Repeatability and Variability of Near Vergence Ranges

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Abstract

The purpose of the following experiment was to assess weekly the repeatability of near vergence ranges in free-space (FS) and in the phoroptor (P) over a 10 week period. Three experienced adult subjects were tested. Near vergence ranges were obtained once a week for 10 consecutive weeks. The base-out (BO) and base-in (BI) blur, break, and recovery points were performed sequentially, as in clinical practice; measured three times and averaged. The BO and BI near vergence mean values and their variability in both the FS and P test conditions revealed relatively consistent and repeatable values over time. Intrasession variability, both within and across test sessions, was low. Differences were also noted when comparing response variability for FS versus P and for BI versus BO. Variability both within and across test sessions was generally consistently less than previously reported. This suggests that the mean values are relatively stable at independent sessions under careful test conditions. In this experienced group, the vergence values may approximate the optimal performance that can then be used for clinical comparison.

Key Words

binocular vision, base in vergence range, base out vergence range, free space testing, phoroptor testing, test repeatability and variability

INTRODUCTION

One of the most important clinical tests of binocular vision integrity is that of relative vergence ranges at near.[1,2] They delineate the limits of one's fusional convergence and divergence limits, when the accommodative stimulus is constant. There are three primary clinical test parameters that define these functions: the relative vergence blur, break, and recovery points. They provide valuable information regarding both the interaction of, and differentiation between, the two major components of the vergence system at near; namely fusional vergence and accommodative vergence, with proximal and tonic vergence maintained constant.[1,3] These two primary interactive components are represented by the blur and break points of the measurements. The blur value indicates the point at which the accommodative interactive aspect has reached its maximum value, whereas the break value indicates where the fusional aspect has reached its maximum value, thus leading to diplopia. Between the blur and break points, the primary drive comes from fusional vergence. Lastly, the recovery value signifies the point at which fusion is regained, presumably primarily through reflex fusion with a possible voluntary component.

Relative vergence measurements are of considerable clinical importance in both diagnosing binocular vision disorders and assessing progress made during their treatment.[1,4,5] Yet there is limited and conflicting information with respect to the repeatability of these measurements.

Past studies have been conducted to determine the repeatability of relative vergence ranges in adults and children, especially with respect to the base-out to break endpoint (BO break) (see Table 1). In some cases, the values were based solely on measurements obtained at a single test session, without repeated testing or averaging across sessions.

Of those BO studies that did repeat and average these measurements [i.e., mean and standard deviation (S.D.)], there was considerable variance in the number of test sessions and in the findings. Most studies also had other main purposes, with information on variability and repeatability only attained indirectly and secondarily. Feldman et al[6] assessed convergence and divergence repeatability between two test periods at the same session separated by 30 minutes in subjects aged 15-42 years. They found a base-out (BO) break value of 26 +/-9 pd with a recovery of 14 +/-9 pd, with the associated intersubject variabilities. Penisten et al,[7] who primarily tested distance convergence and divergence ranges across multiple sessions in inexperienced subjects aged 21-42 years, had four repeated measurements at near in a single session that were of value in terms of variability expectations. Their findings indicated very low intrasubject variability, with the average being 2.7 pd or less for all

Table 1: Summary of past related studies							
Study	Mean BO[a] (blur/brk/rec)	BO S.D.[a]	Mean BI [a]	BI S.D. [a]	Repeat Test Time	Target Used	Apparatus Used
Feldman & Cooper[6] (1989) n=38, 15-42 y/o	26/14 (estimated from graphs)	9/9 (estimated from graphs)	17/9 (estimated from graphs)	4/5 (estimated from graphs)	30 min, 2 sessions on same day	Letters @ 50.8 cm	Phoroptor
Penisten et al.[7] (2001) n=8, 21-41 y/o	19.8/23.1/14.0	2.7/1.7/2.7[d]	11.8/19.7/11.7	2.3/1.9/1.2[d]	4x in session	20/20 letters @ 40 cm	Phoroptor
Rouse et al.[b,8] (2002) n=20, 10-11 y/o	Examiner 1: 22.1, 24.1; Examiner 2: 22.8, 19.1	—	—	—	3x per session; 2 sessions 1 week apart	20/30 letters @ 30 cm	Phoroptor
Scheiman et al.[c,5] (2005) n=47, 9-18 y/o (break only)	Placebo VT: 12.1, 19.8	3.4, 10.3	—	—	4 sessions; 1 every 4 weeks	20/30 column of letters @ 40 cm	Prism Bar

a.. If only two values are given, they represent the break and recovery values. Otherwise blur, break (brk), and recovery values (rec) are listed.
b. Since the study was testing inter/intraexaminer reliability, the two break values obtained from each examiner are reported.
c. The values are reported only for the placebo VT group. The first value listed represents the initial finding, while the second value represents the final re-evaluation finding.
d.. Intrasession variability

All vergence values are in units of prism dioptors (pd).
Symbols: VT=vision training and S.D.=standard deviation.

parameters of base-in (BI) and BO ranges in the phoroptor. The largest calculated mean intersubject S.D. was 7.6 pd for the BO break findings. More recently, Rouse et al [8] tested over two sessions separated by one week in fifth and sixth grade children. They found that an interexaminer difference of 10-16 pd would be needed to indicate a valid treatment-based improvement in ranges, while a 12 pd intraexaminer difference would be required. This suggested large variability in their measurements. Scheiman et al,[5] as a preliminary phase of the Convergence Insufficiency Treatment Trials (CITT) study, re-tested positive fusional vergence (PFV) ranges every four weeks over a 16-week period for a total of four test sessions in patients aged 9-18 years. They obtained a range of pre- and post-therapy mean and S.D. values in analyzing each of their 3 sub-groups [i.e., those given either general vision therapy (VT), placebo VT, or pencil push-ups]. The smallest group S.D. was +/-3.4 pd (at an initial visit), while the largest group S.D. was +/-10.3 pd (at the final re-evaluation), in the placebo VT subgroup.

Those studies of BI vergence with repeated sessions also demonstrated a wide range of variability. Feldman et al[6] found a break point of 17 +/-4 pd and a recovery of 9 +/-5 pd, while Penisten et al [7] reported a mean blur value of 11.8 +/-3.1 pd, a break value of 19.7 +/-5.4 pd, and recovery value of 11.7 +/-5.9 pd, with the associated intersubject variabilities. Related intrasession variabilities for their study are presented in Table 1.

These previous studies on relative vergence ranges, especially with respect to the BO break value, suggested considerable inherent intrasession and intersession variability and a significant S.D. of the mean, with one of the largest reported values being +/-10.3 pd.[5] This is problematic clinically with respect to the diagnosis, prognosis, and treatment of patients with vergence dysfunction. More specifically, it is a potential problem in an on-going clinical trial involved in the comparative treatment of CI, where the BO break point is a main outcome measure.[5]

Thus, in the present study, the BO and BI vergence ranges at near were assessed in three experienced adult subjects over a period of 10 weeks. These results may therefore represent "optimal" or "best case" values expected to be obtained with regard to repeatability of near vergence ranges. Two questions were posed:
(1) What is the variability associated with near relative vergence testing, and
(2) What difference might occur with respect to the mean and variability of near relative vergence ranges tested in free-space (FS) versus the field-limiting confines of the phoroptor (P)?

METHODS

Subjects

Three visually-normal adults (two males and one female; the authors), all of whom were either faculty or graduate students at SUNY State College of Optometry, served as subjects. They were 26, 31, and 57 years of age, and their experience in psychophysical experimentation ranged from moderate to very high. All were able to achieve best corrected Snellen visual acuity of 20/20 in each eye at both distance and near. The experimental procedures were within the guidelines for approved human research projects, and written IRB approval was obtained.

Apparatus

Near vergence testing was performed under two conditions: FS and P. The near target used in both settings consisted of a 7.5 mm matrix of 20/25 letters which subtend a total visual angle of 1.0 H and V degrees at 40 cm. FS testing was conducted in a laboratory apparatus consisting of a headrest/chinrest assembly, an optical bench positioned along the midline, the near test target, and a light source (Figure 1). Target luminance was 70 cd/m^2. During measurements, a standard horizontal prism bar (maximum 40 pd) was placed in front of the patient's left eye in the spectacle plane, with the headrest serving as a physical guide. The P testing was conducted in a clinical examination room. The target was affixed to a nearpoint rod with standard illumination (52 W bulb). Target luminance was 191 cd/m^2. In this case, prism was introduced using Risley prisms placed over both eyes. Target contrast in the two conditions was 90%.

Figure 1. Laboratory test apparatus.

Procedures

Vergence ranges were assessed weekly for 10 consecutive weeks at the same time of day (5 p.m.). At each session, the blur, break, and recovery end points were determined for both the base-in and base-out directions in the conventional manner,[2] with a maximum total value of 40 pd. Counterbalancing procedures were used both within and across test sessions with respect to initial prism direction and test environment. The same examiners were used at each session.

For the P testing, the subject was instructed to keep the target clear and single as the different prism values were introduced. If the target became either blurry or double, or if it shifted laterally, the subject was to report this to the examiner. Prism was introduced at a rate of approximately 2 pd/second equally in front of both eyes simultaneously. Once the target doubled, the dioptric value was increased by 4 pd, and then reduced at the same rate, until the target became single once again which represented the recovery value. The blur, break, and recovery values were measured three times in each direction and then averaged at each test session. Subjects were provided 15 second rest periods between each measurement during which time they gazed into the distance (6m) to minimize prism adaptation effects.[3,4]

Instructions in FS were the same as for those used in the P test environment, although the procedures varied slightly. Prism was introduced before one eye at a rate of approximately 2 pd per second with the prism bar, until a value of 20 pd was attained. At that point, the rate changed to 5 pd per two seconds due to the standard prism bar design. Once the break point was attained, the prism value was increased by either 4 or 5 pd (due to the range dependence of the prism bar design), and then reduced until fusional recovery was achieved. If fusion was maintained up to 40 pd, it was recorded as such, and that maximum value was used as both the break and recovery values for purposes of data analysis.

All data were computer analyzed and plotted. The key parameters examined were the base-in and base-out blur, break, and recovery endpoints for both the FS and P test conditions. The measurements (three each, BI and BO) for individual test sessions were averaged to obtain a weekly mean value. The means were plotted separately for each of the three subjects over the consecutive 10-week test period. The intrasession variability for each session was also calculated and plotted in conjunction with the mean for each week. In addition, the average mean and average intrasession variability across the 10 weeks was determined, along with the standard deviations for the values. These calculations were performed for each parameter (blur, break, and recovery) for both FS and the P for the three subjects.

For each subject under each condition, linear regression analysis was performed to assess for slope values that were not statistically equal to zero. This was done to determine if any trends, such as a learning effect, might have occurred over the 10 week test period

Results

The results over the 10 week period are presented in Figures 2-3 separately for each parameter for each subject. See Table 2 for the exact values of the individual 10 week averages for the mean and intrasession variability of each parameter, along with its standard deviation. The highlights of the data will be described below.

Variability

The variability was assessed for each parameter separately, both within an individual and across the group findings.

(1) Blur

For this parameter, only two of the subjects had valid results, since Subject 3 is an absolute presbyope. Variability never exceeded 5.0 pd within a single test session. This was true for both the BO and BI weekly blur findings. The average intrasession variability values were less than 2.7 pd. Both the BO and the BI blur findings were relatively similar within the same condition.

(2) Break

Individual intrasession variability each week for subjects 1 and 2 was always less than, and in a single instance for S2 equal to, 5 pd for the both BO and BI findings. Subject 3 had only one week in which the BI variability was 5 pd or greater, while there were three weeks at the start of testing in which the BO variability exceeded 5 pd. The BO variability decreased over time. Average intrasession variability across the ten weeks, however, was still less than 5 pd for the three subjects for both the BI and BO findings. It is important to emphasize that the intrasession variability for the BO findings in FS was confounded in subjects 1 and 2, as they consistently attained the maximum prism value, with this saturation effect forcing the variability to zero.

(3) Recovery

The BI recovery results had reasonably consistently low intrasession variability in both free-space and in the phoroptor, with subjects 2 and 3 having only a few outliers that attained a maximum value of 5 pd. For both subjects, these outliers occurred in FS only. The BO results, however, exhibited the most variability among the three subjects; each exhibited a different pattern. FS testing was again confounded by the fact that the recovery findings were usually at the maximum value due to prism bar value limitations. However, all three ultimately had a low 10-week average intrasession variability of less than 3.3 pd.

Free-space vs. phoroptor

The data were also assessed with respect to test environment. However, once again, prism saturation was a confounding factor. All mean BO break averages in FS were higher (by 4.1 to 8.7 pd) than in the P condition. The BO mean recovery values in FS were also higher than those found in the P (by 10.1 to 21.6 pd). However, the BI FS and P mean break and mean recovery averages were similar in the three subjects.

With regard to the average intrasession variability, blur variability in FS tended to be slightly greater than in the P condition for subjects 1 and 2, with a difference range of only 0.4 to 1.2 pd. In both subjects, the difference between the FS and P conditions average variability was greater for BO than BI.

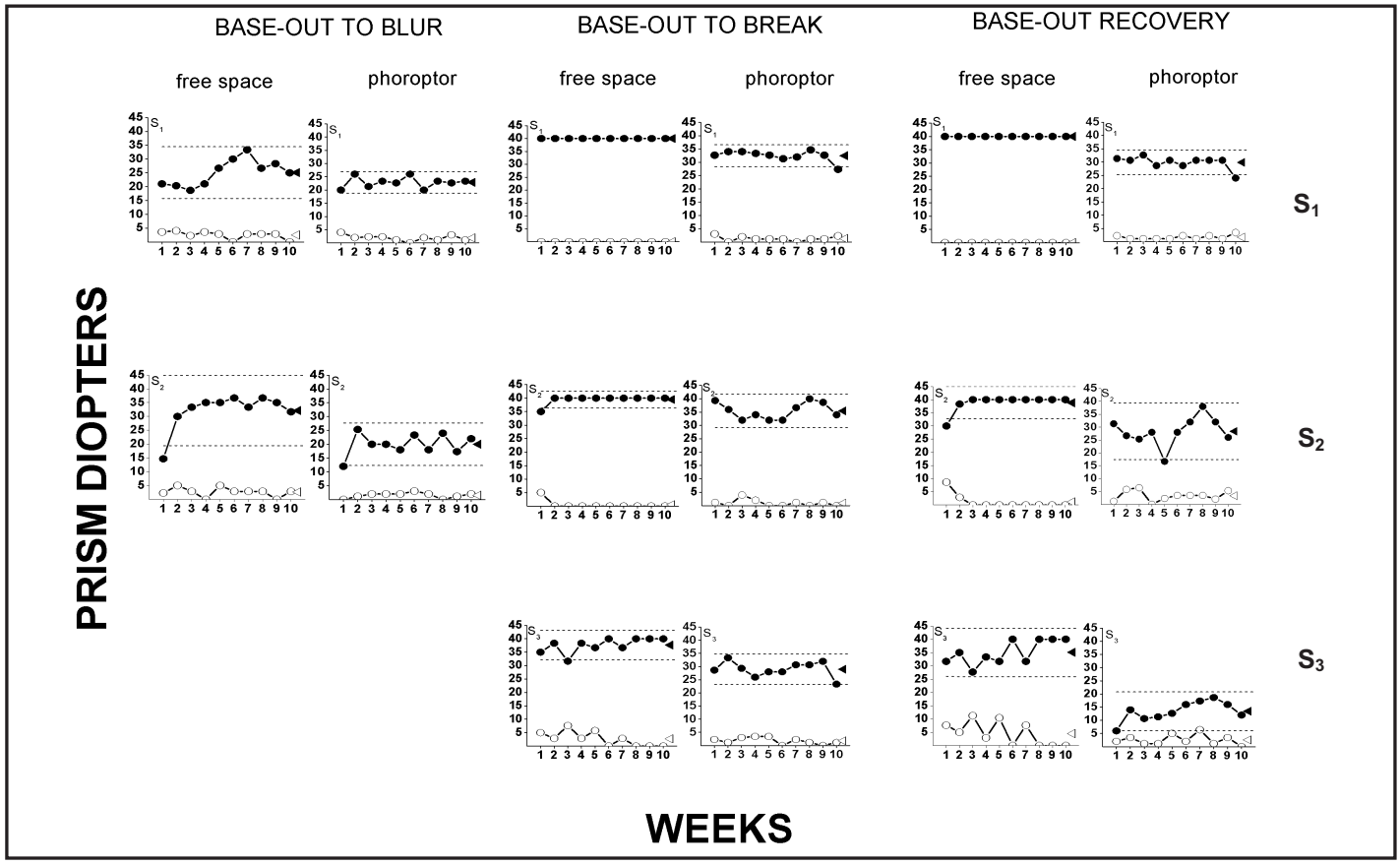

Figure 2. Base-out for blur, break, and recovery in each subject for the two conditions over the 10 week period. Plotted is the intrasession mean (●), intersession mean (◀), intrasession variability (○), and mean of intrasession variability (◁). Dashed lines represent ± 2 S.D. (intersession variability).

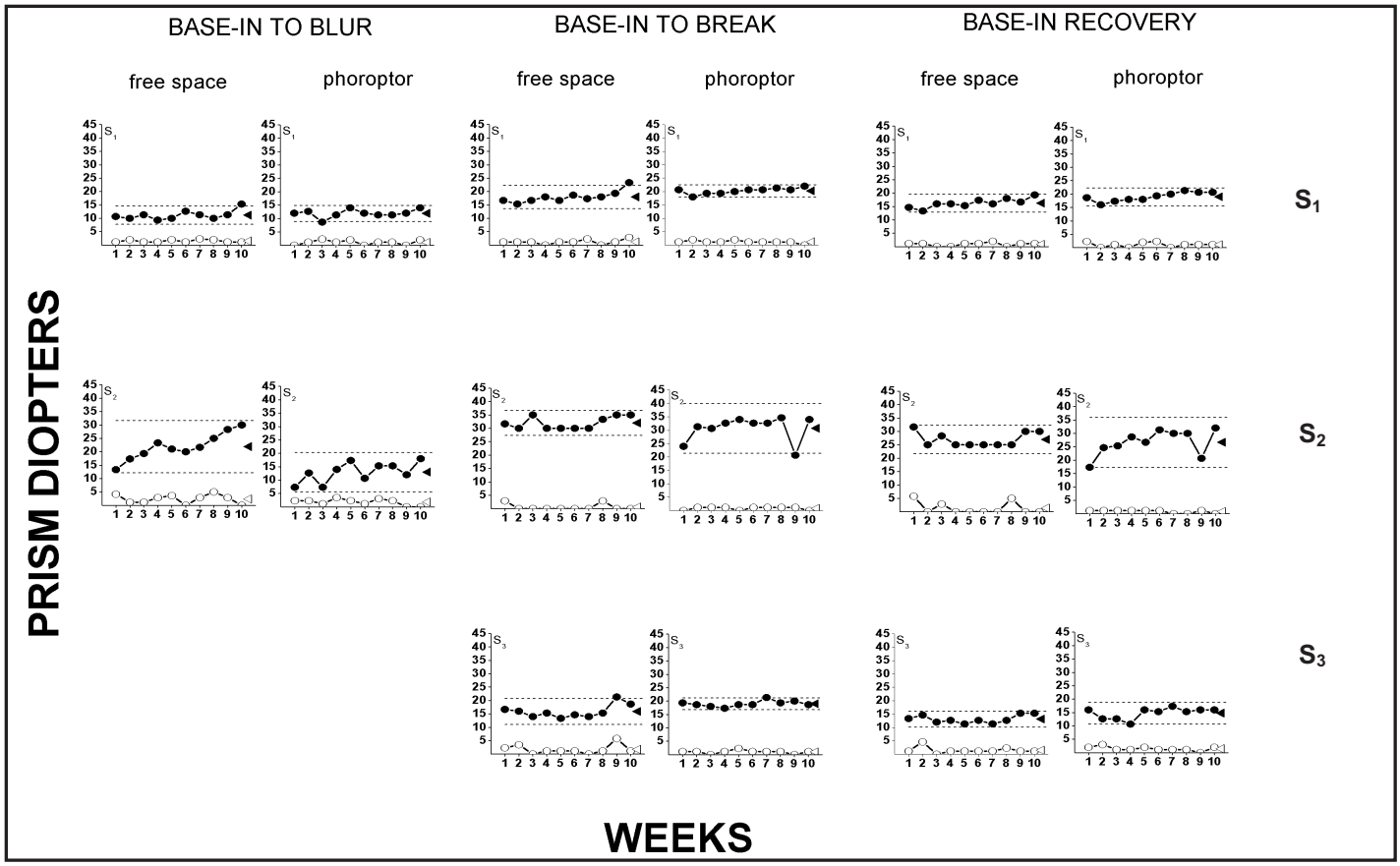

Figure 3. Base-in for blur, break, and recovery in each subject for the two conditions over the 10 week period. Plotted is the intrasession mean (●), intersession mean (◀), intrasession variability (○), and mean of intrasession variability (◁). Dashed lines represent ± 2 S.D. (intersession variability).

Table 2: Individual subject data												
	Subject 1				Subject 2				Subject 3			
Parameters	BO: FS	BO: P	BI: FS	BI: P	BO: FS	BO: P	BI: FS	BI: P	BO: FS	BO: P	BI: FS	BI: P
BLUR												
Intersession Mean (◀)	25.1	22.9	11.2	11.9	32.1	20.0	21.9	13.0	—	—	—	—
Intersession Variability (2 SD) --- [dashed lines]	±9.6	±4.2	±3.4	±3.0	±13.0	±7.8	±10.0	±7.4	—	—	—	—
Mean Intrasession Variability (◁)	2.5	1.9	1.5	1.1	2.7	1.5	2.4	1.8	—	—	—	—
BREAK												
Intersession Mean (◀)	40.0	32.4	18.0	20.3	39.5	35.4	32.0	30.7	37.7	29.0	15.9	19.0
Intersession Variability (2 SD) --- [dashed lines]	0.0	±4.2	±4.4	±2.2	±3.2	±6.2	±4.6	±9.4	±5.4	±6.0	±4.8	±2.2
Mean Intrasession Variability (◁)	0.0	1.3	1.2	1.2	0.5	0.9	0.6	0.8	2.7	1.8	1.7	1.0
RECOVERY												
Intersession Mean (◀)	40.0	29.9	16.3	19.0	38.8	28.4	27.0	26.7	35.1	13.5	13.1	14.8
Intersession Variability (2 SD) --- [dashed lines]	0.0	±4.8	±3.4	±3.4	±6.2	±11.2	±5.4	±9.6	±9.2	±7.4	±3.0	±4.2
Mean Intrasession Variability (◁)	0.0	1.7	0.9	1.1	1.2	3.3	1.4	0.8	4.5	2.6	1.5	1.5

**All values specified in prism dioptors. See Figures 2 and 3.*
**FS= Free-space; P= Phoroptor; SD= Standard Deviation; BO= Base Out; and BI= Base In*

Slope analysis

When the FS versus P parameters were plotted, and a correlational analysis was performed, a significant difference was found between slopes for the combined BI versus combined BO results. The BO linear regression equation was y=0.60x+4.72, while the base-in linear regression equation was y=1.13x-2.89. The difference in slopes can be seen in Figure 4, with the BI slope (1.13) being nearly two times steeper than found for BO (0.60). Slope analysis revealed that each slope was different from zero [$F(1,28)=26.28$, $p<0.0001$] for BI and [$F(1,28)= (8.25$, $p<0.005$] for BO. A two-tailed t-test confirmed that the slopes are also different from each other [$t(58)=11.040$, $p<0.001$].

Slopes were also assessed for the individual subject blur, break, and recovery values over the 10 weeks in both the FS and P test conditions. Of the 32 subject/test condition combinations, 9 had significant slopes (t-test, $p<0.05$) and one exhibited a possible trend (t-test, $p<0.10$). All of the significant slopes and trends were positive. The significant slopes were not consistent for any one parameter or for any one individual. Based on the significant slopes, the smallest difference between the first and last sessions was 2.4 pd, and the largest was 13.6 pd, with an average difference of 6.7 pd.

Table 3: Summary group data analyzed across prism types (top) and between prism types (bottom) for each test condition

Parameter	Predicted result	Result	Percentage increase
Intersession mean	BO>BI	15/16 (94%)	76.5
	FS>P	11/16 (69%)	39.9
Intersession variability	BO>BI	12/14 (86%)	74.1
	FS>P	7/13 (54%)	69.5
Mean intrasession variability	BO>BI	11/14 (79%)	86.5
	FS>P	8/12 (67%)	56.2
Mean value		75%	67.1

Parameter (intersession mean)	Predicted result	Result	Percentage increase
BO	FS>P	8/8 (100%)	45.7
BI		3/8 (38%)	24.6
Mean value		69%	35.2

Summary

The group data are summarized in Table 3. When compared across prism types and parameters, the mean base-out values were larger than for base-in on average by 79%, and FS values were larger than in P values on average by 55%. When compared between prism types, FS values were always larger than P values for BO but not for BI.

DISCUSSION

Variability

Previous studies of vergence ranges were limited in their probing of measurement variability over time. Some had only one test session during which ranges were obtained, and even those that did attempt to address the question of test repeatability were typically performed within a relatively limited time frame, ranging from a minimum of 30 minutes between two test sessions[6] to a maximum of one week apart.[8] When comparing those studies that have examined repeatability of vergence testing across multiple sessions,[5,8] the results varied. This is a problem in both the clinic and clinical research testing, since the expected long-term variability must be understood to know when true gains have been made following some form of treatment (e.g., vision therapy).

Table 4: Average intrasession variability comparison with Penisten et al's study			
	Penisten et al (P)	Present Study (P)	Present Study (FS)
BO	2.7/1.3/2.5	1.7/1.3/2.5	2.6/1.1/1.9
BI	2.3/1.9/1.2	2.0/1.0/1.1	1.5/1.7/1.3

** Each set of values represents the blur, break, and recovery averages, respectively, in prism dioptors.*

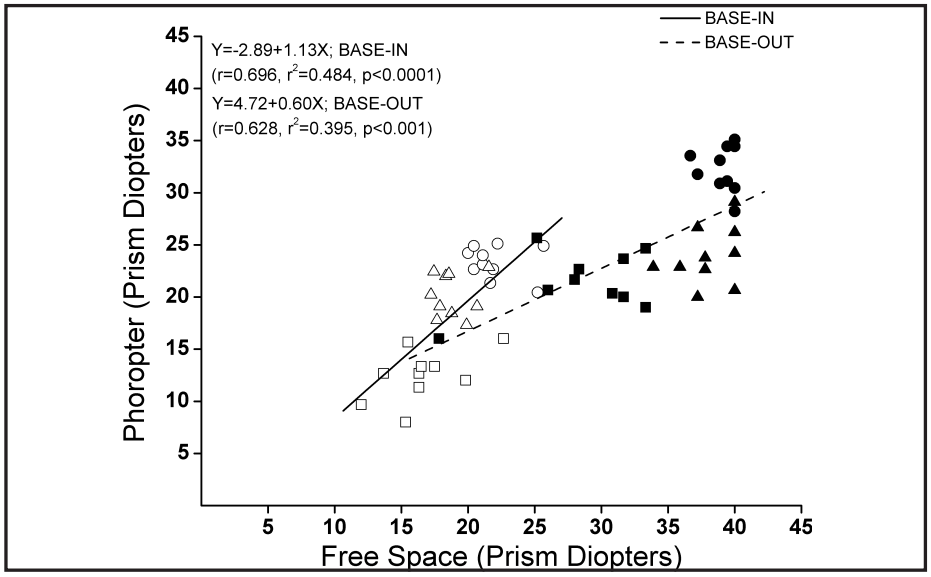

Figure 4. Correlation graph of free-space (FS) and phoroptor (P) for BI versus BO parameters; plotted values represent the average of the 3 individual means for each week. The solid line (—) signifies the BI slope, while the dashed line (- - -) signifies the BO slope. Plotted are BI blur (□), break (Δ), and recovery (○) versus BO blur (■), break (▲), and recovery (●).

The present results were only compared to those past studies that examined vergence range repeatability over an extended time course. All values discussed in the present study refer to the calculated average intrasession variability across the 10 weeks. The reported BO break variability (i.e., S.D.) has been as small as 3.4 pd to as much as 10.3 pd.[5] The BO recovery variability was as little as 4.7 pd [7] and as large as 9.0 pd,[6] while the BO blur variation in the only study performed was found to be 7.5 pd.[7] Knowledge about the BI variability was even more limited. Feldman et al[6] found the BI break variability to be 4.0 pd, while Penisten et al [7] reported 5.4 pd. The BI recovery variability found by Feldman et al [6] was 5.0 pd, and it was 5.9 pd by Penisten et al.[7] Only Penisten et al [7] reported a BI blur variability value, which was 3.1 pd.

The results of the present study demonstrated a smaller degree of variability than reported in most other investigations. In drawing comparisons between studies, it is important to consider the test conditions under which each was performed. The most similar study design to the present study's P condition was that of Penisten et al,[7] although their testing was only performed at a single session. The most similar to the present study's FS testing was that of Scheiman et al.[5] In the present study, BO blur variability in FS was less than 2.7 pd for the 3 subjects, and even smaller in the P condition (1.9 pd). The BO break variability in the FS condition was also less than 2.7 pd, and it was less than 1.8 pd in the P condition. The present BO recovery variability in the FS condition was 4.5 pd, and the P results were less than 3.3 pd.

Most interestingly, when the present average individual data were combined, the intrasession variability findings were surprising similar to Penisten et al's results in adults[7] (Table 4). This is true despite their study having used a relatively small sample of inexperienced subjects at only a single test session, whereas the present study used a very small sample of relatively experienced subjects and averaged the mean variability across the 10 weeks of testing. Their result is important, as it demonstrates that reliable vergence findings can be obtained, even in naïve adult individuals, both within and across test sessions.

When analyzing the weekly findings for the individual subjects, intrasession variability was always less than 7.6 pd, with most weekly sessions having 3.0 pd or less variation. This number may represent the lowest expected variability for repeated vergence range testing within one test session in visually-normal adult patients.

Another important finding was the repeatability of the mean values over the ten weeks. Previous studies have reported much larger variation in vergence range values, especially for the BO to break, which would necessitate larger changes to occur before any treatment intervention would be deemed valid. One of the largest reported required differences was from Rouse et al.[8] They indicated that a 10-16 pd improvement from baseline would be deemed a valid gain given their interexaminer test results, and a 12 pd improvement given their intraexaminer test findings, which suggested large measurement variability. The present results, however, show a smaller and relatively consistent repeatability over time that was less than 5.0 pd for all parameters. However, the former were obtained in children, while the latter were obtained in experienced adults, so a difference in variability would be expected.

Free-space vs. phoroptor

There were several areas in which distinctions could be made between the FS and the P findings. All subjects had significantly larger vergence ranges in FS versus the P, especially for BO. This difference may be due to the influence of peripheral fusion on vergence ability, thus producing greater overall drive to the system. The effect of and strong influence from peripheral fusion has been described in the past, even in strabismic patients, with evidence of peripheral stimulation producing robust vergence eye movements.[9-12] In the present study, allowing peripheral stimulation and fusion to occur in the FS condition added overall drive (i.e. central plus peripheral field) to the fusional (i.e. disparity vergence) system; thus, larger convergence ranges could be obtained, and in fact would be predicted to be found. The P condition, however, limits the influence of peripheral fusion on the vergence system. This distinction becomes more apparent when comparing their respective fields-of-view, with FS

being approximately 160-170 degrees and the P being only about 25-30 degrees.

In analyzing the intrasession variability across the group, differences were found in both the BI and BO blur findings. The FS condition manifested slightly higher intrasession variability than in the P condition. The break and recovery values exhibited non-specific group trends. Individual trends were more apparent, with S3 exhibiting greater variability in FS versus the P, while S1 and S2 demonstrated the opposite. These observations reveal the importance of individual patient analysis, as each may exhibit trends that are not evident when the results are combined across subjects.

Base-in vs. base-out

It has been postulated that BI and BO vergence functions have somewhat different underlying neural mechanisms.[1,12,13] For example, brain lesion studies have shown that one can produce paralysis of one function but not the other.[14,15] And, the convergence controller signal is comprised of a combined step and a small pulse component, while divergence is controlled by a step component alone.[12,16]

The correlation graph of FS and P provides another piece of information supporting the hypothesis that convergence and divergence have distinct physiological processes. This is evident by several observations illustrated in the graph (Figure 4). First, the difference in slopes for the FS versus the P condition average values was two-fold. This demonstrates how the relationship between the FS and P condition is unique to the BI and BO ranges. The BI relative divergence findings have revealed a 1:1 relationship between FS and P, while the BO relative convergence exhibited a 2:1 relationship. Next, when plotted, the two conditions formed distinct and separate clusters without much overlap, thus indicating that the BO ranges are significantly larger than the BI. Finally, the data exhibited different patterns of clustering, with the BI region having a much tighter cluster than the BO. The BO values would likely encompass an even larger range if there had not been a prism response saturation effect.

Other differences between the BI and BO vergence aspects have already been described above with respect to FS vs. the P, as well as the average intrasession variability, in the Results section and in other portions of the Discussion section.

Study limitations

There were some limitations to the present study. One was the small sample size. Similar to the strategy used in a pilot study, this small group allowed one to obtain a detailed and basic understanding of the long-term near relative vergence repeatability and variability. The results also provided insight into individual and small group trends in variability both across and within the various test parameters and conditions.

An unforeseen problem was that of saturation in the FS test condition in the BO direction due to prism bar design, with a 40 pd maximum. It falsely gave the impression of zero variability for both S1 and S2.

Clinical implications

This study was designed to determine the normal variability one should expect in vergence testing over extended periods of time under optimal conditions with experienced subjects. These findings can then be applied clinically with respect to proper determination of binocular vision diagnosis and treatment progression, as related to expected vergence response variability. It will also permit the clinician to confirm, with considerable confidence, when a true improvement has occurred related to vision therapy. The present results suggest that vergence ranges in visually-normal experienced adult individuals are predicted to be reasonably repeatable over extended periods of time. It was also found that the intrasession variability at individual sessions and across the 10 weeks was very low. This is strongly supported by the findings of Penisten et al [7] in inexperienced adult observers.

The results also revealed the potential for a learning effect to occur, in which case improvements would be falsely attributed to an actual increase in fusional ability per se from the prescribed treatment. This was most evident in S2, who was the least experienced subject of the three, although each subject exhibited some degree of this form of motor learning.[17] The possibility of presumed changes based solely on a learning effect indicates the need to obtain multiple baseline measurements of vergence testing prior to the initiation of vision therapy, or any other treatment intervention.

The clinician must also be cautious when comparing the FS and P condition vergence findings, especially with respect to the BO vergence ranges. Based on the present study, values for the two test conditions may not be comparable; therefore, whichever technique was initially performed must consistently be used in all future evaluations. If the values from the two conditions are used interchangeably, increased and false response variation will be evident. Since vergence ranges in young children are more often measured in FS as compared with adults, one must take special care when obtaining such measurements, since a head rest, as used in this study is not the norm. Furthermore, unwanted movement of both the clinician and patient may skew the findings. It is also relatively easy to induce undesired vertical prism in the FS condition through an unintended tilt of the prism bar, especially at higher values, so careful monitoring of orientation is essential.

Such knowledge is valuable in understanding expecteds in both research studies and clinical trials, for example those currently addressing the efficacy of various treatment modes for convergence insufficiency.[5] It must be remembered, however, that the findings in the present study probably represent "best case" examples, and are likely much less than one would find when a binocular vision dysfunction is present.[18]

Future directions

Based on the results of the present small sample study, it would be clinically important to repeat it with a larger sample size. It should be performed with both visually-normal subjects, as well as those with vergence dysfunction, and with adult and pediatric samples of each category.

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