest an extreme near phoria in a given direction.
Thus, the authors, based on the results of this study, can not conclude that a relationship between PD and near phoria exists. Future researchers may continue to investigate for a relationship by expanding the variables measured to include quantification of tonic, accommodative, and proximal convergence. Until then, the clinician is left to his standard array of tests for diagnosing binocular dysfunctions.
REFERENCES


