The correlation of Brock String response, fixation disparity, and anticipation timing

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Abstract
Background: This study investigated the relationship between ocular alignment measurements taken from the standard distance Brock String and the Mentor 0&0 B-VAT II. Also studied was the possible relationship between ocular alignment and the anticipation of a dynamic event as measured by the Bassin Anticipation Timer.

Methods: 71 subjects performed a standard distance Brock String test. The subjects were asked whether they perceived the bead within a fused area of string, and if so, the subject was asked to identify the portion of the fused area where the bead appeared. The subjects’ fixation disparity was also used to determine if there is a correlation with anticipation timing as measured by the Bassin Anticipation Timer.

Results: 47 of 71 subjects (66%) perceived fused sections of the distance Brock String. Of these 47 subjects, 38 (81%) stated the bead was in the front 1/3 of the fused section. 6 (13%) subjects said the bead was in the middle 1/3 of the fused portion. The remaining 3 (6%) subjects reported the bead to appear in the rear 1/3 of the fused area. BVAT analysis claimed 29 (41%) subjects had a mean exo disparity, while 17 (24%) subjects had a mean fixation disparity of ortho, and the remaining 25 (35%) subjects had mean eso fixation disparities. Correlations between fixation disparity and anticipation timing were found to be quite low.

Conclusions: Statistical comparisons made between distance Brock String and By AT fixation disparity performances did not yield the significant results necessary to conclude that distance Brock String responses accurately represent any one fixation disparity category (eso, exo, or ortho). In addition, no statistically significant relationship was determined between distance Brock String or B-VAT fixation disparities and any of the Bassin Anticipation Timer data.

Degree Type
Thesis

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THE CORRELATION OF BROCK STRING RESPONSE, FIXATION DISPARITY, AND ANTICIPATION TIMING.

By
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Kenneth J. Whitwell

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A thesis submitted to the faculty of the
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John D. Hutchison and Kenneth J. Whitwell are both graduates of Pacific University College of Optometry. Their efforts provide the bulk of the material presented in this thesis. They are credited with being involved with many different student activities and organizations while being students at Pacific University College of Optometry.

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Benjamin Fogal graduated from St. John's University (MN) in 2000 with a Bachelor of Science Degree. He attended Pacific University College of Optometry from 2001 to 2005 and graduated May 2005 with the degree of Doctor of Optometry. He plans on returning to the Midwest and beginning his career as an associate doctor in a primary care setting. He would like to specialize in contact lenses and ocular disease.
Abstract:

Background: This study investigated the relationship between ocular alignment measurements taken from the standard distance Brock String and the Mentor O&O B-VAT II. Also studied was the possible relationship between ocular alignment and the anticipation of a dynamic event as measured by the Bassin Anticipation Timer.

Methods: 71 subjects performed a standard distance Brock String test. The subjects were asked whether they perceived the bead within a fused area of string, and if so, the subject was asked to identify the portion of the fused area where the bead appeared. The subjects’ fixation disparity was also used to determine if there is a correlation with anticipation timing as measured by the Bassin Anticipation Timer.

Results: 47 of 71 subjects (66%) perceived fused sections of the distance Brock String. Of these 47 subjects, 38 (81%) stated the bead was in the front 1/3 of the fused section. 6 (13%) subjects said the bead was in the middle 1/3 of the fused portion. The remaining 3 (6%) subjects reported the bead to appear in the rear 1/3 of the fused area. B-VAT analysis claimed 29 (41%) subjects had a mean exo disparity, while 17 (24%) subjects had a mean fixation disparity of ortho, and the remaining 25 (35%) subjects had mean eso fixation disparities. Correlations between fixation disparity and anticipation timing were found to be quite low.
Conclusions: Statistical comparisons made between distance Brock String and B-VAT fixation disparity performances did not yield the significant results necessary to conclude that distance Brock String responses accurately represent any one fixation disparity category (eso, exo, or ortho). In addition, no statistically significant relationship was determined between distance Brock String or B-VAT fixation disparities and any of the Bassin Anticipation Timer data.

Key Words: fixation disparity, heterophoria, Brock String, Panum's fusional area, anticipation timing.
The ability to accurately localize an object in space and anticipate the occurrence of a dynamic event can greatly affect our performance not only in sports, but in everyday life as well. As an example, it has been suggested that the perception of a car in front of us as being further away than it really is may cause us to follow too closely or react slightly too late, and therefore increase the risk of accident.\(^1\) It has been proposed by a segment of the optometric profession that inaccurate real life spatial and/or timing judgment such as this can be due to a tendency of our eyes to over/underconverge on a particular target.\(^1\)

Pointing our eyes closer than the object is termed overconvergence; which, it has been suggested, may lead to the perception of objects as being closer than they really are. Alignment of our eyes beyond the point of regard; termed underconvergence, may lead to perception of objects as being further away than they really are. If this is true, the anticipation of the occurrence of an event may be affected by overconvergence and underconvergence. For example, a baseball player who overconverges his eyes may have a tendency to swing too early, whereas another player who underconverges his eyes may have a tendency to swing too late.\(^2\)

Many studies have investigated the changes that occur in perceived distances as a result of the manipulation of the binocular vergence system. Fixation disparity and lateral heterophorias have been studied in both naturally occurring and induced cases. Studies by Ebenholtz and Wolfson\(^3\) and Ebenholtz\(^4\) both showed shifts in distance perception judgments with induced heterophorias. The authors of these studies use a muscle potential theory to explain the changes in perceived distance occurring after an induced change in
heterophoria. In essence, they propose that changes in distance perception result from continued reflexive innervation of the extraocular muscles in the direction of the previous stimulation. Other studies have focused on naturally occurring fixation disparities and heterophorias and their relationship to distance judgments. A study by Fronk and Coffey found no relationship between direction and/or magnitude of naturally occurring fixation disparities and golf putting error. A different study by Coffey, Reichow, Colburn and Clark found that as the eyes deviate from primary gaze there is less flexibility and increased stress upon the binocular system. And, presumably, the esward shift seen in non-primary gaze moves the sensorimotor fusional process toward the limit of Panum’s fusional area. A continuation of this work by Makini, Yamamoto, and Coffey was also inconclusive in determining the predictability of spatial error tendencies from fixation disparity. Another study by Reddin found that neither induced fixation disparity nor induced heterophoria can be used to predict size or location of spatial errors. However, some association of oculomotor factors and spatial judgements was found due to a trend of longer distance judgements after base out prism wear. Recently, a study by Fogt and Jones revealed that there are differences in objective and subjective fixation disparities.

There are two forms of sensory compensation required for fusion. One process was the fusion integration of the stimuli within Panum’s fusional areas. The other process is a change in binocular retinal correspondence that supplements the normal fusion process first elucidated by Panum. This small alternation in correspondence shifts Panum’s area toward the fusion target, therefore decreasing the measure of subjective fixation disparity by the magnitude of the correspondence shift.
Although a person may not be pointing both eyes at the same exact point on a target, she/he may still see it clearly and singly. A binocularly fixated object may create retinal images that do not stimulate exactly corresponding retinal points. However, the target will still be perceived as a single, fused object because these retinal points lie within Panum’s fusional area \(^{11,12}\). Panum’s area is approximately 12 arc minutes in diameter at the fovea and 30 arc minutes in diameter ten degrees peripheral to the fovea \(^{11}\). Therefore, larger objects in the field remain fused over a greater range of disparities than smaller objects. If the horizontal target disparities do not exceed these values, a single image is seen in front of or behind the plane of the fixated object \(^{13}\). Instances such as these, when fixating a target with both eyes, the relative over or underconvergence is termed an eso- or exo- fixation disparity, respectively.

Historically, the distance Brock String has been one device used to test for the phenomenon of fixation disparity. The distance Brock String is a simple device consisting of about three meters of string with, most frequently, three beads (one cm diameter) spaced along its length. Reports in sports optometric literature state that while holding the string taut to your nose (with the other end fastened to a stationary object) and looking down the string at one of the beads, information about the binocular vergence system can be gathered \(^{2,14}\). It is generally agreed that if the two strings cross in front of the fixated bead (closer to the observer than the position of the bead), the person is over-converging his/her eyes. Similarly, under-convergence would be indicated if the strings crossed behind the bead \(^{2}\).
Although the distance Brock String is an accepted testing and training device, the types of patients for whom it is prescribed, the way it is administered, and the interpretation of its results vary somewhat from practitioner to practitioner. It has been stated that the Brock String shows vergence posture relative to a point in real space, very similar to fixation disparity data. At this point, the Brock String indicates precisely in real space where the patients' lines of sight intersect one another. A very similar interpretation says the Brock String yields excellent results in enhancing accommodative and convergence performance which makes it very useful for everyday visual skills used in such activities as driving, working, and reading.

The preceding discussion shows the subtle differences surrounding the Brock String and, therefore, invites the possibility of misinterpretation of its results. Most practitioners ask for the exact place at which the strings cross (this assumes one single point). Patients are to respond “at”, “in front of”, or “behind” the bead. Others simply tell their patients to perceive the strings crossing at the center of the bead, creating an “X” pattern (but no mention of the strings crossing in front or behind the bead). By definition, Panum’s fusional area indicates that there is a range of points within which a binocularly fixated object will stimulate the retina and still be perceived as single. Therefore, there may be more than just one single point at which the strings cross. This may create a fused portion of the string for the patient which would resemble a “Y” instead of an “X” pattern (see Figure 1). In addition, the bead’s location within this fused portion could possibly reveal more accurately where the lines of sight are actually pointing in real space.
The primary goal of this study is to measure any correlation between ocular alignment as measured by the standard distance Brock String and by the Mentor O&O B-VAT II. A secondary goal is to determine if these measurements correlate with timing tendencies in the anticipation of an event, as measured by the Bassin Anticipation Timer.

Methods:

71 subjects were recruited on a volunteer basis from the Pacific University College of Optometry student body. Participation requirements were limited to demonstration of gross stereopsis (at least 240 sec of arc) at a distance of 3 meters and habitual 6m static visual acuities of 20/20 OD, OS, OU. Testing took place at the Pacific University College of Optometry Vision Therapy Clinic in Forest Grove, Oregon. Subjects were randomly assigned one of six testing sequences for data collection (see Table 1), and provided informed consent prior to commencing the experimental measurements.

Three main rooms were utilized for the acquisition of data, and a fourth room was used for preliminary screening. In Room 1, subjects were tested for fixation disparity at 3 meters using the Mentor O&O B-VAT II (Refer to protocol in Appendix). Responses of each subject were collected designating each Exo response as a negative value and each Eso response as a positive value. These fixation disparity data were recorded as to obtain
not only the direction, but also the magnitude of the disparity. This allowed for the determination of each subject's mean fixation disparity as well as their range of fixation disparity responses.

Subjective response of vergence posture relative to a 3m Brock String bead was obtained in Room 2 (Refer to protocol in Appendix). The first subjective distance Brock String response obtained from each subject was the perception of the strings as crossing in front of the bead, at the bead, or behind the bead (designated as F, A, or B respectively). The second Brock String response recorded was the perception either of a fused area of string as represented by Figure 2a, or no fused area of string as represented by Figure 2b. For each of the subjects that reported seeing a fused area of string, a third subjective Brock String response was recorded; each subject was asked to diagram on a recording form the location of the bead with respect to the fused area. Since the fused area reported by the subjects differed in physical length, Figure 2a could not be scaled for accurate measurement. The location of the diagrammed bead was recorded for each subject as being in the front, middle, or back 1/3 of the fused portion of string (designated as F, M, or B respectively).

INSERT FIGURE 2

In Room 3, a 6m Bassin Anticipation Timer was utilized to make objective and subjective assessments of visual motor anticipation timing for the occurrence of a dynamic event (Refer to protocol in Appendix). The Bassin Anticipation Timer consists of a 6m rail
that is 20cm wide with a series of small lights spaced 2.5cm apart which span the entire length of the rail. The subject is asked to stand at one end of the rail, the top of which is 86cm above the floor, and hold the handheld trigger in his/her preferred hand. Initially, a small white light at the furthest end from the subject lights up for 1.5 seconds, followed by a series of red lights which turn on-off sequentially and travel down the rail toward the subject, thus simulating the perception of motion. The subject's task is to press the button at the exact moment the red light reaches them. The Bassin Anticipation Timer data consisted of each subject's objective and subjective responses. The objective measurements recorded included the specific amount of time (to the nearest one-thousandth of a second) the subject was early or late. An early response was designated as a negative value and a late response was designated as a positive value. This enabled obtaining the mean timing error as well as the total timing error for each subject. Subjective responses for each trial were also recorded by asking the subjects if they thought they were early, late, or on-time in judging the occurrence of the event. Testing protocols were derived from the Pacific Sports Visual Performance Profile (PSVPP)\textsuperscript{19}. For specific testing protocols and a copy of the two recording forms used in the study see Appendix 1.

Results:

The findings revealed that of the 71 subjects, 12 (17%) reported the distance Brock String cross behind the bead, 31 (44%) reported the strings to cross at the bead, and 28 (39%) reported the strings to cross in front of the bead. The data for Brock String responses of in front (F), at (A), or behind (B) were used to categorize subjects for subsequent analysis using ANOVA, of any group differences in fixation disparity mean,
fixation disparity range, Bassin Total error and Bassin mean error (see Table 2).

Significant differences were shown for the comparisons between Brock String response (F/A/B) and fixation disparity mean (F=3.547, df=2.68, p=0.0343), as well as between Brock String response (F/A/B) and fixation disparity range (F=3.141, df=2.68, p=0.0496). Post-hoc analysis using Fisher’s PLSD showed that the A and F groups differed (p<0.05) for comparisons between fixation disparity mean and fixation disparity range. The statistics showed no significant differences between groups in either Bassin total or Bassin mean error, based upon Brock String responses of F, A or B.

47 (66%) of the 71 subjects reported seeing a fused section of the Brock String similar to Figure 2a on the recording form. The remaining 24 (34%) subjects saw the strings cross at one point as in Figure 2b (see Table 2). ANOVA analysis of fixation disparity mean, fixation disparity range, Bassin total error, and Bassin mean error data (based upon the Brock String Figure 2a or 2b data) showed no significant differences (p>0.05).

Of the 47 subjects who reported seeing a fused section of the Brock String (Figure 2a), 38 (81%) subjects drew the bead as being in the front 1/3 (F) of the fused section of string (see Table 2), six (13%) subjects diagrammed the bead as being in the middle 1/3 (M), and three (6%) subjects reported the bead to be in the back 1/3 (B) of the fused section. Fixation disparity mean and fixation disparity range differed among these subjects (F=5.704, df=2.44, p=0.0063 and F=4.238, df=2.44, p=0.0207 respectively) based upon analysis between groups using one factor ANOVA. Post-hoc analysis using Fisher’s PLSD
and Scheffe F-test showed that the F and M groups differed (p<0.05) for both comparisons. Comparison with the Bassin total and mean errors showed no statistically significant differences using ANOVA (p>0.05).

INSERT TABLE 2

Of the 71 subjects, 29 (41%) had a mean Exo disparity when tested for fixation disparity at 3 meters with the Mentor O&O B-VAT II. 17 (24%) subjects had mean fixation disparity of Ortho, and the remaining 25 (35%) subjects were tested to have mean Eso fixation disparities (see Table 3). The fixation disparity category (Exo, Ortho, or Eso) of the subjects was used to compare their individual performances on the Bassin Anticipation Timer for Bassin total time as well as Bassin mean time (table 3). The groups did not differ based upon ANOVA (p>0.05).

INSERT TABLE 3

Comparisons were also made between the subject's fixation disparity category (Eso, Ortho, Exo) and each of the three subjective Brock String responses (strings cross in front, at, or behind the Brock bead, Figure 2a or 2b), as well as the bead's location within the fused portion of string (front, middle, or back 1/3 of Figure 2a). These comparisons were analyzed using coded Chi-Square analysis which revealed no differences based upon the fixation disparity categories (p>0.05).

INSERT TABLE 4
Individual performances on the Bassin Anticipation Timer were categorized into three additional groups consisting of the number of objective early responses, the number of subjective early responses, and the number of times each subject's response of early or late agreed with their objective performance on that particular trial (see Table 5). Non-parametric analysis of these data by fixation disparity category, Brock String response of F/A/B, Brock String response of Figure 2a/2b, and Brock String response of F/M/B (based upon the three aforementioned Bassin Anticipation Timer groups data) showed no significant differences (p>0.05).

INSERT TABLE 5

The correlations, whether positive or negative, were found to be quite low when comparing the specific groups of data: fixation disparity mean, fixation disparity range, Brock String responses (F/A/B), Brock String 1/3's responses (F/M/B), Bassin total error, and Bassin mean error. There did happen to be a high correlation between Bassin total error and Bassin mean error (see Table 6).

INSERT TABLE 6

Discussion:

The primary goal of this study was to determine if a relationship exists between ocular alignment as measured by the standard distance Brock String and fixation disparity as measured by the Mentor O&O B-VAT II. Within the confines of this study, statistical comparisons made between distance Brock String and B-VAT fixation disparity measures do not yield the significant results to conclude that distance Brock String responses accurately represent any one fixation disparity category. The data show that the subjects who saw the strings cross in front (F) of the bead tended to show a mean Eso fixation
disparity, whereas the subjects that saw the strings cross at (A) and behind (B) the bead tended to show a mean Exo fixation disparity, although to a smaller magnitude for the latter group (B).

Interestingly, the only significant difference shown by statistical analysis in the comparison of fixation disparity mean and range by Brock String response (F/A/B) was between the F and A groups. If the distance Brock String is a true representation of fixation disparity, one would expect the group perceiving the strings to cross in front of the bead to be the most Eso and the group perceiving the strings to cross behind the bead to be the most Exo, however this was not found to be the case.

When comparing the fixation disparity ranges of the Brock String (F/A/B) groups, the A group exhibited the smallest mean range, the B group showed a mean range slightly larger, and the F group had the largest mean range. Once again, the only statistically significant relationship among the fixation disparity ranges when analyzed by the Brock String (F/A/B) groups was between the F and A groups. Also, there was no significant correlation found when comparing fixation disparity mean and range to the other Brock String categories of Figure 2a or 2b.

There was a statistically significant difference shown in the comparison of fixation disparity mean and range by the Brock String F/M/B 1/3’s. However, the relatively few number of subjects in the M and B groups is cause to refute the data based upon too small
of a sample size. Therefore, this study showed no basis for the ability to predict a subject's fixation disparity based on their performance with the distance Brock String.

The comparative analysis of the subject's performance on the Bassin Anticipation Timer with their performance on the distance Brock String and fixation disparity test was made to determine if any relationship exists between timing tendencies and oculomotor alignment as tested in this study. No statistically significant relationship was determined between any of the previously stated Brock String or fixation disparity categories and any of the Bassin Anticipation Timer data. Hence, this study showed no capacity to predict a subject's ability to anticipate the occurrence of a dynamic event based upon their performance on the distance Brock String or on their fixation disparity. Therefore, as determined by this study, no assumptions or predictions can be made between a person's performance on the distance Brock String and their timing tendencies (such as swinging too early or late when playing baseball).

The notable number of subjects who perceived a fused section of the distance Brock String was 47 of the total 71 subjects (66%). This may warrant the need to expand the standard instruction set when using the distance Brock String as a testing or training procedure; not only should the patients be asked if they perceive a fused section of the string, but also if they can describe the location of the bead within that fused portion of string.
Further research related to this study could include the addition of phoria measurements to give further information about oculomotor alignment tendencies and their relationship to timing and spatial judgment. A spatial judgment task could be added to determine any correlation between spatial localization and oculomotor alignment. Timing tendencies could also be further evaluated by using a more dynamic reactive timing task than the Bassin Anticipation Timer. Testing of saccadic eye movements may have been a beneficial screener for the patients who participated in this study. Proper eye movements are essential in anticipating a dynamic event. It would benefit further research to expand the number of subjects participating in the project. A larger sample size may give more conclusive data on the relationships shown between those subjects who did or did not see a fused section of the distance Brock String. Even though this study found no significant relationships between subjects perceiving the string as either Figure 2a or 2b, the high frequency of occurrence of those reporting the fused section of string gives basis for more research to determine any possible correlations.
Acknowledgements

The authors would like to thank Dr. Alan Reichow and Dr. Bradley Coffey for their support, expertise, and guidance throughout this project. We would also like to thank Michelle Lewis, Dan Hock, Dan Perdue, and Greg Chin for their assistance in data collection, and Lance Mintle for his help in creating the figures. Thanks also to those individuals who took time out of their busy schedules to participate in this study.
Appendix 1

KEY FOR TESTING PROTOCOLS

E: Evaluates: definition of the primary ability evaluated by the test
I: Instrumentation
TD: Test Distance
IL: Illumination
P: Position of subjects
CF: Critical factors; to be observed in administering the test
IS: Instructional set; IS should be presented nearly verbatim to maintain consistent test standards.
R: Recording; how to record data, what data should be recorded
N: Norm performance level
FIXATION DISPARITY

Brock String Protocol

E:  Vergence posture relative to a point in real space.

I:  Brock String consists of a long string (approximately 15 ft.) thin enough to contain three 3/4" wooden beads that can be moved along the string as necessary.

TD:  10 feet (target bead)

IL:  Standard room (34-79 footcandles)

P:  Standing comfortably with eyes in primary position of gaze.

CF:  String should be held against bridge of nose with index finger. String must be taut at all times. Record data from subject’s response within 2-3 seconds of viewing the target bead.

IS:  “Hold this string against the bridge of your nose and pull the string so it’s tight. Look out directly at the bead (at 10 feet). Do you see two strings? (Yes) Where exactly do the strings cross? Do they cross in front of the bead, right at the bead, or behind the bead?”

R:  For any response indicating vergence is postured at the target bead, record an A (at); closer to the subject than the bead, record an F (front); behind the target bead, record a B (behind).
FIXATION DISPARITY

Mentor O&O B-VAT II Protocol

E: Lateral ocular alignment while viewing under binocular conditions.

I: Mentor O&O B-VAT II with binocular vision testing system accessories. Monitor screen with central binocular lock only, and no corner binocular locks.

TD: 3 meters

IL: Standard room (34-79 footcandles)

P: Standing comfortably aligned with test stimuli wearing B-VAT glasses

CF: Head held vertical and frontal to the monitor screen and spectacles properly adjusted. No head movement may be allowed.

IS: “Please position these special glasses over your eyes. What do you see on the screen?” If vertical line is missing or if “2”, “A” and “3” are missing, suppression is present.

“Look at the vertical line in the center of the screen. Is it stable or is there movement to it? Is the vertical line directly over the line A or is it oriented to the right or left of the top point of the A?” If misalignment exists, adjust position of the vertical line until alignment is reported, by saying, “Please tell me when the vertical line is directly aligned over the top point of the A.”

R: Record presence or absence of suppression, stability, direction, and magnitude of fixation disparity.

N: To be determined
ANTICIPATION TIMING

Bassin Anticipation Timer (Eye-Hand) Protocol

E: Objective (examiner) and subjective (subject) assessment of visual motor anticipation timing based upon visually-guided eye-hand motor response to a stimulated moving target.

TD: Top of rail 86 cm above floor. Subject’s toes one foot behind response end of rail.

IL: Dim room (6-7 footcandles)

P: Standing relaxed on imaginary axis of rail

CF: 1.5 second stimulus delay. Instrument panel not visible to subject.

C: No criterion, normative data analysis.

IS: “Please stand facing the rail with your toes up to the line on the floor at the end of the rail and hold the hand-held trigger in your preferred hand. Initially a white light nearest me will light up and remain lit for 1.5 seconds. Following that a series of red lights, beginning with the one closest to me, will turn on, then off, and continue in that sequence one at a time down the rail. You will perceive motion as if the light were traveling down the rail towards you. Your task is to press the button at the exact moment the last light turns on. After you have pressed the button I will ask you if you thought you pressed the button too early, right on, or too late. You will be tested three times at each of five different speeds. I will let you know when the speed will be increased. You will have one practice trial.

R: Record the digital readout, whether the subject was early (E), on (O), or late (L), and subjective response of early (E), on (O), or late (L). Three sets of readings will be taken for each of the five speeds (1, 5, 10, 20, 30 mph).

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FIXATION DISPARITY

Subjective Brock String

“Looking at the bead, does there appear to be an area where the strings seem to be fused, as in diagram 2a, or do they cross at exactly one point, as in diagram 2b?”

(Demonstrate using Figure 2)

If string is “fused” as in Diagram 2a, then, “Please draw a small bead where it appears to be on Diagram 2a.”
Schematic representation of the theoretical basis for the perception of a fused section of the Brock String, based upon the lines of sight and Panum’s fusional areas. The area of intersection between the two lines of sight is the range of possible fusion.

- Line of sight
- Limits of Panum’s fusional area
- Range of possible fusion
Schematic representation of possible perceptual outcomes when viewing the Brock String. Figure was shown to subjects to structure Brock String responses.
<table>
<thead>
<tr>
<th>Brock String Response</th>
<th>Count</th>
<th>F.D. Mean (arc min.)</th>
<th>F.D. Range (arc min.)</th>
<th>Bassin Total Error (sec.)</th>
<th>Bassin Mean Error (sec.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Mean</td>
<td>Std. Dev.</td>
</tr>
<tr>
<td>Front</td>
<td>28</td>
<td>0.161</td>
<td>0.913</td>
<td>1.536</td>
<td>1.374</td>
</tr>
<tr>
<td>At</td>
<td>31</td>
<td>-0.516</td>
<td>1.084</td>
<td>0.903</td>
<td>0.831</td>
</tr>
<tr>
<td>Back</td>
<td>12</td>
<td>-0.292</td>
<td>0.838</td>
<td>0.917</td>
<td>0.289</td>
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<td>Figure 2*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At</td>
<td>47</td>
<td>-0.287</td>
<td>1.183</td>
<td>1.298</td>
<td>1.159</td>
</tr>
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<td>0.558</td>
<td>0.875</td>
<td>0.797</td>
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<td>Brock 1/3rds*</td>
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<td></td>
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<tr>
<td>Front</td>
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<td>1.100</td>
<td>1.132</td>
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<td>2.074</td>
</tr>
<tr>
<td>Back</td>
<td>3</td>
<td>-0.167</td>
<td>1.155</td>
<td>1.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

* Subject group headings are defined in the results section

F.D. Mean (arc min.) = Fixation Disparity in minutes of arc
Table 2
Bassin Anticipation Timer Data by Fixation Disparity Category

<table>
<thead>
<tr>
<th>F.D. Category</th>
<th>Count</th>
<th>Bassin Total Error (seconds)</th>
<th>Bassin Mean Error (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Exophoric</td>
<td>29</td>
<td>0.290</td>
<td>0.627</td>
</tr>
<tr>
<td>Orthophoric</td>
<td>17</td>
<td>0.517</td>
<td>0.551</td>
</tr>
<tr>
<td>Esophoric</td>
<td>25</td>
<td>0.485</td>
<td>0.688</td>
</tr>
</tbody>
</table>

* Subject group headings are defined in the results section

F.D. = Fixation Disparity
Table 3

Observed Frequency by Brock String Response

<table>
<thead>
<tr>
<th>Brock String Response*</th>
<th>Fixation Disparity Category</th>
<th>Exophoric</th>
<th>Orthophoric</th>
<th>Esophoric</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td></td>
<td>9</td>
<td>5</td>
<td>14</td>
<td>28</td>
</tr>
<tr>
<td>At</td>
<td></td>
<td>14</td>
<td>11</td>
<td>6</td>
<td>31</td>
</tr>
<tr>
<td>Back</td>
<td></td>
<td>6</td>
<td>1</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>28</td>
<td>22</td>
<td>25</td>
<td>71</td>
</tr>
<tr>
<td>Figure 2*</td>
<td></td>
<td>21</td>
<td>8</td>
<td>18</td>
<td>47</td>
</tr>
<tr>
<td>At</td>
<td></td>
<td>8</td>
<td>9</td>
<td>7</td>
<td>24</td>
</tr>
<tr>
<td>Back</td>
<td></td>
<td>8</td>
<td>9</td>
<td>7</td>
<td>24</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>30</td>
<td>17</td>
<td>25</td>
<td>71</td>
</tr>
<tr>
<td>Brock 1/3rds*</td>
<td></td>
<td>20</td>
<td>7</td>
<td>11</td>
<td>38</td>
</tr>
<tr>
<td>Front</td>
<td></td>
<td>20</td>
<td>7</td>
<td>11</td>
<td>38</td>
</tr>
<tr>
<td>Middle</td>
<td></td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Back</td>
<td></td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>21</td>
<td>8</td>
<td>16</td>
<td>47</td>
</tr>
</tbody>
</table>

* Subject group headings are defined in the results section
Table 4

Bassin Anticipation Timer Response by Fixation Disparity Category and Brock String Response

<table>
<thead>
<tr>
<th>F.D. Category*</th>
<th>Count</th>
<th># Early Objectively</th>
<th># Early Subjectively</th>
<th># Responses Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Standard Deviation</td>
<td>Mean</td>
</tr>
<tr>
<td>Exophoric</td>
<td>29</td>
<td>5.862</td>
<td>4.077</td>
<td>4.345</td>
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<tr>
<td>Orthophoric</td>
<td>17</td>
<td>4.824</td>
<td>2.506</td>
<td>4.000</td>
</tr>
<tr>
<td>B.S. Response*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front</td>
<td>28</td>
<td>4.821</td>
<td>3.104</td>
<td>4.536</td>
</tr>
<tr>
<td>At</td>
<td>31</td>
<td>5.516</td>
<td>3.385</td>
<td>3.710</td>
</tr>
<tr>
<td>Back</td>
<td>12</td>
<td>5.500</td>
<td>4.719</td>
<td>5.500</td>
</tr>
<tr>
<td>Figure 2*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At</td>
<td>47</td>
<td>5.489</td>
<td>3.729</td>
<td>4.213</td>
</tr>
<tr>
<td>Brock 1/3rds*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front</td>
<td>38</td>
<td>5.447</td>
<td>3.944</td>
<td>4.026</td>
</tr>
<tr>
<td>At</td>
<td>6</td>
<td>5.500</td>
<td>3.391</td>
<td>4.833</td>
</tr>
<tr>
<td>Back</td>
<td>3</td>
<td>6.000</td>
<td>1.732</td>
<td>5.333</td>
</tr>
</tbody>
</table>

* Subject group headings are defined in the results section.
### Table 5

**Correlation Matrix**

<table>
<thead>
<tr>
<th></th>
<th>Fixation Disparity Mean</th>
<th>Fixation Disparity Range</th>
<th>Brock F/A/B</th>
<th>Brock 1/3rds</th>
<th>Bassin Total</th>
<th>Bassin Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bassin Mean</td>
<td>0.075</td>
<td>-0.028</td>
<td>0.120</td>
<td>-0.130</td>
<td>0.993</td>
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</tr>
<tr>
<td>Bassin Range</td>
<td>0.055</td>
<td>0.005</td>
<td>0.127</td>
<td>-0.121</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Brock 1/3rds</td>
<td>0.289</td>
<td>0.179</td>
<td>-0.018</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brock F/A/B</td>
<td>0.276</td>
<td>0.333</td>
<td>1.000</td>
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</tr>
<tr>
<td>F.D. Range</td>
<td>0.080</td>
<td>1.000</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>F.D. Mean</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

F.D. = Fixation Disparity  
F/A/B = Front/ At/ Back
References


