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Comparison of variability in sterio-acuity and apparent fronto-parallel plane judgments

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Abstract

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INTRODUCTION

The purpose of this thesis was to compare variability in performance of two stereoscopic discrimination tasks: a stereo-acuity task in which a subject judges whether a test array is co-planar with a background; and an orientation task, in which a subject determines when a rotating plane of dots is in a fronto-parallel position. The judgement of when a plane rotated around the Y-axis appears to be in the fronto-parallel position is a function of each observer's visual egocentric localization skills, especially when there are no peripheral cues for a frame of reference. In contrast to this, the judgement of when a stimulus moved along the Z-axis appears to be co-planar with an objective fronto-parallel array depends on sensitivity to binocular disparity alone. Since the orientation judgements depend on postural cues (Johnson and Lamb, 1971, and Hegland and Vandenberge, 1973)[1] and a history of relating these to disparity, it was predicted that such judgements would not be as accurate as those depending on disparity cues alone. Therefore, the standard deviation from the plane of reference would be greater for judgements involving the apparent frontal-parallel plane (AFPP) task than for those involving the stereo-acuity task; or in other words the "F" test would be expected to indicate that the overall variance of the stereo-acuity task would be less than that for the AFPP task.

SUBJECTS

The subjects used for this experiment were all young male students of the College of Optometry. The ages of the subjects ranged from twenty-one to twenty-eight. A pre-experimental screening procedure was used in which each had to attain a score of eighty percent or higher on the standard Keystone SI and SII stereoscopic card slides.

APPARATUS

The apparatus was basically a rectangular box, open at the back and left end. On the front side is an opening for the face of the subject. The face is inserted into the box far enough for the shoulders to come into contact with the front surface of the box. This assured that the subject's shoulders are in the same plane as the front of the box, which is in the same parallel plane as the zero setting of target one (i.e. the fronto-parallel plane). The chin is placed in a chin rest and the forehead rests against a forehead stop. This body-head position is maintained throughout conditions One and Two of the experiment.

Target one (Condition One) consists of a randomly scattered array of paired spots of light at the center of which is located a red fixation spot. The fixation spot is in the straight-ahead position and is at eye level for the subject. The target rotates around the vertical (Y-axis) axis and the fixation spot lies on this axis of rotation. Thus, judgements of AFPP can be made when target one rotates in this manner.

Under Condition Two, the subject maintains his body and head position as outlined for Condition One. Target two consists of a smaller array of spots of light which move physically in the subject's X-axis, but appear to move in the subject's Z-axis via reflection from a piece of glass, which acts like a half-silvered mirror. The experimenter places such a piece of glass within the apparatus box set at a forty-five degree angle to, and half the distance from the subject's eyes and target one. In this position the glass acts as a half-silvered mirror, which allows the subject to see the straight ahead target (one), and also see the reflection of target two. Thus, judgements of stereoacuity can be made when the second target is moved along the

apparent Z-axis to the point reported by the subject to be co-planar with target one. Target one is in its primary position at the objective fronto-parallel plane, and it remains stationary in this position throughout Condition Two. With target two moving in and out, target one is a plane of reference for judgements of stereoacuity.

The light sources for both target one and target two were independent and could be varied in intensity. Light source and target one were set on a platform and this was supported by a vertical dowel so that both target and light could rotate on the AFPP axis. Target two and light source rode on a platform, which was moved back and forth by a worm-screw-crank arrangement. (Refer to Figure 1)

TOP VIEW

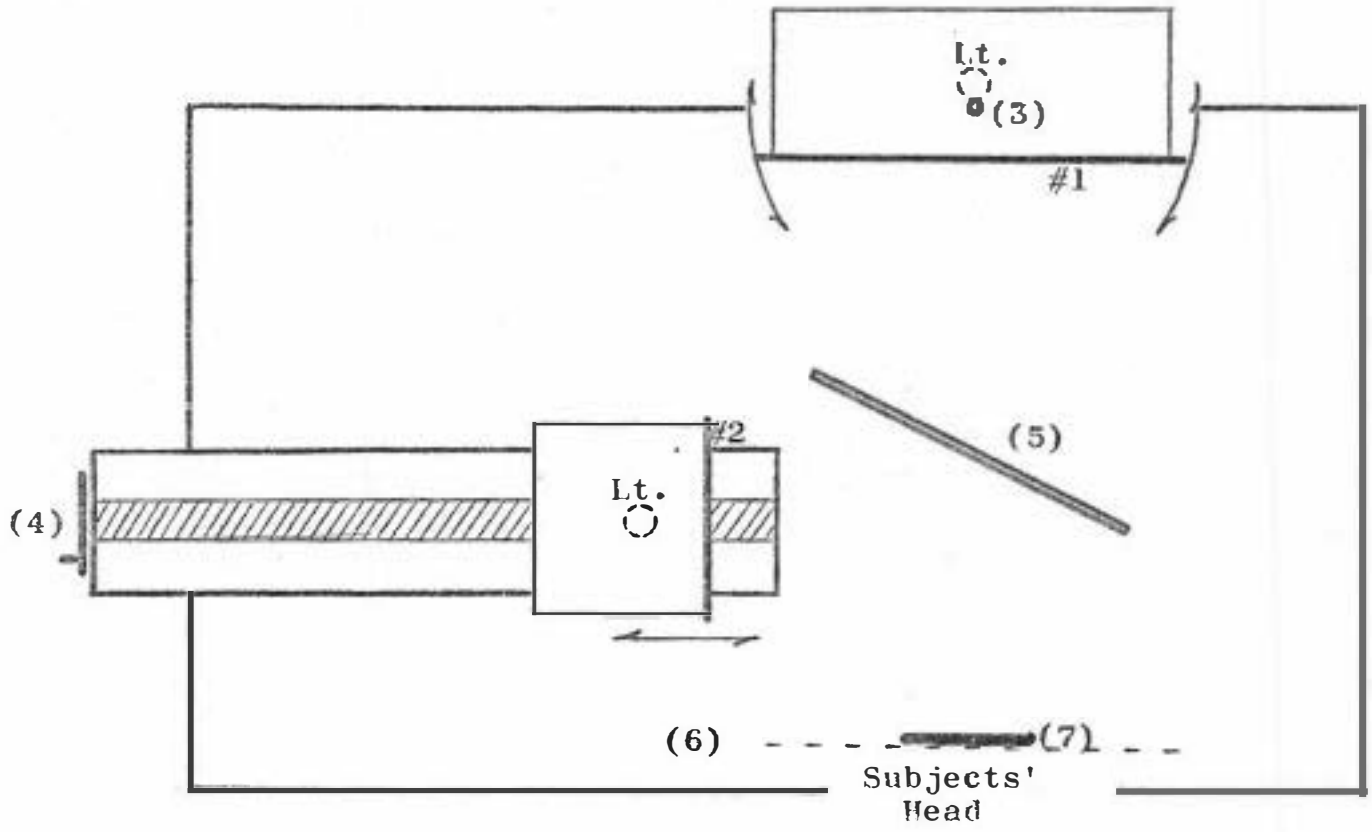

FIGURE 1

KEY FOR DRAWING OF APPARATUS BOX

#1: Target One

#2: Target Two

(3): Center of rotation for Target One (vertical dowel)

(4): Hand crank to turn worm-screw, thus moving Target Two

(5): Half-silvered mirror (glass), set at 45 degree angle

(6): Fronto-parallel plane of subjects' eyes

(7): Forehead rest

PROCEDURE

The experiment took place in the visual perception laboratory of Pacific University's College of Optometry.

If a subject scored 80% or better on the Music Stand test, he was seated before the testing apparatus and given the instructions for the first phase of the experiment.

Condition I. "Say 'now' when the distance from the plane to each eye appears to be equal." This sometimes was further clarified with the statement, "when the plane appears to be parallel with your shoulders."

Five trials were taken from starting positions where the plane was closer to the right eye. Then, five trials from positions where the plane was closer to the left eye. The starting position for each trial was chosen randomly.

Between each trial, as the plane was being rotated to a starting position, the subject was required to keep his eyes closed.

The mirror was put in place and the condition was set for the second phase of the experiment.

Condition II. The reflected image was positioned so that it appeared in front of the reference plane. The subject was asked, "Where is the array of lights relative to the fixed reference plane?" "Say 'now' when it (the array) is coincident with the reference plane."

Five trials were taken from a starting position where the reflected image appeared in front of the reference plane, and five trials from a position where the image appeared behind the reference plane.

Here again, each starting position was chosen at random, and between each trial the observer had his eyes closed.

On the average, the total time involved was ten minutes.

DATA

	JUDGEMENTS OF Y-AXIS (A.F.P.P.)				JUDGEMENTS OF Z-AXIS (STEREO-ACUITY)			
SUBJ.	MEAN	STD. DEV.	VAR.	S. of SQ.	MEAN	STD. DEV.	VAR.	S. of SQ.
RW	+2.70	1.77	3.12	28.10	-2.25	0.59	0.35	3.13
KM	+0.85	0.53	0.28	2.53	-3.30	1.03	1.07	9.60
MM	-0.30	0.82	0.68	6.10	0.50	0.53	0.28	2.50
GL	0.00	1.13	1.28	11.50	+0.60	0.32	0.10	0.90
BM	+1.75	1.69	2.85	25.63	-3.30	0.75	0.57	5.10
MH	+1.85	1.25	1.56	14.03	-4.95	0.55	0.30	2.73
TM	+1.55	1.88	3.53	31.73	-8.20	0.63	0.40	3.60
BH	+0.65	0.78	0.61	5.53	+0.40	3.32	11.04	99.40
BW	+0.15	0.75	0.56	5.03	-1.05	0.98	0.97	8.93
CD	-0.60	2.41	5.82	52.40	+1.20	0.63	0.40	3.60
SS	+0.05	1.42	2.03	18.23	-0.80	1.53	2.34	21.10
DE	+2.00	1.76	3.11	28.00	-4.20	0.42	0.18	1.60
EN	-0.22	2.32	5.38	43.06	-1.15	0.24	5.83	0.53
DB	+0.15	0.94	0.89	8.03	-3.15	0.67	0.45	4.03
TC	-0.15	0.97	0.95	8.53	-2.10	0.31	0.10	0.90
RF	+0.85	0.94	0.89	8.03	-1.90	0.91	0.82	7.40
BB	+0.15	2.61	6.84	61.51	-0.45	0.64	0.41	3.73
PW	+1.30	1.81	3.29	29.60	+0.30	3.09	9.57	86.10
KB	+4.80	2.38	5.68	51.10	-7.75	1.34	1.79	16.13
		Av 1.48				Av0.97		

RESULTS

The purpose of taking the data was to make a comparison of the variabilities of the stereo-acuity task with the variabilities of the AFPP task. Is there a significant difference between the tasks? When the subjects made AFPP judgements, the average of individual standard deviations was $\pm$ 1.48. When the subjects made 'acuity' judgements, the average of individual standard deviations was $\pm$ 0.97mm. The variance measured for each condition was a pooled estimate of the individual variances. Comparison was made using an "F" ratio, with AFPP variance in the numerator, and stereo-acuity variance in the denominator. The "F" test for significance resulted in an "F" value of 1.56, which is significant at the 0.01 level with 171 degrees of freedom.

DISCUSSION AND CONSLUSION

Stereo-acuity is defined as "the ability to perceive depth by the faculty of stereopsis, represented as a function of the threshold of stereopsis."[2] It is an inherent characteristic of each binocular observer and has been shown that thresholds of two seconds of arc are achievable in tasks where the threshold was influenced by the separation and length of the targets and by contrast.[3]

An apparent fronto-parallel plane "is a surface containing the point of fixation and all other points judged by the observer to be equidistant from his frontal plane."[4] Localization of such a plane is in most cases dependent on the observer's repertoire of responses to this type of situation.

In our experiment, we set out to make a comparison between the two tasks. Since the experiment was performed under light-absent conditions, monocular cues for the stereo-acuity task and cues for a frame of reference for the AFPP task were minimal. Our hypothesis was that observers would demonstrate greater accuracy in doing a stereo-acuity task than in doing the AFPP task. The reason for this prediction is that the stereo-acuity task requires evaluation of the visual information at hand on the basis of retinal disparity, using a visible reference plane with minimal aid from kinesthetic cues. The AFPP task involves past learning experience correlating retinal local sign distances with visual perception of the AFPP. The reference system is non-visible in AFPP judgements, according to Johnson and Lamb, 1971, who related use of kinesthetic cues to head position. Therefore, such judgements must be limited not only by stereo-acuity, but by kinesthetic sensitivity as well. Hence, we expected greater variability of response for the AFPP task. This prediction was confirmed by the "F" test, allowing us to accept our hypothesis.

RECOMMENDATIONS FOR FUTURE WORK

Suggestions and recommendations for future work include the following. The first consideration would be for a correlation between or coordination of the light illumination levels used under the two test conditions. The way we controlled this aspect was to have each individual "set" the illumination level for the first task (low foot candle ratings), and then set the second light source at an "apparent equal" level before performing the second task. A better way would have been to set both light sources equal and constant by use of a lightmeter. The second consideration for closer control might be to use a better technique for calibration of the metric "zero" point as used for a score of "perfect" localization in each of the two tasks. The technique used was to test an individual with 100% stereopsis (using the standard music stand card series with a stereoscope) and set the zero at the point where he most consistently saw the plane in an AFPP for task one and saw all of the dots in the same plane for task two. The third recommendation would be to use a piece of actual half-silvered mirror in place of the plate glass which "acted" like a half-silvered mirror. The plate glass "mirror" caused two images for each point on the target of the second light source. A critical observer could tell that one image was closer to him (reflected from the first glass surface) and brighter than the second image (reflected from the second glass surface). The difference in distance from the observer of the two imaged points had a direct relationship to the thickness of the glass plate (1/8 inch thick). One image appeared brighter and 1/8 inch closer than the second image--both images being from a single point source of light at target number two. Some of the results obtained could be influenced by individual subjective judgements

of whether they were placing the first image, second image, or some in-between distance on the fronto-parallel plane, calling this "on the plane" for the second task. By using the true half-silvered mirror, you would get only one image for each point light source of target two, and thus eliminate some of the ambiguity of the task settings. The fourth recommendation would be to use a higher cut-off level on the pre-test screening of stereopsis which an individual can attain. It might be better to use only subjects which scored 90% or better on the standard music stand test. Also, since most optometry students are familiar with this type of stereopsis test, it might be advisable to use non-optometric students who would be more naive to the task involved. The degree of stereopsis of each individual might also be correlated to the pupillary distance, corrective error and/or correction possible, and also the visual phoric pattern.

FOOTNOTES

[1]Terry R. Johnson and David P. Lamb, "Constancy of the Perceived Fronto-Parallel Plane" (Unpublished thesis of College of Optometry, Pacific University), 1971.

[1]Donald C. Hegland and Glen C. Vandenberge, "Adaptation of Apparent Fronto-Parallel Plane and Felt Head Position after Short Duration Head Turn" (Unpublished thesis for College of Optometry, Pacific University), 1973.

[2]Max Schapero, David Cline, and Henry Hofstetter, Dictionary of Visual Science (New York 1968), p. 669.

[3]Max Schapero, Amblyopia (Philadelphia 1971), p. 5.

[4]Max Schapero, David Cline, and Henry Hofstetter, Dictionary of Visual Science (New York 1968), p.550.

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