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Thesis

Development of a Clinical Stereofield Test

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Grade A

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Abstract

Several new stereoscope test cards were designed for this study to measure the maximum magnitude of the phenomenal stereofield. The magnitude of the stereofield was then compared to stereoacuity measurements. Using a Brewster stereoscope, 50 volunteer subjects viewed the test cards with each of three different instruction sets.

A significant difference was found between two of the instruction sets and the size of the stereofield elicited. No correlation was found between stereoacuity and the perceived limits of the stereofield.

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Development of a Clinical Stereofield Test

Introduction

The scientific study of stereoscopic visual perception was initiated by the discovery of the stereoscope by Wheatstone in 1838. Since that time, many researchers have investigated the neurological, physiological, and psychophysical aspects of stereoscopic vision.

This study of stereoscopic vision has both clinical and theoretical implications. It was designed to determine the clinical feasibility of measuring the maximum magnitude of the stereofield using targets designed for a Brewster style stereoscope under three different sets of instructions. The study was further designed to determine if stereoacuity (stereopsis) as measured by the minimum parallactic angle threshold is related to the physical magnitude of the maximum parallactic angle for single stereo-unification (or stereo-fusion).

Theoretically, this study provides a means of experimentally testing several notions and operational definitions advanced by Professor Haynes as well as other workers in their attempt to adequately define various stereoscopic behaviors.

Before proceeding with a review of the relevant literature for this specific study, a review of the terms used throughout this study is required. These definitions are in accord with most published literature and include additionally the postulated performance areas by Haynes for an adequate clinical description of stereoscopic behavior.

Stereo-response or **stereoscopic behavior.** These are general or generic terms indicating a response to the stereo stimulus variable(s) of crossed and/or uncrossed disparity measured at the retinal level or at the target plane of the stereo display. The term stereopsis is sometimes used also in this generic way.

Stereo-display. Physical description of the stereo stimulus elements [disparity] in the natural environment or in simulated stereoscope displays, or with anaglyph, polaroid printed or projected halfview targets.

Stereoacuity or **stereopsis**. Psychophysical or psychometric threshold measurement of minimum parallactic angle either centrally or peripherally.

Stereofield. Several theoretical dimensions are postulated to define this term. The stereofield is a geometric construct used to describe the phenomenal appearance of any set of stereoscopically localized items resulting from the disparate elements within a given stereo-display as a function of distance, target features, instructions, fixation conditions, stereoscopic response history and the physiological limits for stereo unification of disparate objects. The physiological limit to the stereofield may be operationally described as the maximum parallactic angle for the test conditions imposed.

The perceived stereofield may be further described as incomplete, partial or fractured. *Incomplete* or *partial* response indicates that part of the stereofield is subjectively reported as double while other objects within the stereo-display are reported as single. *Fractured* indicates that one or more small objects are reported diplopic while other objects both proximally and distally are reported as single.

Spatial Summation. A theoretical construct used to describe the fraction of the total stereo information available which can be assimilated or responded with per fixation or per unit of time when fixation is held constant.

Temporal Summation. The continuous transformation of the stereo perception over time resulting from successive fixations throughout the stereodisplay as more stereo information is gathered. Thus, spatial summation is integrated over time. The stereofield is assumed to be organized by these two processes.

Stereolocalization. The term has two separate uses. [i] Expected phenomenal locus of a given object based on calculations using interpupillary distance, magnitude of target disparity and viewing distance. [ii] Quantitative or qualitative measurement of the perceived locus of objects relative to the stereo-display plane, the calculated position, a comparison object or to the observer.

Stereo-mobilization time. Reaction time is measured by the elapsed time after presentation of the stereo stimulus to first observable stereo response and response time is measured by the time required to meet a specific criteria.

Panum's area. Three distinct uses of the term are common. [i] Operationally, the area is measured by the geometric transposition to the retina of the results of measuring the *empirical horopter* or by performing a physiological diplopia experiment. These results may be recorded in degrees or meter angles. [ii] Panum's area is used as a theoretical construct to suggest the limits of disparity in various neuro-physiological models involving correspondence models. [iii] Panum's area is used to order electro-physiological measurement of receptive fields and related study. Great care has to be employed to avoid circular reasoning with this term.

As of this date, we are not aware of any relevant clinical studies that were designed to quantify the linear extent of the stereofield when fixation is not limited. The nearest study to measuring the extent of the stereofield with scanning fixations was by Bleything[1] who studied stereolocalization with ring float. Landmark research, pertaining to horopter studies and measures of Panum's area where fixation is held constant, is summarized briefly below.

The neurological basis of stereopsis was hypothesized by Ogle[2] in 1952. He theorized that the existence of disparity limits provided evidence that there were neuro-anatomical limitations in the visual cortex. Hubel and Wiesel[3], in their neuro-anatomical research using cats, found that there are areas in space specific for each neuron in the visual cortex. They called these areas receptive fields. Each binocularly activated neuron was shown to have two receptive fields, one for each eye. The majority of these cells have receptive fields in slightly different locations in space.

This slight disparity in the receptive fields provide one of the physiological correlates for stereoscopic depth perception. Later, Barlow, Blakemore, and Pettigrew[4] showed that specific neurons, located in areas 18 and 19 in the visual cortex, respond to different disparities. These disparity detecting neurons are thought to be responsible for fine and gross stereopsis. In order for an optimal response to occur, the stimulus must be correctly oriented and match the set disparity of the neuron. These neurons require simultaneous input from both eyes. The result of this binocular input is the encoding of information used to perceive stereoscopic depth. In summarizing the literature, Adler[5] concurs with the above neurological basis of stereopsis.

The clinically related studies of stereoscopic depth perception by Brock[6] focused on the phenomenal aspects of vision. This theoretical approach describes the perception of depth by geometrically organizing visual space into a construct known as a horopter. Brock defined the empirical horopter surface as the sum of certain points in space whose images fall on geometrically corresponding retinal points. Stereoscopic fusion is possible in a limited area in space surrounding the horopter surface. Within certain disparity limits, the brain is capable of unifying the two retinal images into a single perception where the perceived objects are seen at different distances from each other by the observer.

Using the theoretical horopter concept, Blakemore[7] attempted to quantify the limits of both crossed and uncrossed disparity. Blakemore defined crossed or convergent disparity as objects inside the Vieth-Muller circle and uncrossed or divergent disparity as objects falling outside the Vieth-Muller circle. The convergent disparity limit , measured in degrees from fixation, was found to be 4-7 degrees and the divergent disparity limit was 9-12 degrees.

The absolute limit of disparity has been studied in a quantitative and qualitative manner by Ogle[8]. He found that subjective depth is related quantitatively to the disparity between images of the two eyes. Limiting disparity for a patent stereoscopic experience of depth at the fovea is about 20 minutes of arc and 90 minutes of arc for a peripheral angle of 6 arc degrees. Subjective depth or visual spatial localization is the cumulative total of primary stereoscopic depth and secondary learned associations between objects and images. Ogle[9] defined three levels of depth perception. The first level corresponds to an increase in disparity while within Panum's area. The resulting image is single and stereoscopic. A second level of depth perception is found when the object's disparity falls outside of Panum's area. By definition, the object is now diplopic, but depth perception can still be appreciated. In the third level, the disparity increases to a point where binocular stereoscopic depth perception is lost. This represents the outside limits of disparity. Ogle[10] suggested that since stereoscopic depth exists with images that are seen double, fusion is not necessarily needed to perceive stereoscopic depth.

There are several theoretical approaches to explain disparity and its effect on stereoscopic responses. When slightly different (or disparate) areas of the two retinas are stimulated, the perception may exhibit characteristics such as increased depth discrimination. Disparity that is temporal to the center of the fovea results in an image that is perceived closer and is defined as *crossed disparity*. If the disparity is nasal to the center of the fovea, the image is seen further away and called *uncrossed disparity.*

Within a certain limited area, known as Panum's area, disparity can be increased or decreased while phenomenal "oneness" is reported. Outside of this area, diplopia [or suppression behavior] results and appreciation of stereoscopic depth perception decreases or ceases depending on the stimulus.

To summarize, stereoscopic perception of three dimensional visual space results from responses to lateral disparity of objects located proximally and distally from the fixation point.

According to Haynes[11] stereoscopic behavior is composed of a number of essentially independent performance parameters. These can be conceived as relatively independent discriminatory stereoscopic skills in response to crossed and uncrossed disparity in the proximal stimulus. These postulated parameters [or functions] can be distinguished by theoretical analysis, statistical analysis, and by operationally defined methods of measurement both at the clinical and laboratory level.

Haynes contends that a complete clinical and behavioral description of stereo discriminatory behavior would include: [i] measuring central and peripheral stereoacuity, [ii] measuring the accuracy of stereolocalization by comparing the perceived with the mathematical expected locus or position, [iii] measuring the maximum extent or volume of the stereofield under steady and searching fixation conditions, [iv] determining the presence or absence of clinically significant amounts of aniseikonia and [v] determining the interaction of stereoscopic behaviors with both motor performance and non-stereoscopic depth discriminations arising from the so called "monocular clues." The latter are better described as non-stereoscopic stimuli since binocular viewing is the rule rather than the exception.

Under normal seeing conditions and under many training conditions, stereo responses occur with scanning eye movements. With scanning eye movements, the phenomenal stereofield responses are probably not predictable based (entirely) on empirical measurements of Panum's areas or on geometrical predictions based on horopter models where fixation is held constant.

By contrast to this view, Griffin[12] states that "the level of stereopsis can be used to determine the level of binocular status." Further, he suggests that "if stereopsis is good, then the binocular status is good, though the opposite cannot be said with certainty." We are not aware of any statistical studies to support this broad assertion. And, such an assertion is in disagreement with the generally recognized fact that peripheral stereoacuity does not correlate highly with central stereoacuity.

Problem:

Clinically, especially for VT cases, it is important to describe normal from abnormal stereo-behavior. The primary objective of this study was to evaluate a new set of stereoscope test cards designed to measure the extent of the phenomenal stereofield under three different sets of instructions. The study was further designed to compare central stereoacuity to the stereofield measurements.

Comparison of central stereoacuity measurements with the stereofield results provides data of theoretical importance for clinically describing normal and abnormal stereoscopic performances. If stereoacuity (the minimum parallactic angle) is closely related to the stereofield results (maximum parallactic angle) then no further clinical testing of stereoscopic behavior would be required. The extensive theoretical discussion outlined above under the discussion of the stereofield would be of little clinical importance. However, if a low statistical relationship were found, then the clinical importance of the Haynes performance model for stereoscopic behavior would be supported.

While this study was limited to analyzing the results of the stereofield test, visual acuity, vertical and lateral phorias, and vertical and lateral fixation disparity tests were taken for future analysis.

Design of Study

Four stereoscope cards (3 test and 1 demonstration) were designed for this study using an Apple Macintosh computer and the MacPaint program. They were printed on a Laser Writer printer.

The cards were designed to test crossed and uncrossed disparity simultaneously. The boxes on the cards increase in both crossed and uncrossed disparity as you proceed up each card from the start box. The disparity also increases as you proceed in the card series from A to C. The test cards are shown in Figure 1. Table 1 displays the target disparities for each of the three test cards.

Preliminary testing, prior to testing the stereofield with the experimental targets, included the Keystone Signboard Dot Discrimination Test, cards DB-3D and DB-2D, Multi-stereo test- music stand series; and specially designed lateral and vertical phoria and lateral and vertical fixation disparity cards. The latter tests are shown in Figures 2 & 3.

Demonstration Test. After the preliminary testing, each subject was asked to view the monocular demonstration stereofield card #1. Each subject was asked to look at the start box and report how many boxes they saw, one or two. Successively, the same instruction was given as the subject fixated each box from 1 to 4 and then from box A to D. When the correct response was obtained for each of the 8 test boxes, then the stereofield test was performed.

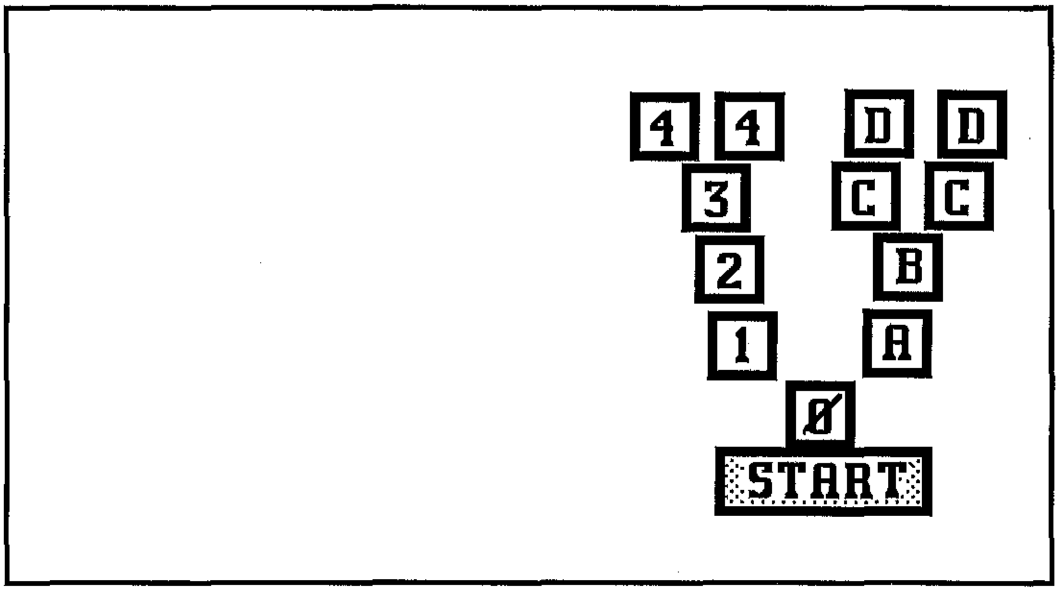
Instructional Set One (IS#1). Each subject was asked to look at the start box and report if they saw one or two boxes. If one box was reported, they were asked to look consecutively at boxes labeled 0,1,2,3,4; then at A,B,C, and D and report how many boxes they saw with each fixation.

Instructional Set Two (IS#2). Each subject was asked to look at [fixate] box A and report how many box #1's they saw, one or two. This same instruction was given for boxes B and #2, C and #3, D and #4. Then, each subject was asked to fixate box #1 and report how many box A's they saw, one or two. This same instruction was given for boxes #2 and B, #3 and C, #4 and D.

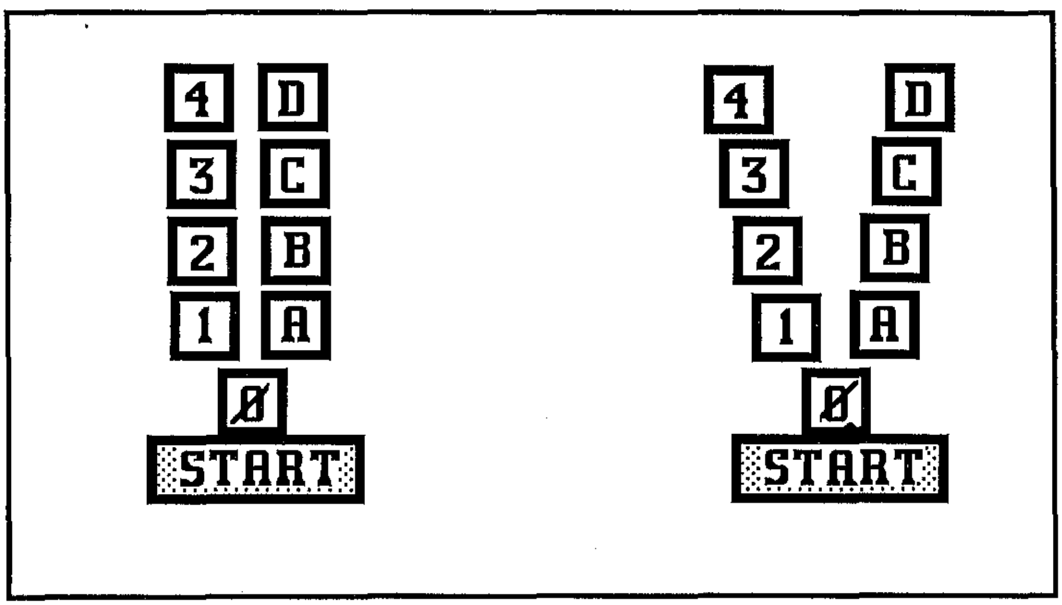
Instructional Set Three (IS#3). Each subject was asked to look back and forth between boxes A and #1 and report how many boxes they saw two, three, or four. The procedure was repeated for box sets B and #2, C and #3 and D and #4. The testing continued in the same manner on cards B and C.

All testing was done in a room with standard overhead lighting. Equipment consisted of a Keystone 95 O.C. Brewster type stereoscope with internal lighting. A shaft setting of 1.25D to optically simulate an 80cm distance in physical space was used for the stereofield tests, for the lateral phoria, lateral fixation disparity, vertical phoria and fixation disparity and the Multi-stereo test. Near interpupillary distance [PD] was measured using a penlight and millimeter rule.

FIGURE 1A. STEREOFIELD TEST SLIDES

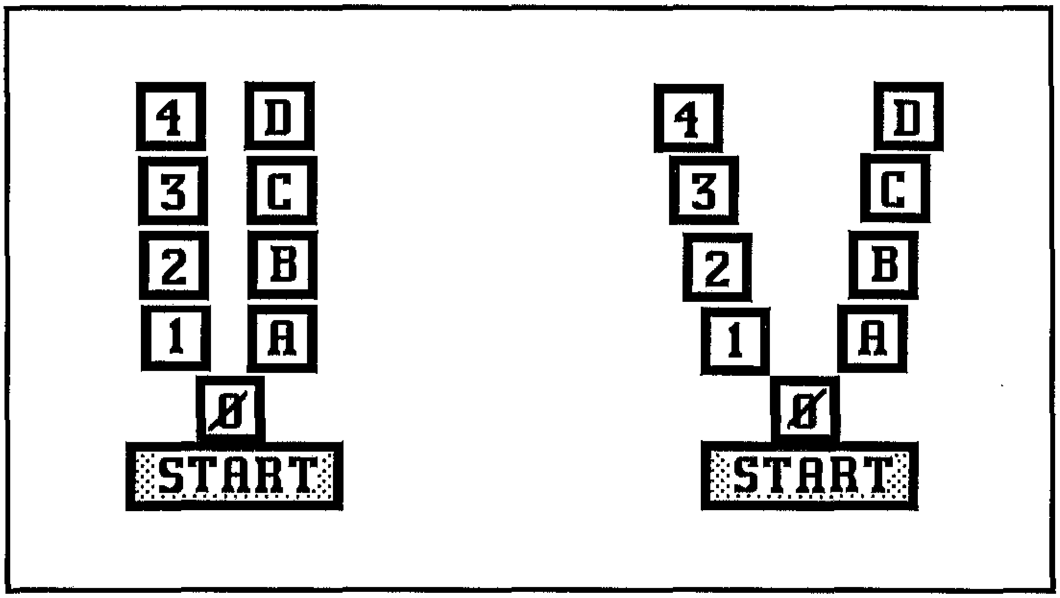


Stereofield demontration slide. StFd-Demo

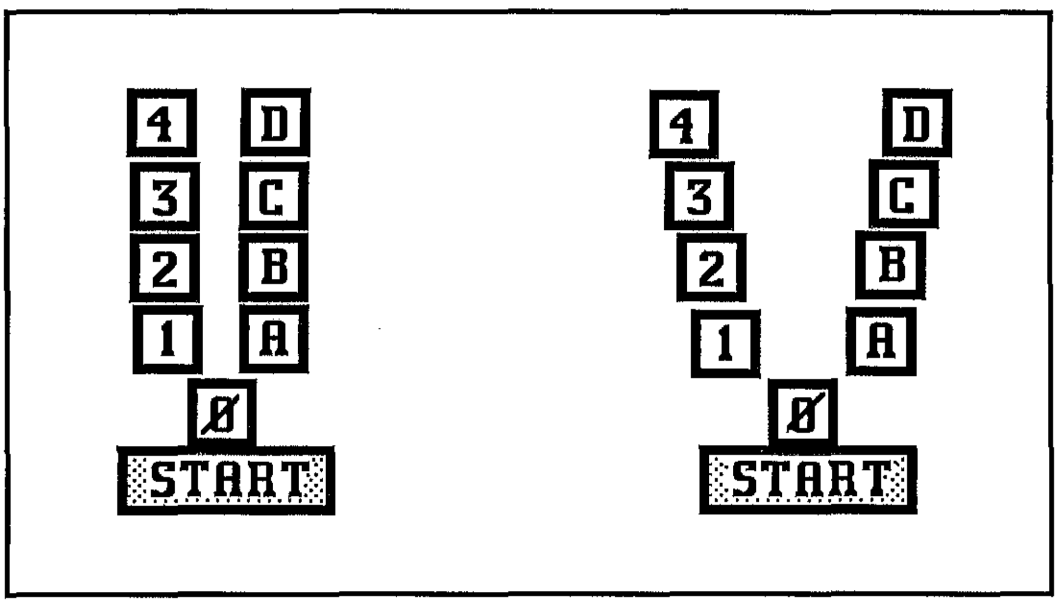


StFd-A. First of set of three stereofield halfview tests.

FIGURE 1B. STEREOFIELD TEST



StFd-B. Second of three Stereofield halfview test targets.



StFd-C. Third in series of three Stereofield test targets.

TABLE 1. PHYSICAL DESCRIPTION OF STEREOFIELD CARDS

TABLE 1. STEREOFIELD TEST CARD DISPARITIES IN PRISM DIOPTERS									
St.FD-A				St.Fd-B			St.Fd-C		
Crossed	Tar. Sep.	mm	Δ	Tar. Sep.	mm	Δ	Tar. Sep.	mm	Δ
Start/0	77			76			77		
1	76.5	1.5	0.94	74	2.0	1.3	73.5	3.5	2.19
2	74	3	1.88	71.5	4.5	2.8	72	5	3.13
3	72.5	4.5	2.81	70	6.0	3.8	70	7	4.38
4	71	6	3.75	68.5	7.5	4.7	68.5	8.5	5.31
Uncrossed									
A	77.5	1.5	0.94	78	2.0	1.3	80	3	1.88
B	79	2	1.25	79.5	4.5	2.8	81.5	4.5	2.81
C	81	4	2.5	81	5.0	3.1	83	6	3.75
D	83	6	3.75	83	7.0	4.4	84.5	7.5	4.69
Combined	Δ[1-A]	1	0.63		4	2.5		6.5	4.06
Crossed and	Δ[2-B]	5	3.13		8	5.0		9.5	5.94
Uncrossed	Δ[3-C]	8.5	5.31		11	6.9		13	8.13
Disparity	Δ[4-D]	12	7.5		14.5	9.1		16	10
	ND		8			10.0			12

FIGURE 2. FRACTIONAL DISSOCIATION LATERAL PHORIA.

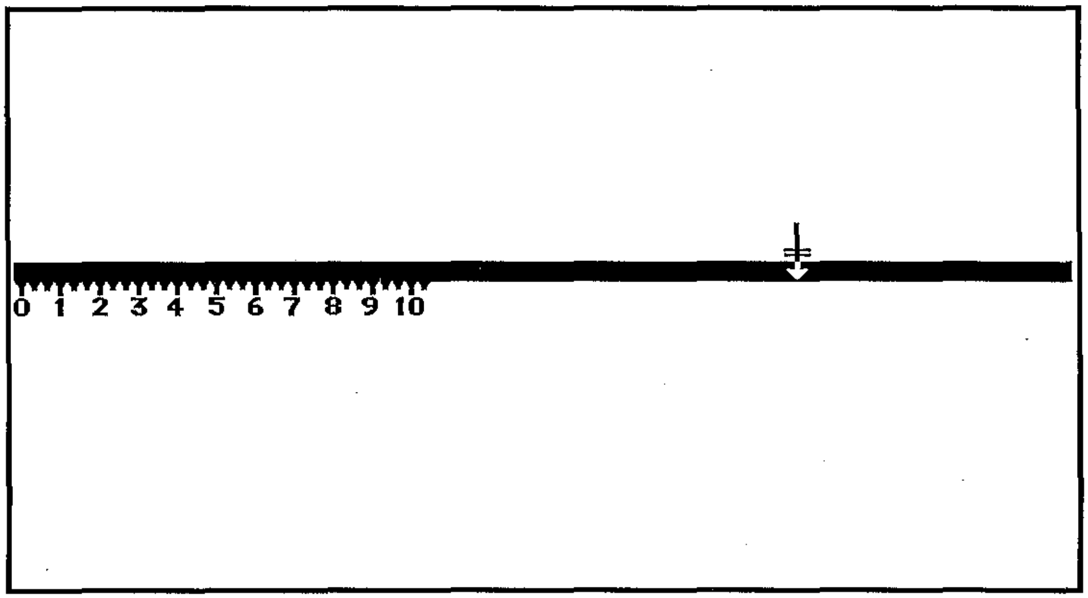
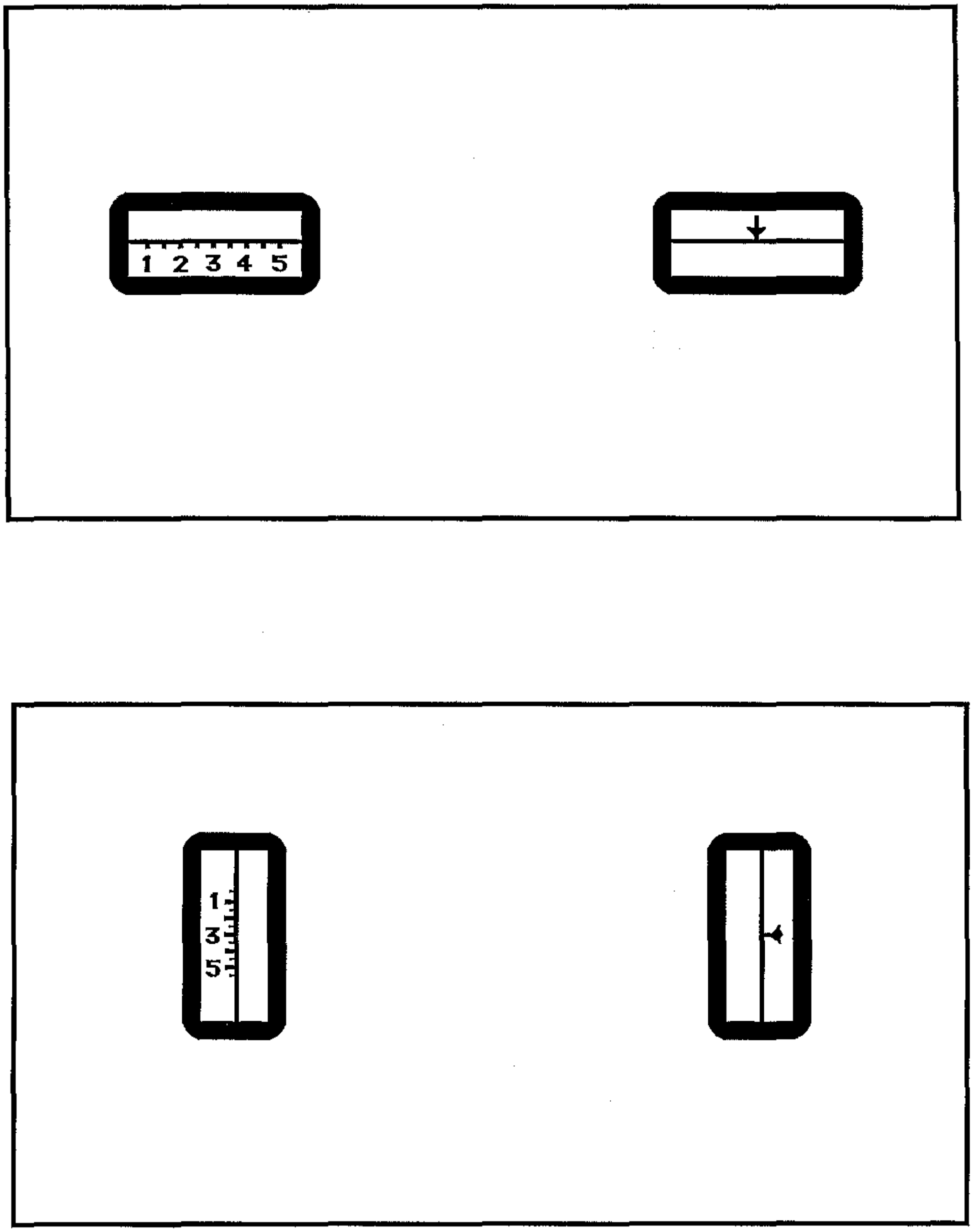


FIGURE 3. LATERAL AND VERTICAL FIXATION DISPARITY FOR 1.25 DIOPTER SHAFT SETTING.



Subject responses were recorded on a special form displayed in Figure 4. The blanks were checked according to the subject's responses to make recording as constant as possible. Space was provided for notes and comments.

Figure 4 (Recording Sheet)

DEVELOPMENT OF A CLINICAL STEREOFIELD TEST

NAME:________________ AGE:______ SEX: M F Near pd:______

Correction: none spectacle contacts

Signboard Dot: OD:________ OS:________

Lateral Phoria:________________ Vertical Phoria:________________

Vertical F.D.:__________ Hyper Hypo Lateral F.D.:__________ Ex Es

Multistereo Test:____________________ Start Time:______

	Slide A		Slide B		Slide C	
	One	Two	One	Two	One	Two
Start						
O						
1						
2						
3						
4						
A						
B						
C						
D						
A-1						
B-2						
C-3						
D-4						
1-A						
2-B						
3-C						
4-D						

	(2)	(3)	(4)	(2)	(3)	(4)	(2)	(3)	(4)
A & 1									
B & 2									
C & 3									
D & 4									

End Time:________________

COMMENTS:

Results

Fifty volunteer college students, thirteen females and 37 males served as subjects. Ages ranged from 21 to 35 with a mean of 26 years and a standard deviation of 3.5 years. Eighteen wore no lens correction, 19 wore spectacles and 13 wore contact lenses.

The results for the three stereofield instructional sets for each of the three stereofield targets were analyzed independently and then IS#2 and IS#3 were compared on each of the three cards to determine the effect of the two different fixation instructions. Limits for the extent of the stereofield for crossed, uncrossed and the combined crossed and uncrossed disparity were defined when three or more consecutive diplopic responses were obtained on any one test card or across two. The least disparity for the three consecutive diplopia findings was recorded as the limit of the stereofield. Statistical significance for analysis purposes was set at the five percent [5%] confidence level [p = .05, two-tailed].

Subject responses on each of the three test cards varied with the three instructional sets. The first instructional set (IS#1) produced few diplopia responses. This indicated that most subjects could resolve the maximum disparity, both crossed and uncrossed, on each test card with a simple fixation instruction and question about the fixated object. Card A resulted in one diplopia response [1/50], card B produced two [2/50] and card C produced four [4/50] diplopic responses.

With instructional set two (IS#2), fixation was limited and the maximum disparity limits of the subjects varied with each card's target disparity and the subject's PD. The physical differences in target disparity for each test card are shown in Table 1. Each subject's individual disparity limits were calculated by dividing the target disparity by the subject's estimated far PD in centimeters. This was done by adding 3mm to all near PD measurements. This calculation records disparity in meter angles [MA].

With instructional set three (IS#3), fixation was not limited to steady fixation. Subjects were instructed to look back and forth between each pair of boxes and to report the number of boxes seen. Disparity for individual subjects were calculated as described above for IS#2.

A summary of the number of diplopic [D] and no diplopic [ND] responses to the three instructional sets is shown in Table 2 for each of the three test targets. The differences between instructions and crossed and uncrossed conditions are apparent. Individual diplopic responses are described in the paragraphs to follow. Summary indicates one or more diplopia responses per condition.

On card A: IS#1, 49 subjects reported no diplopia, 1 reported diplopia. IS#2: 41 subjects reported diplopia, 9 reported no diplopia. IS#3: 39 subjects reported diplopia, 11 reported no diplopia.

TABLE 2. SUMMARY OF DIPLOPIC RESPONSES

STEREOFIELD SUMMARY FOR TARGETS A,B & C.									
CONDITIONS	1a	1b	1c	2a	2b	2c	3a	3b	3c
No Diplopia [ND]	49	9	11	48	4	8	46	2	6
Diplopia [D]	1	41	39	2	46	42	4	48	44
Crossed		3			3			2	
Uncrossed		38			46			46	

Table 2. Summary of subject responses by target and by instruction. Note the disproportionate number of diplopic responses to uncrrossed disparity at the limits.

On card B: IS#1, 48 subjects reported no diplopia, 2 reported diplopia. IS#2: 46 subjects reported diplopia, 4 reported no diplopia. IS#3: 42 subjects reported diplopia, 8 reported no diplopia.

On card C: IS#1, 46 subjects reported diplopia, 4 reported no diplopia. IS#2: 48 subjects reported diplopia, 2 reported no diplopia. IS#3: 44 subjects reported diplopia, 6 reported no diplopia.

Table 3 displays the frequency distribution of the extent of the stereofield as defined by IS#3 for each of the three test cards using the 3 successive diplopia criteria described above.

Graph 1 displays the mean, range and standard deviation for the limits for the stereofield for each subject as derived from measurements obtained for three successive diplopic responses for IS#3. Linear distances were obtained from disparity values calculated in meter angles.

Graph 2 shows a double frequency distribution plotted from IS#2 and IS#3. A statistical analysis of the difference ofIS#2 and IS#3 was performed by subtracting the results for each subject of IS#2 from the results of IS#. A chi square test of the signs (+ and -) revealed no significant difference for card A and significant differences for cards B and C. (p= .025, p= .001).

Inspection of computer spread sheet rank orders of the results with IS#3, card C with other columns suggested that the effects of variable fixation were more marked with increased levels of target disparity. This hypothesis was tested by algebraicly subtracting the differences in disparity for each subject measured by sets [1c-1b], [2c-2b] and [3c-3b]. The cases were rank ordered using the the 3c data from least to greatest disparity and divided into two halves. Table 4 displays the results of these algebraic differences. The suggested hypothesis was confirmed as the results are statistically significant.

The question of how the minimum parallactic angle (stereoacuity) compares to the maximum parallactic angle (linear extent of the stereofield) was studied by calculating Pearson's coefficient of correlation ratio , which showed no significant correlation (r = -.07). This correlation is no better than chance. This result supports Haynes' theoretical position that the two measures are best viewed as independent variables. Rank order of Multi-stereo Test responses is shown in Table 5.

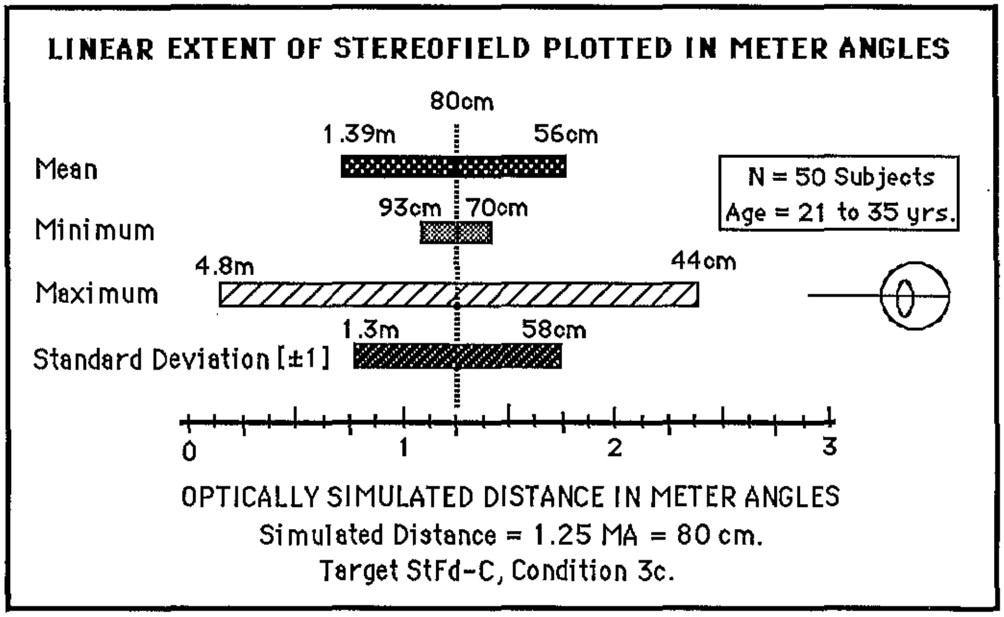
TABLE 3. FREQUENCY DISTRIBUTION OF DIPLOPIA

TABLE 3. FREQUENCY DISTRIBUTION OF SCORES TO DIPLOPIC RESPONSE BY CARD			
Δ Disp.	1C	2C	3C
0-1	1	xxxx	xxxx
2-3	2	2	xxxx
4-5	28	25	24
6-7	8	12	16
8-9	11 [ND]	3	2
10-11	xxxx	8 [ND]	2
12-13	xxxx	xxxx	6 [ND]

xxxx = Stimulus not present on card.

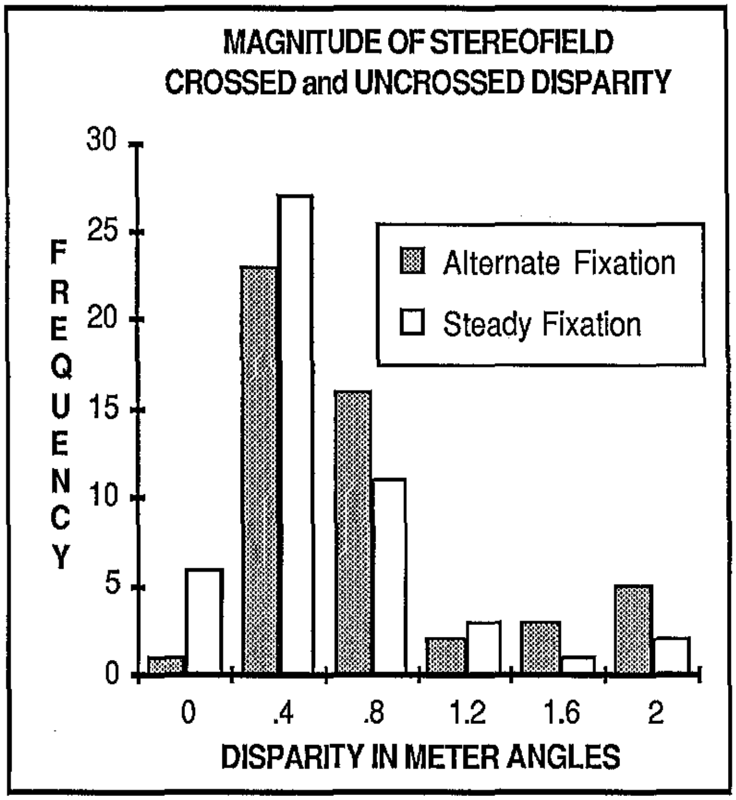
ND = No Diplopic Responses

GRAPH 1.



Graph 1. Linear extent of the stereofield for 50 subjects is plotted in meter angles for a simulated optical distance of 80cm. Mean, range and standard deviation are displayed.

GRAPH 2



Graph 2. Frequency distributions of maximum stereofield measurement on Cards A, B and C using constant and alternate fixation instructions. Fifty volunteer college students served as subjects.

TABLE 4. STEREOFIELD - SIGN DIFFERENCE ANALYSIS

TABLE 4. STEREOFIELD ALGEBRAIC DISTRIBUTION OF SIGN DIFFERENCES					
SORT: Stereofield target 3c in decending rank order.					
Target		St.F-A	St.F-B	St.F-C	
	Δ Sign	Δ[1c-1b]	Δ[2c-2b]	Δ[3c-3b]	Σ [A,B,C]
First 25	Zero = 0	12	17	21	50
Subjects	Plus = +	7	7	1	15
	Minus = -	6	1	3	10
Second 25	Zero = 0	12	13	7	32
Subjects	Plus = +	8	10	18	36
	Minus = -	5	2	0	7
The first 25 subjects with the shallowest stereofields differ from the					
second 25 subjects as a function of increasing crossed and uncrossed					
target disparity. Differences are significant.					

TABLE 5. SORT: MULTI-STEREO TEST - SUMMARY SHEET

	1	2	3	4	5	6	7	8	9	10
1	TABLE 5. SUMMARY SHEET -- SORT MULTI-STEREO TEST, INSTRUCTIONAL SET #3, CARDS A,B, C.									
2							StFd-A	StFd-B	StFd-C	
3	Last Name	Age	Sex	PD	Rx	M-stereo	Σ 1cΔ	Σ 2cΔ	Σ 3cΔ	Σ 3c in MA
4	SOLBRACK	22	M	57	C	1300	0.6	2.5	4.1	0.11
5	KERNIE	22	F	59	C	145	8	10	12	2.03
6	HARTMAN		M	61	S	36	5.3	5	5.9	0.97
7	PATZER	25	F	55	S	36	5.3	6.9	8.1	1.47
8	CHESLOCK	21	F	59	C	25	5.3	9.1	4.1	0.69
9	JAWORSKI	23	M	61	N	22	5.3	5	4.1	0.67
10	ANTONI	30	M	62	S	22	8	10	10	1.61
11	STERNITZKY	29	M	64	S	18	7.5	5	4.1	0.64
12	THOMPSON, B	34	M	63	N	18	5.3	5	4.1	0.65
13	ADAMS	24	M	62	N	18	7.5	6.9	4.1	0.66
14	ICHIMURA	21	F	61	C	18	5.3	5	4.1	0.67
15	BRILL	22	F	58	C	18	5.3	5	5.9	1.02
16	JECH	35	M	56	N	18	5.3	5	5.9	1.05
17	CLAUSS	24	M	59	C	18	8	10	12	2.03
18	RHEE	25	M	64	S	14	7.5	6.9	4.1	0.64
19	TAKAKI	23	M	61	N	14	5.3	5	4.1	0.67
20	COOPER	32	M	61	S	14	5.3	6.9	5.9	0.97
21	KELLY	22	M	59	C	11	5.3	5	4.1	0.69
22	ROBINSON	24	M	62	N	11	5.3	6.9	5.9	0.95
23	CAMPBELL	25	M	62	S	11	7.5	6.9	5.9	0.95
24	ATRIA	22	F	57	S	11	5.3	6.9	5.9	1.04
25	ANKRUM	23	M	65	N	9	8	6.9	5.9	0.91
26	TAKAHASHI	23	M	62	C	7	3.1	5	5.9	0.50
27	PHARRIS	23	M	61	C	7	5.3	5	4.1	0.67
28	BAKER	28	M	66	C	7	7.5	9.1	5.9	0.89
29	STODDARD	28	M	65	C	7	5.3	5	5.9	0.91
30	MARI	23	M	65	N	7	5.3	6.9	5.9	0.91
31	ITO	22	F	59	N	7	8	9.1	10	1.69
32	GIARDINA	28	M	61	S	7	8	10	12	1.97
33	CHIU	23	F	61	N	6	5.3	5	4.1	0.67
34	LEASHER	24	F	62	C	6	3.1	5	4.1	0.50
35	HEISLER	22	M	64	S	6	5.3	5	4.1	0.64
36	BRECKENRIDGE	25	M	62	N	6	5.3	5	4.1	0.66
37	HAYTAYE	25	M	62	S	6	5.3	5	4.1	0.66
38	TUTT	31	M	62	S	6	7.5	6.9	4.1	0.66
39	CLOYD	31	F	61	S	6	5.3	2.5	4.1	0.67
40	BRAUN	25	F	61	S	6	5.3	5	4.1	0.67
41	FRANTA	23	M	61	N	6	5.3	5	4.1	0.67
42	CONNELLY	24	M	60	N	6	5.3	5	4.1	0.68
43	SCHEELE	29	M	60	S	6	5.3	6.9	4.1	0.68
44	HIKIDA	22	F	65	N	6	7.5	5	5.9	0.91
45	GEHLER	29	M	64	S	6	5.3	5	5.9	0.92
46	NORRIS	24	M	62	N	6	7.5	6.9	5.9	0.95
47	KOJIMA	25	M	69	S	6	8	10	12	1.74
48	MCLUNG	29	M	62	S	6	8	10	12	1.94
49	BLARE	27	M	61	N	6	8	10	12	1.97
50	DENENBERG	28	M	63	N	4	5.3	5	4.1	0.65
51	THOMPSON, A	29	F	59	S	4	8	5	4.1	0.69
52	WIERSMA	26	M	65	C	4	5.3	5	5.9	0.91
53	SOESBE	27	M	61	N	4	8	10	8.1	1.33

Discussion

The results of this study demonstrate the influence of instructional set on the perceived stereofield. The subject's responses to the phenomenal stereofield differed with each of the three instructional sets. For example, with the third instructional set, the subject's fixation was not limited and the measured stereofield was the largest. We interpret this behavioral result to indicate that both temporal and spatial summation of the stereoscopic information has been demonstrated.

This last conclusion should be accepted with some caution because the effect might have occurred as a result of learning since the sequence of IS#3 and IS#2 were not randomized or otherwise controlled. This should be done in future experiments. By reversing the order of instructional sets two and three the possibility of learning effects on the organization of the stereofield could be controlled.

The stereofield responses given demonstrate that the organization of the stereofield cannot be predicted solely on a geometrical basis derived from measuring Panum's area. When the effects of unlimited fixation, temporal summation, and spatial summation are included, a much larger stereofield is measured. The phenomenal stereofield is, in many ways, the result of many internal subjective variables. Therefore, the stereofield may be different for each subject or group of subjects.

No correlation was found between stereoacuity and the size of the phenomenal stereofield. This indicates that a stereoacuity measurement alone do not adequately describe or predict subjective stereofield organization.

The data gathered demonstrated that the phenomenal stereofield is more complex than was previously thought. Presently, in clinical settings, stereoacuity is measured. No data is currently available on the subjective volume or organization of the stereofield. This qualitative measurement, combined with some measure of stereomobilization, could give a more complete idea of normal vs. abnormal stereofield organization. The abnormal response then more accurately determines the subject or patient for whom further testing and training would be appropriate.

Suggestions for Improving the Test

This study was designed to measure the extent of the phenomenal stereofield. Six of the subjects did not report diplopia throughout the card series. This indicates that the disparity for the card series should be increased. Also, the cards should be adjusted to have even intervals of disparity. The inadvertant variations shown in Table 1 resulted from not being able to adequately quantify target separations with Mac Paint. The new series Mac Draft, which was not available, will allow precise calibration.

A problem was encountered with the instructional set for the third test condition. The subjects were asked to look back and forth between boxes on the test card and report how many boxes they saw. For some subjects, the instructions were confusing and their responses were unclear. A better instruction would eliminate the use of the word "between" asking the subject to simply look back and forth at the boxes and report how many are seen 2, 3, or 4.

Instead of measuring a near PD, a far PD should be taken since the formula for calculating the predicted stereo-response is based on the far PD.

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