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James Dean
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William Ludlam

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A COMPARISON BETWEEN CLINICAL AND LABORATORY MEASUREMENTS OF ACCOMMODATIVE-CONVERGENCE

In Partial Fulfillment of
a Doctorate of Optometry Degree
Pacific University

James Dean

Michael K. Matsunami

Advisor

William Ludlam, O.D.

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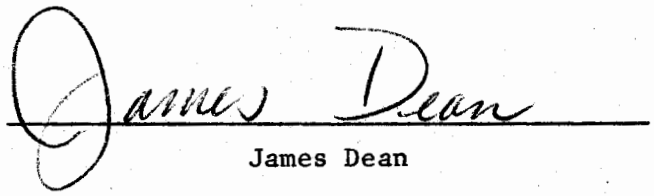
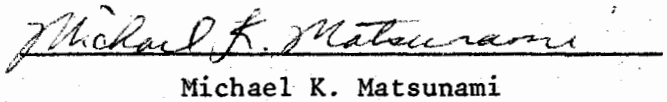


James Dean



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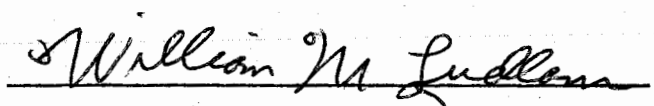

William Ludlam, O.D.
Advisor

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We would also like to express our gratitude to Dr. Niles Roth for assisting and supplying us with the Badal optometer/haploscope and laboratory facilities; Dr. Harold Haynes for his assistance in the statistical portion of this project; and to all of the subjects for devoting their time to us.

Mike and Jim

Abstract

Differences between accommodative-convergence ratios as determined by the gradient (delta phoria/delta sphere) method and the phoria (delta phoria/delta diopters) method are studied in order to investigate the validity and reliability of these tests clinically. Comparisons of these two methods were performed using the Badal optometer/haploscope (laboratory method), and an American Optical phoropter (clinical method), in order to establish the correlation between A_s and A_r measurements when determining the accommodative-convergence ratio. The results of this study show that the coefficient of correlation for ACA values obtained between clinical and laboratory methods is low, indicating a significant discrepancy between the two methods. It was concluded that measurement of ACA is dependent upon many factors, rendering valid and reliable measurement difficult over time. Recommendations for appropriate ACA measurement include cognizance of the complexity and variability of the ACA relationship, as well as maintaining consistency of and between test methods.

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INTRODUCTION

Visual efficiency at nearpoint tasks is highly dependent upon the ability of the eyes to converge and accommodate efficiently. In cases where either one of these systems is in poor relation to the other, visual efficiency drops off markedly thereby giving rise to symptoms of asthenopia and nearpoint stress. The relationship between accommodation and convergence therefore, is indeed important for those individuals involved in extensive nearpoint tasks.

As clinicians then, part of our task during a routine visual exam is to search and prescribe therapy for those patients exhibiting poor binocular coordination at near. Where tests show an abnormally high accommodative-convergence relationship, one typically correlates data derived from currently accepted clinical tests. It is generally assumed by the clinician that the results of these tests are valid and reliable, such that one can prescribe appropriate lens therapy for the patient's poor accommodative-convergence relationship. One must keep in mind however, that current clinical methods of measuring the accommodative-convergence ratio are based upon accommodative stimulus units, which often do not truly represent the patient's accommodative response. Therefore, an erroneous determination of the accommodative-convergence ratio may be made, resulting in inappropriate lens therapy and patient dissatisfaction.

We have therefore designed this study to compare results of certain clinical tests used in ascertaining the accommodative-

convergence ratio, to data found using tests measuring accommodative response. A statistical analysis of this data will allow us to determine if there is a correlation between the two methods.

In order to understand the behavior of accommodative-convergence, we must first give some consideration to its relation to its other components. Although the following is a simplified scheme of convergence, one must keep in mind that the relationship is indeed, complex, particularly when higher cortical levels are involved. The relationship is therefore subject to variability and nonlinearity, depending upon such neural factors as mood, fatigue, etc.[1]

In his description of convergence, Maddox[2] classified convergence as consisting of essentially four component parts, namely:

1. Tonic convergence
2. Fusional convergence
3. Accommodative-convergence
4. Proximal (psychic) convergence

Briefly, tonic convergence describes the amount of convergence that is active due to the physiological tonus of the extraocular muscles. It exists independently of accommodation and convergence due to a fusion stimulus. Therefore, measurement of the tonic convergence component would involve inhibition of accommodation, maintaining a constant awareness of nearness, and elimination of all fusional cues. Since tonic convergence is the only component of convergence left after all other factors are eliminated, it is maintained that the level of tonic convergence inherent in the sensorimotor behavior of the individual yields the phoria value. An excessive amount of tonic convergence yields esophoria. Likewise, insufficient tonic

convergence yields exophoria.

The fusional convergence component is the amount of convergence required to fuse the lines of sight of the two eyes upon the object of regard when brought from far to near, over and above the level of tonic convergence that is active, and independent of accommodation. It follows, therefore, that where tonic convergence is excessive giving rise to esophoria (designated positive phoria), fusional convergence must compensate by diverging (negative convergence) of the eyes. In exophoria, fusional convergence is positive, in order to converge the eyes appropriately upon the fusion stimulus.

The accommodative-convergence component is held to be the most significant in producing asthenopic symptoms in patients experiencing nearpoint stress when the relationship is abnormally high. If one eye is occluded and the other eye fixated along the primary visual axis, as accommodation is stimulated, the occluded eye has been shown to turn accordingly.[3] Thus, for every unit of accommodation, there is a corresponding amount of convergence that follows. This is expressed as the ACA ratio - the change in the amount of convergence divided by the associated accommodative effort. When each unit of accommodation stimulates an excessive amount of convergence (as in the case with an abnormally high ACA ratio), esophoria (or tropia) results, giving rise to nearpoint asthenopia. Various norms have been established over the years regarding mean ACA ratios in the population. The currently used norm for the ACA ratio has been most frequently quoted as being approximately 4 prism/1.00 diopter.[4, 5]

Proximal, or psychic convergence is a convergence phenomenon brought about solely by the awareness of nearness of an object. It

occurs independently of accommodation and any optical device placed before the eye (prisms or lenses). It can often lead one to erroneously determine the near phoria level of a patient, being more esophoric than is the true case.

Given that a large proportion of optometric therapeutic procedures (visual training, and lens or prism application) are based upon results given by clinical accommodative-convergence measurements, it is the goal of this study to establish the accuracy of presently accepted methods of measuring accommodative-convergence, and to make recommendations as to which method(s) if any can be reliably used as a basis for therapeutic remediation. Specifically, the following methods will be compared and statistically analyzed to determine the reliability and validity of each:

1. Gradient method (delta phoria/delta sphere) with phoropter
2. Phoria method (delta phoria/delta diopters) with phoropter
3. Gradient method (delta phoria/delta sphere) with optometer
4. Phoria method (delta phoria/delta diopters) with optometer

These methods were specifically chosen since the phoria and gradient methods are most frequently used clinically to determine the ACA relationship of a given patient. In addition, previous literature by Morgan states that, ". . . the only reliable method for determination of the accommodative-convergence ratio is the gradient method."[6] Psychic (proximal) convergence is virtually eliminated due to the constant working distance. Since lenses are used to stimulate accommodation, the ACA value may be determined directly by the associated change in phoria. Morgan further states, however, that,

"Its disadvantage is that the change is small, and an error in measurement will represent a rather large proportion of the whole measurement." To emphasize the point, stimulus units are the assumed denominator in the ACA determination, and hence, the magnitude of measurement error will be exaggerated due to the variation of accommodative response.

The phoria method has been supported by Morris, in that, ". . . the Fry technique (phoria method), in spite of the factor of proximal convergence, is more accurate than the Morgan technique (gradient method)."[7] The statement is made based upon the low variance of ACA as measured by the phoria method in his study.

These methods will be compared utilizing phoropter (A_s) and optometer/haploscope (A_r) ACA findings, in order to determine statistically, the accuracy and reliability of each technique in determining ACA values.

METHODS

Sixteen males and two females ranging in age from twenty-one to thirty-two years of age were tested. The mean age was 24.5 years, and all but two of the subjects were optometry students. All subjects were fully corrected for refractive errors by either their current habitual prescription or trial lenses. Subjects presenting with strabismus, amblyopia, any active ocular pathology, or those taking any medication that would affect the eyes were eliminated from the study.

Phoropter testing was performed with an American Optical Ultramatic phoropter. Subjects were told to wear their habitual corrective lenses (where applicable), while being tested. For subjects with

uncorrected refractive error, a subjective to best monocular visual acuity was performed, and the resultant lens left in place. Interpupillary distances were taken, and phoropter PD adjustments were made accordingly.

Gradient phoria testing was performed with a horizontal series of 20/40 letters located at six meters, using a -1.00, -2.00, and -3.00 lens consecutively placed before both eyes. Base up prism was placed before the subject's left eye to dissociate the letters vertically. Base-in prism was placed before the subject's right eye such that the subject reported that the top chart appeared to the right of the left chart. Subjects were instructed to keep the bottom chart (left eye) as clear as they could. Base-out prism was then added in front of the right eye until the patient responded "now", indicating that the two charts appeared vertically aligned. The alignment represented the associated phoric posture of the subject with a specific accommodative stimulus. This reading was recorded, and a second similar trial was performed for each new accommodative stimulus. In situations where the letters could not be cleared, as was frequently the case with the -3.00 lens, a slash was recorded for this finding, indicating that accommodative response was not satisfactory.

The phoria method was performed in a similar manner and conditions to the gradient phoropter method, with the exception of varying the distance of the target rather than utilizing lenses to stimulate accommodation. The same distance target was utilized as in the gradient method. The nearpoint target however, consisted of a horizontal series of 20/40 letters calibrated for 40 cm.

Therefore, acuity demand was not constant at all distances has to be due to unavailable time and monetary resources. Two trials were performed at these specific test distances: 6 M., 50 cm., 40 cm., and 25 cm. Subjects were again instructed to keep the bottom chart as clear as they could and to report alignment as base-out prism was increased before the right eye.

Optometer testing was performed on a Badal optometer/haploscope system. Briefly, the Badal optometer allows a change in stimulus vergence without a change in the angular subtense of the retinal image. Therefore, it allows us to measure the accommodative response of a subject based upon the formula:

1. $$-\overline{CF} = RE + A_R + L$$

where: $\overline{CF}$ = conjugate focus of the visual system

RE = refractive error of the subject

A_R = accommodative response

L = lens value used in front of the eye.

Given that:

2. $$-\overline{CF} = 15 \text{ cm.} - \text{s.r.}$$

where: s.r. = scale reading of stigma

We can thereby determine the A_R of a given subject by simply recording the scale reading. By rearrangement of equation (1), it can be seen that:

3. $$A_R = -\overline{CF} - RE - L$$

Since the subjects were corrected for their respective refractive errors, the RE term may be eliminated, thus simplifying the equation to:

4. $$A_R = -\overline{CF} - L$$

In order to validly measure an isolated accommodative response,

we must eliminate intervening factors which may influence accommodation other than the fixation target accommodative demand. Such factors would be:

1. control of pupillary fluctuation
2. control of variable contrast of fixation target; illumination must be held constant at all distances
3. control of head movements
4. control of proximal accommodation and/or convergence, thus utilizing both distance and lenses as accommodative stimuli
5. full correction for all ametropia; must exclude aniseikonia cases.
6. control of vertex distance - 14 mm.

- Control of pupillary fluctuation was performed by maintaining constant illumination of targets. Complete elimination of pupillary fluctuation proved impossible, unless one uses a pinhole aperture which was unfeasible in this project.

- Since illumination remained constant, contrast was controlled and held constant.

- Head movements were controlled by having the subject place his/her head in a headrest with chin support.

- Vertex distance was held at 14 mm. since the headrest arrested forward/backward movement of the head.

All subjects were instructed to keep and maintain the target letters as clear as they could. A flash presentation of the stigma was given which, when presented, appeared simultaneously alongside the target. The subjects were told to report when the stigma appeared clearest. Scale reading were bracketed, recorded, and repeated for a second trial. All A_R testing was performed through the right eye only, while the left eye remained occluded (it was

found to be unfeasible to perform separate tests for each eye). Associated phoria measurements were taken by presenting a stigma simultaneously to both the right and left eyes of the subject while keeping the letters clear. Flash presentation was again employed in order to prevent distraction of the subject from the target of regard (A_S). Lateral manipulation of the stigma was then performed until the subject reported alignment of the stigma. The procedure was repeated in association with each A_R reading, and recorded. Units of convergence were printed in degrees, thus necessitating the conversion to prism diopters by multiplying the reading in degrees by 1.75.

The gradient optometer method was performed with a horizontal series of 20/40 letters at six meters. Near findings were done at 50, 40, and 25 cm. Lighting at far and near was held constant as determined by a photometer.

The phoria method was performed with the same target as in the gradient method. A -1.00, -2.00, and -3.00 lens was placed before the subject's right eye in order to stimulate accommodation (the left eye was occluded) for each respective trial.

RESULTS

Accommodative-convergence values from each of the four methods are listed in Table I. The ACA values for each subject were determined by averaging trials (a) and (b) for a given method. Data for the phoropter delta phoria/delta sphere method has been listed in rank order from highest to lowest (findings for individual subjects are identified by their initials on the left). The mean, standard deviation, and variance for a given data set are listed at the

bottom of each column. The symbol "N/T" indicates that the subject was not available for testing.

The data from Table I show that:

1. The phoropter delta phoria/delta sphere method yielded the smallest and least variable values, while the optometer delta phoria/delta diopters method yielded the largest and most variable values.

2. The average ACA values found for delta phoria/delta diopters are larger than those found for delta phoria/delta sphere. This holds true whether the ACA is determined using accommodative stimulus units (phoropter), or accommodative response units (optometer). The larger values for delta phoria/delta diopters can be explained at least in part, by the failure of this method to eliminate proximal or psychic convergence.

3. The average phoropter accommodative findings are larger than the corresponding optometer findings. If convergence is considered constant for both methods, then accommodative response is smaller than the corresponding accommodative stimulus.

Figure I illustrates the frequency distributions for the differences between trial (a) and (b) for each method. These distributions represent the mean differences between trials. Negative values indicate that trial (a) is less than trial (b), while positive values indicate that trial (a) is more than trial (b). Plotting these data points yields an even distribution about the zero point - this shows that values derived from trial (a) were not consistently higher than trial (b).

Figure II represents a scatter diagram of ACA data points illustrating ACA differences between trials (a) and (b) - trial (a) is represented along the ordinate, and trial (b) is represented along the abseissa. These points have been plotted in relation to the one to one line, which represents a theoretically perfect

correlation between trials. In essence, Figure II shows us the plot of trial (a) vs. (b) for each method used, again indicating that there is a significant correlation between values derived from trial (a) and (b).

Table II confirms numerically, the correlation shown graphically in Figures I and II. The mean, standard deviation, variance, and coefficient of correlation were calculated for trials (a) and (b). A very high correlation (_ 0.795) for test-retest reliability within a given method is demonstrated. It can therefore be stated that any difference between methods as they are compared cannot be attributed to variation in test-retest.

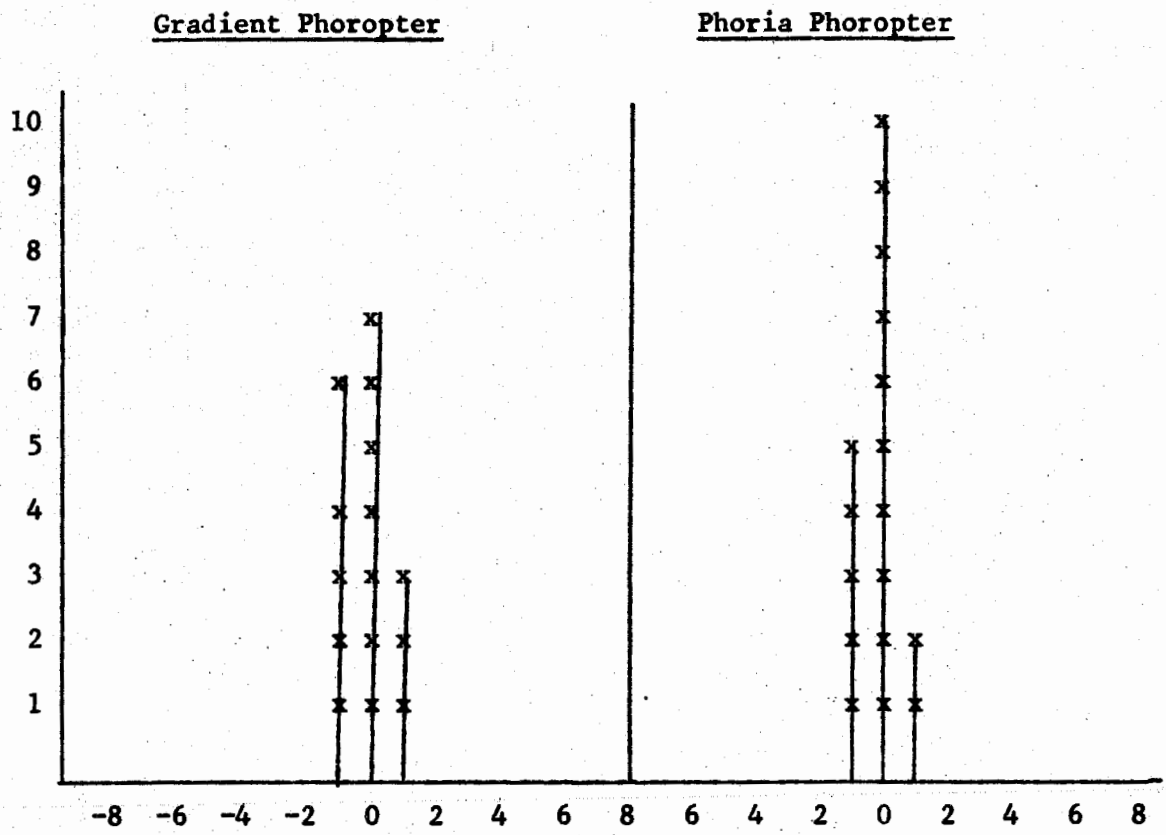
Figure III gives us the frequency distributions of differences in ACA for a given subject as found between test methods. This illustrates that a wide range of differences distributed in a random fashion exists for each comparison. Note that the smallest difference occurs between delta phoria/delta diopters phoropter - delta phoria/delta sphere optometer findings, while the largest difference occurs between delta phoria/delta sphere phoropter - delta phoria/delta diopters optometer.

Figure IV shows scatter diagrams for each of these comparisons. As in Figure II, values are plotted on the x and y axes. If a strong correlation exists between the two methods being compared we would expect to see the majority of the points to fall along the one to one line as in Figure II. The scatter diagrams in Figure IV show that the correlation between tests studied is low. This low degree of correlation indicated that the tests being compared do not measure the same visual parameters.

The data displayed in Figures III and IV are represented numerically on Table III. The means, standard deviations, variance, and coefficients of correlation (r-values) have been calculated for each set of comparisons. It can be seen from the extremely low r-values that no correlation is demonstrated in any of these comparisons (beyond what would be expected to occur randomly). If we propose a null hypothesis that no relationship exists between the two methods compared, the statistical significance of these r-values can be determined. Using the standard error, a student t-value can be calculated for each comparison. These values indicate that the null hypothesis must be accepted. In other words, the r-values for our comparisons are not significantly different from those expected under conditions where no relationship exists between the methods being compared.

FIGURE I

Frequency distributions of differences between trial (a) and (b) are shown for each method studied. Differences are expressed as (a - b); therefore, negative values are assigned to those cases where b a. Inspection of these diagrams shows that differences are evenly distributed about the zero point for each method. This indicates that no significant difference in ACA occurred as a result of trial sequencing (ie: trial (a) then (b)).



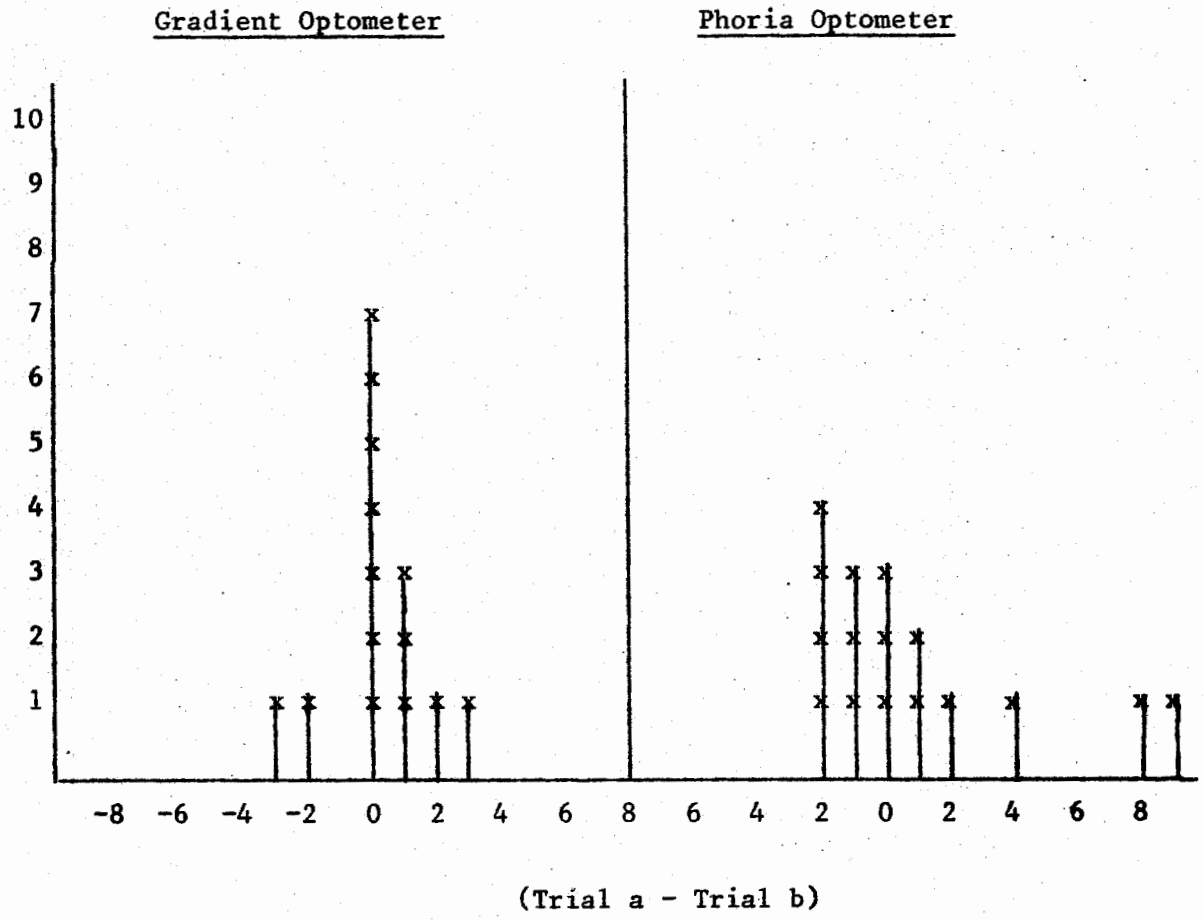
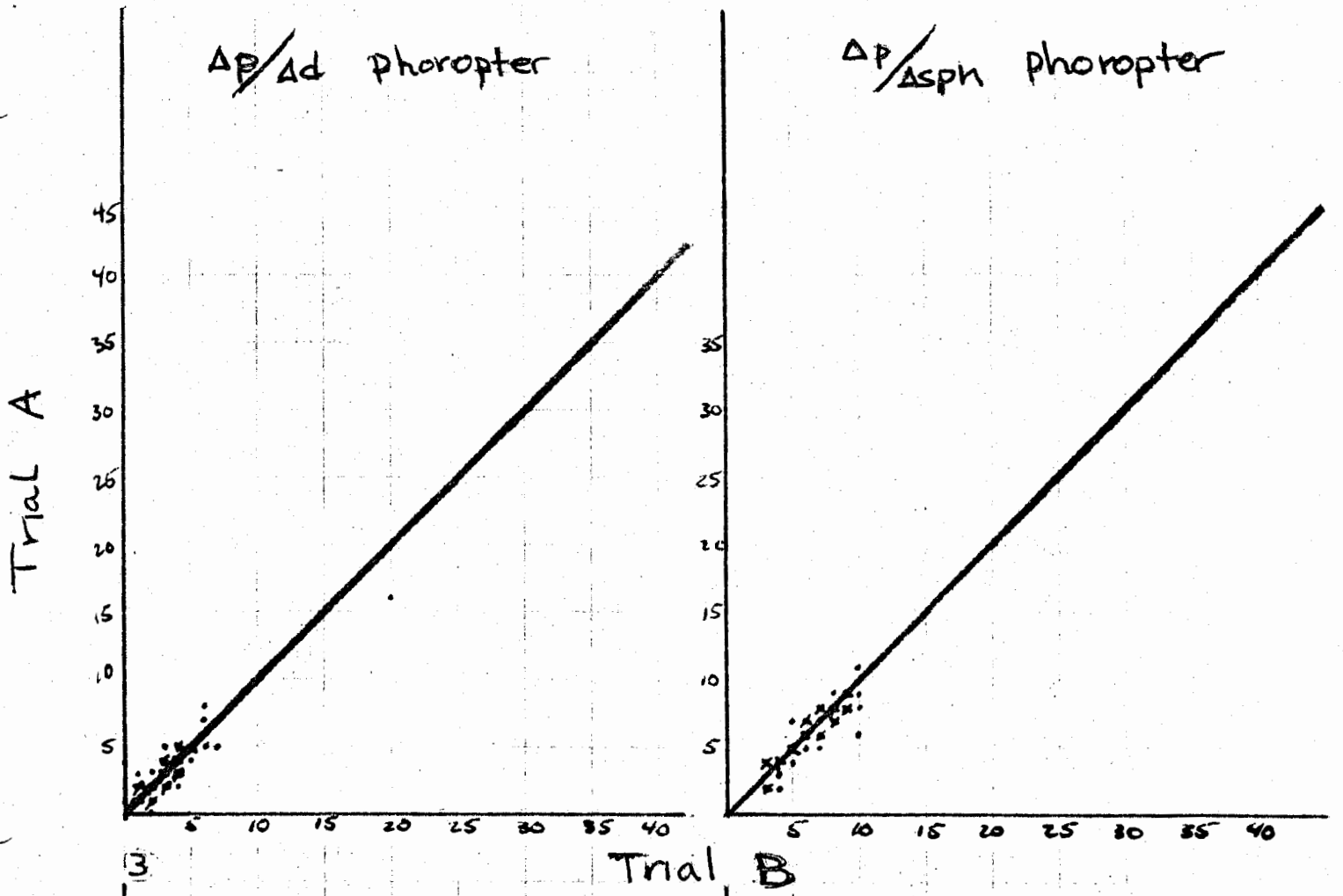

Gradient Optometer
Phoria Optometer
10
9
8
7
6
5
4
3
2
1
-8 -6 -4 -2 0 2 4 6 8 6 4 2 0 2 4 6 8
(Trial a - Trial b)

FIGURE II

Scatter diagrams for trial (1) and (b) are shown in Figure II. Values for trial (b) are plotted on the x-axis, and (a) values on the y-axis. Note that points represent a single set of coordinates, and as (x) represents two or more points with the same coordinates. A one-to-one line has been drawn to show the theoretical case of a perfect correlation. Note the tight grouping of points near the one-to-one line, suggesting a high correlation between trial (a) and (b).

Figure II


Δp/Δd phoropter
Δp/Δsph phoropter
Trial A
Trial B
5 10 15 20 25 30 35 40
5 10 15 20 25 30 35 40

3

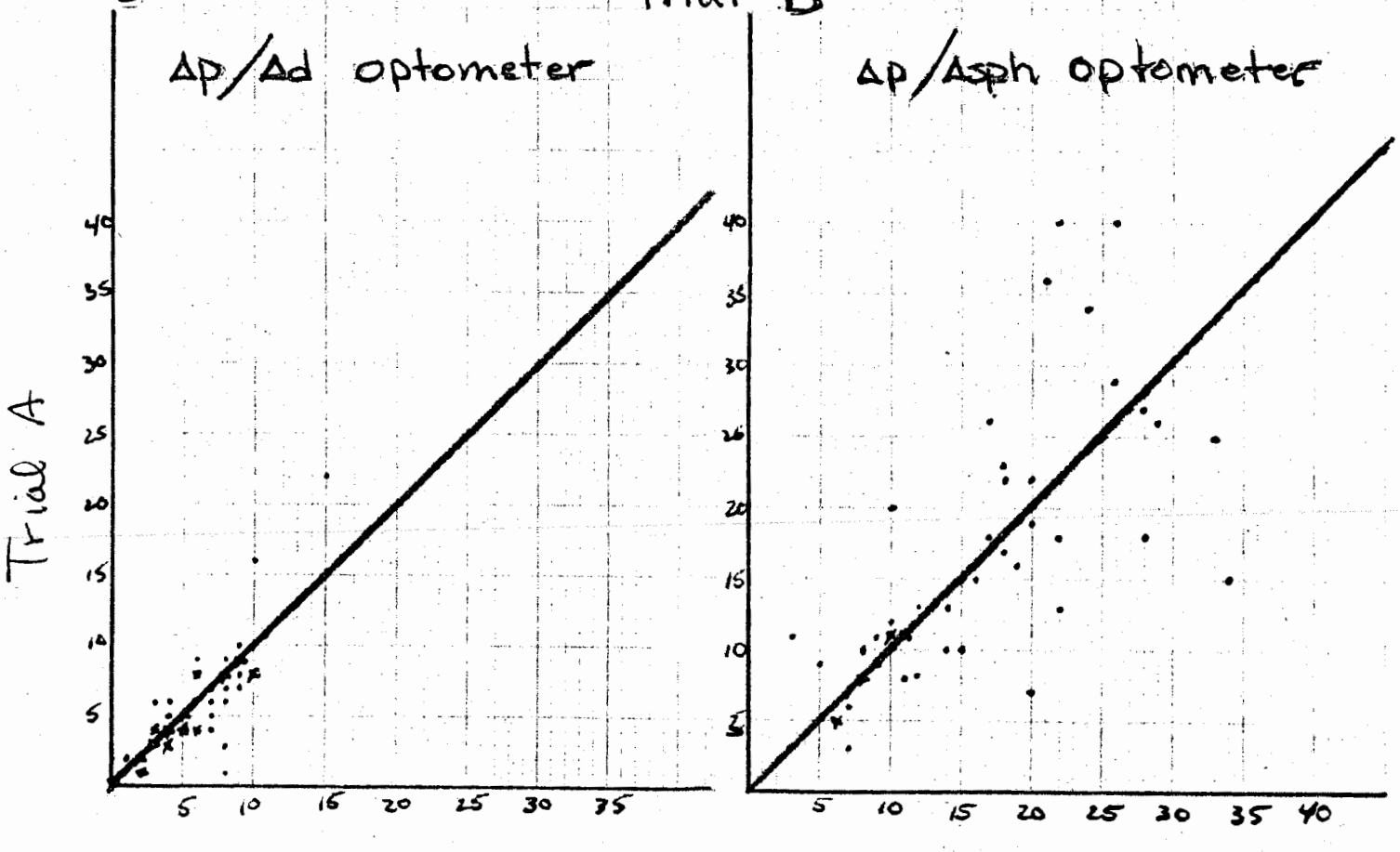
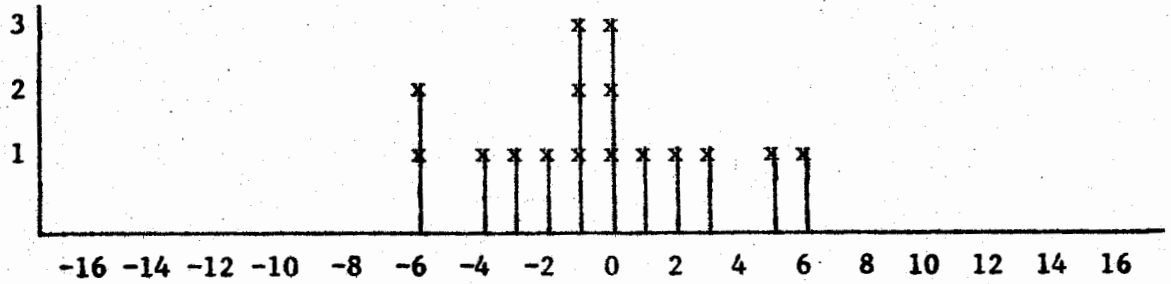

Δp/Δd optometer
Δp/Δsph optometer
Trial A
Trial B
5 10 15 20 25 30 35
5 10 15 20 25 30 35 40

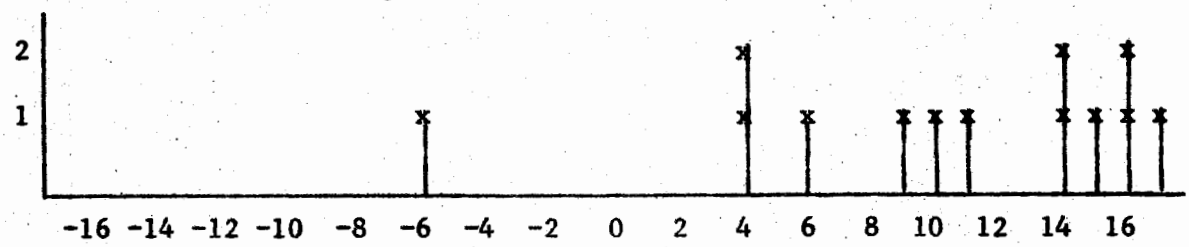
FIGURE III

Frequency distributions of differences between methods are shown in Figure III. This diagram represents differences obtained by subtraction of ACA values found using one method, from those determined by another. Signs are considered here, such that it can be determined if one method yields ACA's that are consistently larger than the other.

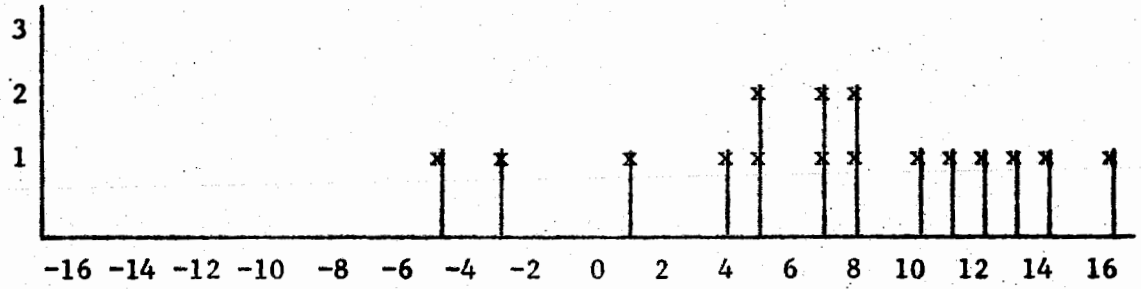
Gradient Optometer - Phoria Phoropter



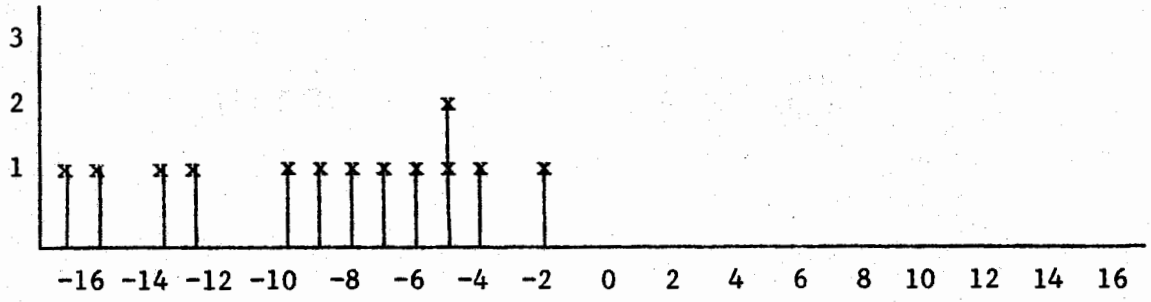
Phoria Optometer - Gradient Phoropter



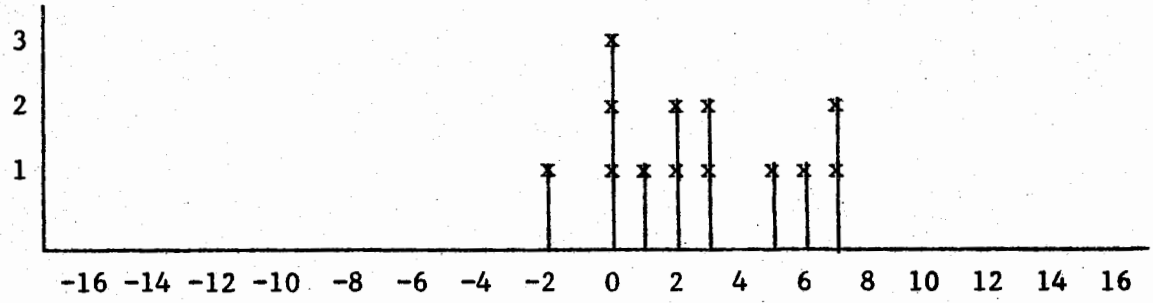
Phoria Optometer - Phoria Optometer



Optometer (Gradient - Phoria)



Gradient Optometer - Gradient Phoropter



Phoropter (Phoria - Gradient)

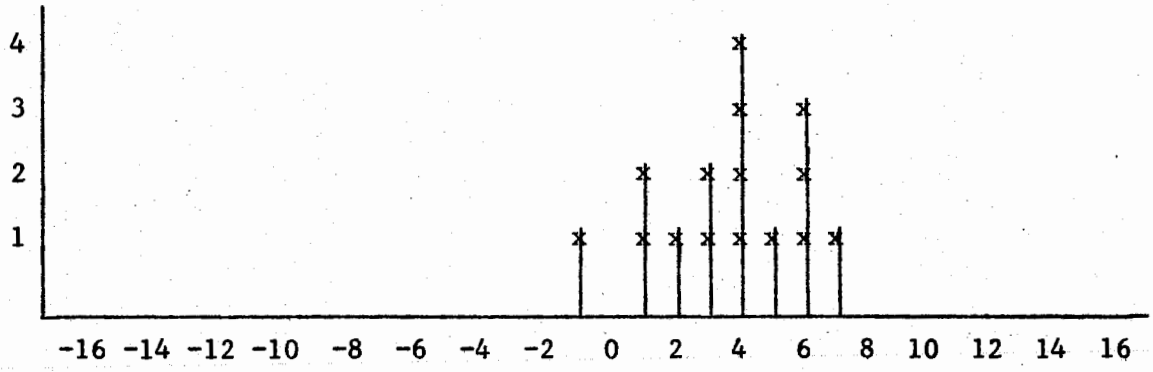
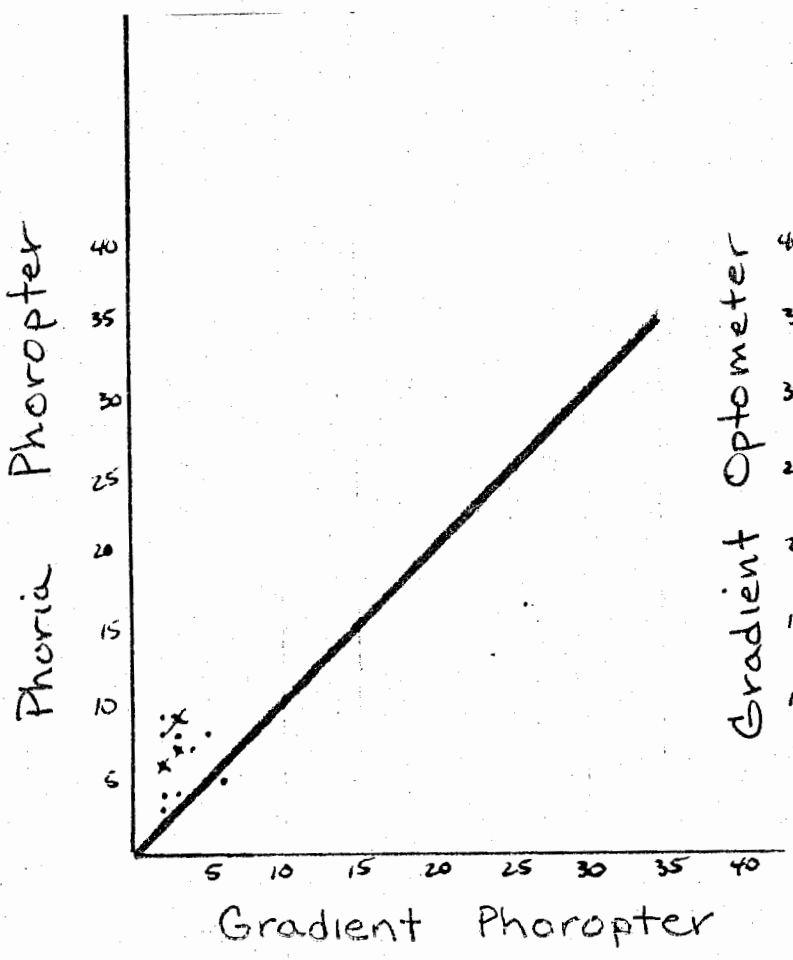


FIGURE IV

Scatter diagrams for comparisons between methods are shown in Figure IV. The ACA values determined by one method are plotted, vs. the values determined using another. The resulting diagram indicates the degree of correlation between the two methods. A theoretically perfect correlation is represented by the one-to-one line.

Figure IV


Phoria Phoropter
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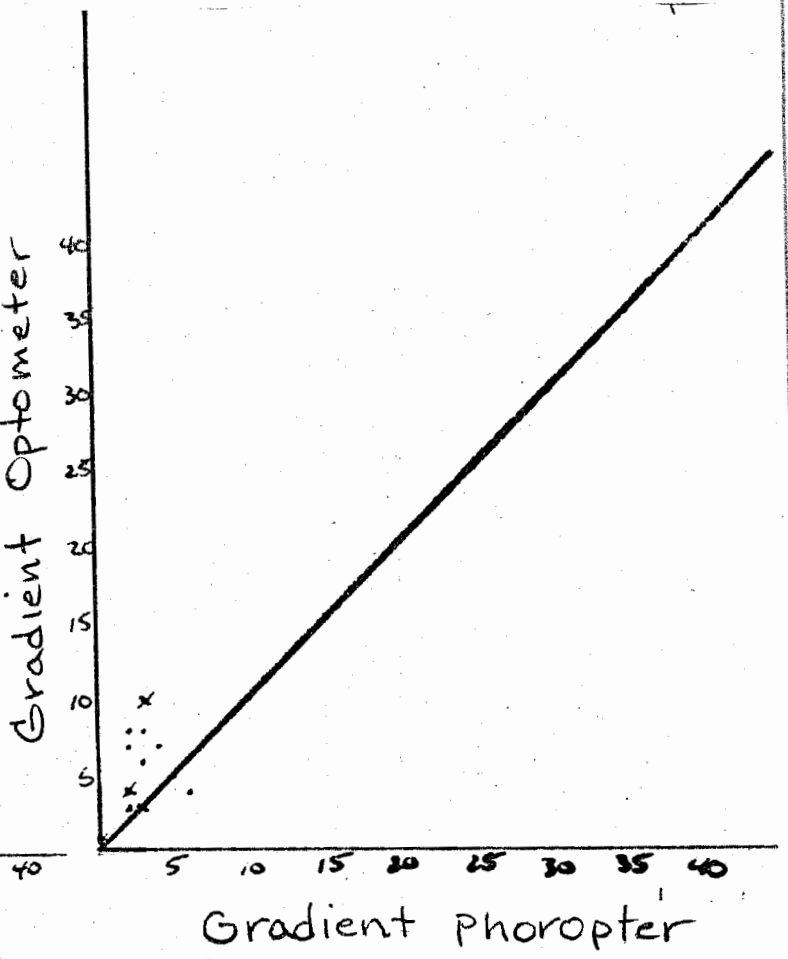
Gradient Phoropter


Gradient Optometer
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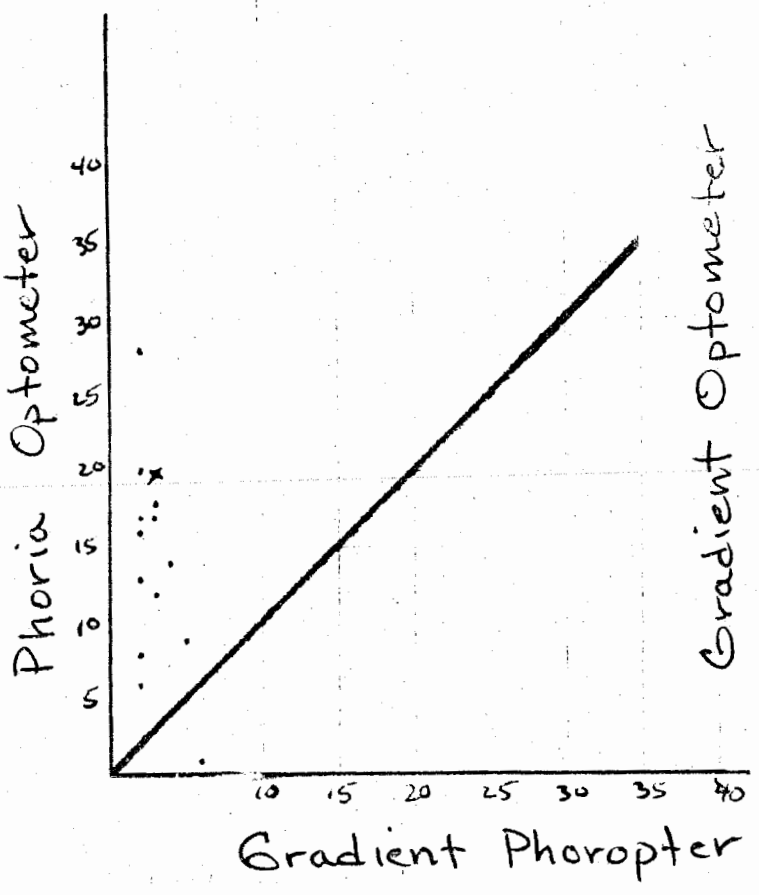
Gradient Phoropter


Phoria Optometer
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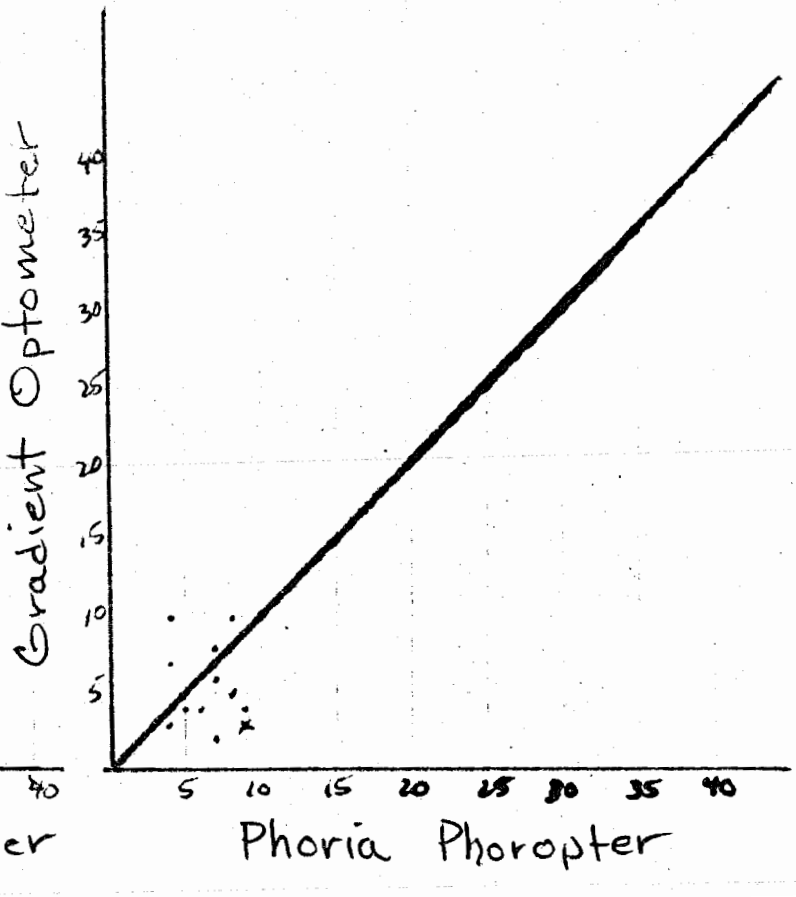
Gradient Phoropter


Gradient Optometer
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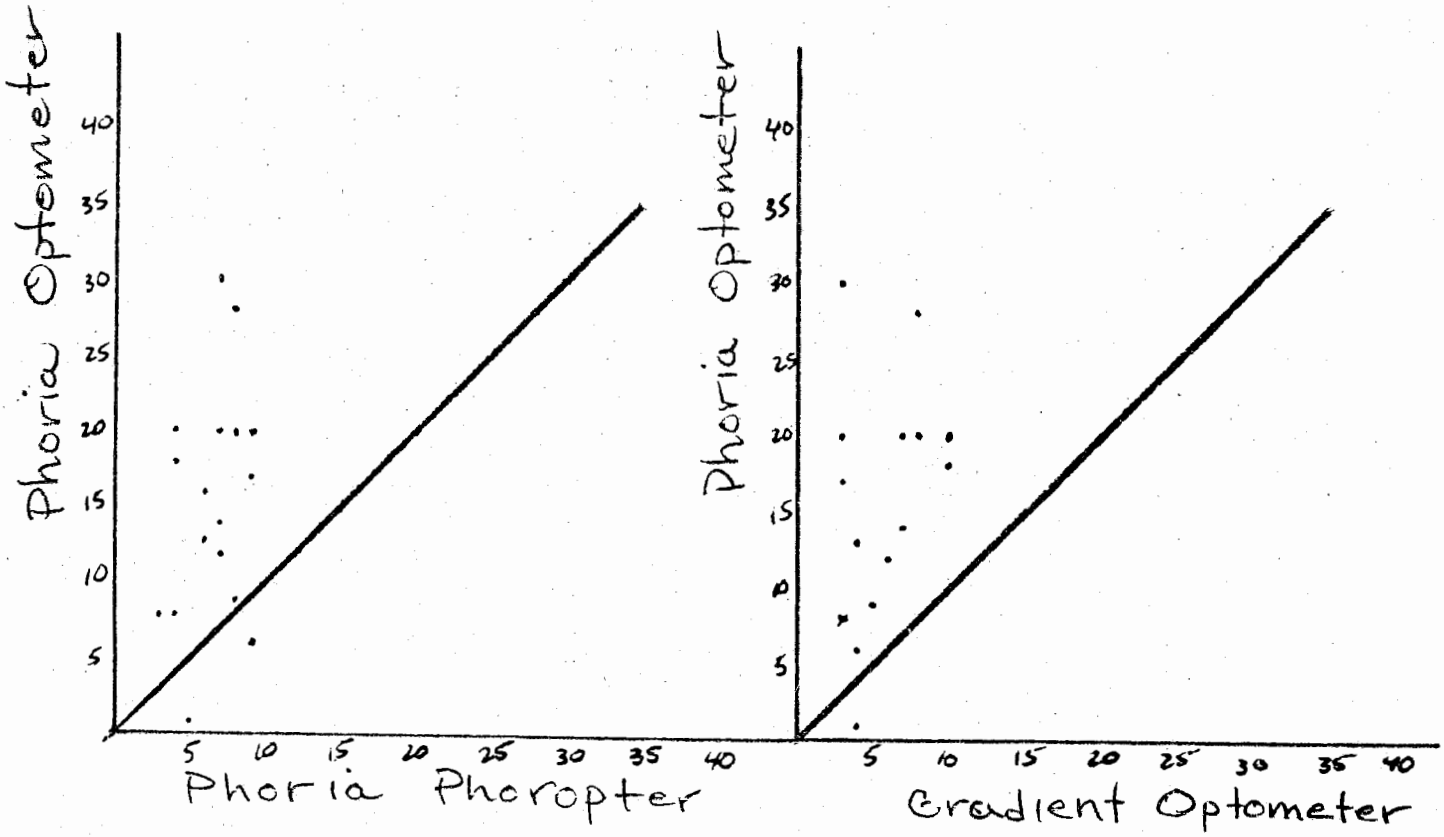
Phoria Phoropter


Phoria Optometer
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Phoria Phoropter
Phoria Optometer
40
35
30
25
20
15
10
5
5 10 15 20 25 30 35 40
Gradient Optometer

TABLE I

Each of the four methods studied are listed. ACA ratios are expressed as prism diopters of convergence per one diopter of accommodation. The ACA's represent the average of trial (a) and (b) for each subject. Individual subjects are identified by initials at the left of the table. Note that values for the phoropter gradient method are listed in ranking order from highest to lowest. The mean, standard deviation, and variance of values for each method have been placed at the bottom of each column.

TABLE II

The values pertaining to test-retest data are shown in Table II. The mean, standard deviation, and variance are listed for both trials (a) and (b), for each method studied. Coefficients of correlation for comparison of trial (a) to trial (b) are shown at the bottom of each column. These r-values are significant at the one percent level when student t-values are calculated using the method of standard error.

TABLE I

Subject	Phoropter ph/ sph	Phoropter ph/ d	Optometer ph/ d	Optometer d/ sph
T.W.	6	5	1	4
K.W.	5	8	9	5
I.K.	4	7	14	7
K.P.	3	7	12	6
G.M.	3	7	20	8
K.D.	3	4	18	10
M.N.	3	8	20	10
K.J.	3	9	30	3
M.C.	3	9	17	3
D.P.	2	8	28	8
J.S.	2	N/T	N/T	N/T
G.K.	2	6	13	4
N.Y.	2	3	8	3
D.B.	2	4	20	7
D.O.	2	9	6	4
N.M.	2	6	16	N/T
J.H.	N/T	4	8	3
K.Y.	N/T	7	30	3
X	3.00	6.70	15.25	5.50
	1.15	1.88	7.63	2.44
2	1.30	3.50	58.19	6.00

TABLE II

	Optometer p/ sph		Phoropter p/ sph		Optometer p/ d		Phoropter p/ d	
	A	B	A	B	A	B	A	B
$\bar{X}$	5.16	5.14	3.10	2.96	15.08	15.39	6.59	6.41
	3.04	3.40	2.80	2.70	8.77	10.49	2.10	2.10
2	9.27	11.70	7.80	7.20	77.01	110.04	4.40	4.30
r-value	0.803		0.837		0.795		0.874	

TABLE III

Statistical data for differences between accommodative stimulus (A_S) and accommodative response (A_R) are listed in Table III. These values include: mean, standard deviation, and variance for 188 trials. These values represent the difference between A_S and A_R using the optometer and the gradient method.

COMPARISON	PH. OPT. ph/ d - ph/ d	PH. OPT. ph/ d - ph/ sph	PH. OPT. ph/ sph - ph/ d
$\bar{X}$	-8.76	1.06	-11.80
	7.34	3.27	7.51
2	53.94	10.73	56.46
r	0.272	-0.0329	-0.488

COMPARISON	PH. OPT. ph/ d - ph/ d	PH. OPT. ph/ d - ph/ sph	PH. OPT. ph/ sph - ph/ d
$\bar{X}$	-2.78	-9.75	-3.67
	2.86	7.37	2.22
2	8.18	54.33	4.95
r	0.0726	0.0612	0.0612

DISCUSSION

Analysis of data here shows that when accommodative-convergence ratios are statistically compared between the gradient and phoria methods - as performed through the phoropter and the Badal optometer/haploscope - a poor correlation exists. These results raise doubts upon the validity and reliability of present clinical tests in determining a patient's accommodative-convergence ratio. What then, must one consider when measuring ACA, and what test (if any) most truely represents the ACA of the patient?

Based upon previous literature on this topic, it has come to our attention that the explanation for these results may be multifold. First of all, it has been stated by Manas and Morgan[6] that when ACA as calculated by the phoria method is compared to ACA as calculated by the gradient method, a low correlation can be expected. This lies in the fact that the phoria method includes proximal convergence, while the gradient method does not. Therefore, the ACA as determined by the phoria method will be larger than that calculated by the gradient method. This is described graphically in Figure IV, which shows that the data points for each method are grouped together, but shifted away from the one-to-one line. This indicates that the two methods measure related but different functions.

One must also consider the inherent difference in individual responses to the given stimulus. Haynes[7] has pointed out that individuals may react differently to various stimulus parameters such as distance vs. change in dioptric vergence of light (lenses)

depending upon mood, attention level, motivation, etc. Thus, even if the effects of proximal convergence were eliminated, we would still expect differences in the ACA's as determined by each method based solely upon subject response variability.

In independent studies, Manas and Morgan have reported that ACA as calcualted by the phoria method showed smaller variance than gradient ACA on test-retest reliability. When comparing the results of the present data derived from the phoropter phoria method vs. the optometer phoria method, we have found that the phoropter phoria method shows a smaller variance on test-retest reliability. In contrast, the optometer phoria measurements shows the greatest test-retest variance of all methods studied. Thus, while the phoropter data supports the results given by Manas and Morgan, the optometer data does not. This discrepancy can be attributed to the relationship between the stability of ACA measurements using the phoria method, and the stability of distance and near phoria measurements.[8] Further investigation is therefore necessary in establishing the correlation between phorias determined using the Von Graef technique, as is presently employed on the phoropter, and phoria determined using the optometer. The value of this correlation would indicate that the variability of the optometer ACA findings can be attributed to the instability of its inherent phoria findings.*

Regarding the correlation between A_S and A_R our data** shows a low coefficient of correlation between phoropter (A_S) and optometer

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* It should also be noted that this discrepancy could be due to bias in a small sample.

** n = 188, $\bar{x}$ = 0.645, = 0.26, = 0.50

(A_R) ACA. Even when the method of calculation is the same (ie: gradient optometer vs. gradient phoropter), the correlations found were no greater than those expected to occur by chance. Manas and Morgan have stated that the main disadvantage of the gradient method is that the changes in accommodation and convergence are small; therefore, an error in measurement will represent a large proportion of the entire measurement.[9] The difference between A_S and A_R in the present study would be expected to produce large discrepancies between optometer and phoropter ACA calculations.

Previous literature has shown that ACA cannot be considered consistent over time.[10] These studies have shown that, over a period of several weeks, the ACA of an individual cannot be shown to be stable or linear based upon test-retest. In the present study, two trials were taken for each set of stimulus parameters. Trial (b) was taken immediately following (a) for each method tested. By reducing the amount of time between trials, inconsistencies in the ACA's due to test-retest error are minimized. Statistical analysis of our data shows that a high correlation exists between trial (a) and (b) in every method studied. These coefficients of correlation have been shown on Table I. The r-values can be compared using the standard error test for significance. Such a comparison shows that the correlation of trial (a) and (b) is significant at the one percent level. Therefore, it can be said that differences between methods were not due to test-retest errors.

CONCLUSION

The results of this study and others show that the accommodative-convergence relationship is indeed, complex. We have found that accommodation and convergence does not exist in a fixed ratio which can be measured accurately and reliabily over time. Rather, this relationship is dependent upon many intervening factors such as:

1. the level of proximal convergence characteristic of an individual
2. the neural and physiological status of the subject
3. the test method employed and its inherent errors in measurement
4. instructions given by the examiner when performing the given test
5. A_R and A_S correlation

It must therefore be re-emphasized that although there exists a relationship between accommodation and convergence, Maddox's classification is indeed, an over-simplification of the underlying relationship between accommodation and convergence. Any reference to an individual's "ACA" which is not followed by an operational definition of the term (method used, instructions given, etc.) is meaningless.

Prescribing an appropriate prescription for an individual manifesting an abnormally high ACA relationship should be done with the knowledge that the individual's ACA ratio will vary according to the aforementioned factors. It is recommended therefore, that:

1. The clinician employ the same method each time when determining the ACA of the patient - based upon results of this study, each test method has

its inherent idiosyncracies; it has been found that neither the gradient nor the phoria methods are significantly better than the other in determining ACA. Consistency in test method therefore, will yield most representable data of the ACA.

2. And, instructions should be coherent and constant for each test and between tests.

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