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Stereopsis thresholds measured with different techniques

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STEREOPSIS THRESHOLDS MEASURED WITH DIFFERENT TECHNIQUES

BY

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INTRODUCTION

The purpose of this thesis is to compare the results of spatial localization of the various stereo instruments at the far point. The main objective of the tests used is to compare the results of the Howard-Dolman Peg test, Chromostereopsis, Space Eikonometer, and Ortho-rater to the clinically routine test, the telebinocular.

PROCEDURE

Each subject was brought into the examining room and seated on a stool at the Master Ortho-Rater. The patients: majority of them were Optometry students assumed to be more observant, giving sophisticated responses, and wearing their habitual prescription. As the subject looked into the instrument the question was asked "What is the number you see at the top?" and then "Which one looks closest to you?" If a correct response was obtained the test proceeded to Row A. "Now in line A which of the numbers looks closest to you?" "In line B?" and so forth to the end of the test. If an incorrect reponse was obtained on the top row, the subject was allowed to look around the scene in an attempt to get a greater effect of stereopsis. Room illumination on this test was fairly low.

At the conclusion of this test the subject moved to the telebinocular given and the standard Pacific University card skill test on cards A, S1, and S2, concerning stereopsis. As the subject looks into the instrument the instructions were given "As you look around this living room scene you see a music rack with vertical bars on it." "Look at bars number one and number two, can you make a choice as to the one that appears closest to you?" This procedure was repeated asking the subject to compare each pairs of vertical bars as for example: one and two, two and three, and so forth, until all three cards are completed successfully or two consecutive incorrect scores made. Initial recording on this test was done in terms of percentage of stereopsis and again room illumination was fairly low.

Following the telebinocular the subject moved to the space eikonometer and the room illumination was turned off in order to allow the best brightness contrast possible. The subject was 13.75 millimeters from the lenses of the instrument. "As you look into this instrument you see two green vertical lines, two white vertical lines, a red cross with orange bar throught it." Zero settings were axis 180 degrees and declination setting throughout the test. The light was turned off and the axis 90 degrees was moved to its maximum and then light was turned on again. "Now look just at the two green lines, can you tell which one was closest to you?" Following the subjects choice, the light was turned off, the lever was moved to the maximum setting at the opposite end of its travel. The procedure was repeated moving the lever back and forth while the light was off and the subject allowed to make a judgment while the light was on, until the subject reported that the two green lines appeared to be of equal distance from his eyes. When the equal point was found, the axis 90 degree lever was moved slowly forward until a difference in depth was reported. This procedure was repeated moving the lever backwards from the equal point again until a difference in depth was noticed.

Chromostereopsis was tested next by having the subject seated in the standard Pacific University clinical refracting situation. The phoropter was placed in front of the patient while wearing his habitual prescription, with the pupillary distance set at one millimeter less than the far pupillary distance of the subject. The bichrome box was placed directly in front of the subject at a distance of one meter as measured from the front of the phoropter to the front of the bichrome box. Room illumination was then turned off, the bichrome box was turned on and the subject was asked to look at the box. "As you look at the bichrome box are you able to make a choice as to which side of the box appears closest to you, the red or the blue", "It might help you to make a choice if you looked along the borders of the box or at the line separating the two colors". The Risley prism were then introduced and the prism either base out or base in until the subject reported that the two sides of the chart appeared to be of equal distance from him. From this point the prism was moved until the subject first reported a noticeable difference in depth of the two sides of the target.

The Pacific University Howard Dolman Peg Test concluded the series of tests. The test was placed in the refraction room directly across the hall from the testing room, the subject remained seated in the refracting chair and was handed the cord to the movable peg on the Peg test. The testing room lights were turned on as were the lights in the Howard Dolman Peg Test, but the lights were off in the room in which the test was placed. "You see two vertical pegs and with the cord in your hand you find you can move the left peg toward and away from you, while the peg on the right side remains stationary." "Move the peg back and forth to the limits of its travel to get the feel of the amount of movements and then move the peg so it appears exactly beside the peg that does not move." When the subject had move the pegs until they appeared equal distance from him the instructions were given "Move the peg toward you until you first can visually detect a difference in the distance away from you." This position was recorded and the peg moved back to the position originally designated by the subject as being equal. "Now move the peg away from you until you first can visually detect a difference in depth." This finding was recorded, giving a total distance which the subject had reported no disparity, thus no depth.

INSTRUMENTS

The instruments used in this thesis are the same which could be used in any standard examination routine.

First we utilized a Bausch and Lomb Master ortho-rater, essentially a Brewster stereoscope, which makes it possible to optically obtain any predetermined testing distance and to control what each eye sees. The instrument is lowered 15 degrees from the horizontal position, which simulates a testing distance normal for a subject a normal posture when one is observing a distant object. The instrument is designed to optically simulate a distance of twenty feet which is comparable to the testing in a normal routine. The interpupillary distance of the subject has no effect on the test.

The target F-6 is transparent glass which is back-illuminated which has a constant control of intensity. The slide gives a distant target which has projections that appear to be located closer to the eyes of the subject. The stereoslide has nine varying distance. Low illumination was used for this finding.

The second instrument we used was a Keystone Telebinocular which is used in a clinical card skill routine. This instrument is also a Brewster stereoscope and it makes it possible to optically predetermine the testing distance as mentioned in the above. The testing distance was set for infinity and the targets used were A, S1 and S2. The three targets, steregrams, consisted of bars which the subject was to determine between two bars at a time which appeared close to him. Low illumination was used.

The third instrument we used as a Space-eikonometer which has a photographic transparency target mounted before each eye. A septum prevents the target seen by the right eye from being seen by the left eye and vice versa.

The eikonic target consists of Kodachrome transparencies, one for each eye, which gives a three dimensional appearance of the vertical lines. The two green vertical lines were the only elements used. The projection lens is a +6.00D which simulates the image of the test to a distance of ten feet from the eye. Dark illumination was used.

The fourth instrument we utilized was a Green's refracting unit, a Bausch and Lomb refractor and a standard bichrome box. The bichrome box of blue and red filter is placed one meter in front of the Risley prisms for that part of the testing procedure. Dark illumination was used.

The last instrument we used was the Howard Dolman Peg test. This consisted of a box with one stationary black peg and ano-other black peg (of equal dimensions) which is movable. The front surface of the box was black, with a rectangular open-ing. The subject was placed 5.64 meters from the stationary peg to the eye of the observer, at eye level.

DISCUSSION OF THE LITERATURE

DEFINITIONS:

1. Stereopsis - "binocular visual perception of three dimensional space based on retinal disparity" (1)
2. Chromostereopsis - "stereopsis resulting from differential prismatic effects in the eyes for different wavelengths of light when the pupils are eccentric with respect to the optical axes, whence, binocularly, a red object will normally appear closer than an equally distant green object. The effect may be eliminated, reversed, or accentuated by the proper placing of artificial pupils before the eyes."(2)

It has been said that with both eyes spatial localization is developed to its highest degree and that this phenomena is known as stereoscopic depth perception. Perception of a third dimension is never as great monocularly as it is binocularly.

In the course of phylogenetic evolution of the human being, the eyes have gradually come to be in a position in the front of the head. Resulting in a condition more favorable for development of stereopsis. Intricate coordination of a highly complicated order has become necessary. "Thus the need for accurate depth perception as provided by stereopsis must have had an important influence in the phylogenetic development of the eyes"(3)

Ordinarily, awareness of simultaneous use of both eyes is not present and the image that is observed appears to come from an area defined as the cyclopean eye. Elements in each eye, having a common visual direction are defined as corresponding retinal points.

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(1) Schapero, Max, David Line, Henry William Hofstetter editors, Dictionary of Visual Science, Chilton Company, Book Division Philadelphia, 1960, page 660.

(2) Ibid., page 129-130.

Thus it can be said that stereopsis has as its major cause stimulation of noncorresponding retinal elements. "Stereoscopic vision is the judgement of depth by the disparateness of the retinal images"(4)

Theoretcally the right eye image and the left eye image are not exactly identical and fusion of these two non-identical images initiates the perception of depth. Some writers claim that disparation is not the cause of stereopsis but that the difference in "subjective contrast" of the images.

Four of the five tests used in this research utilized the principal stimulation of noncorresponding retinal elements in order to induce an effect preceived as depth. The Orthorater and the telebinocular present two similar half views to the observer which, due to optical principles, are perceived as being single and at a phenomenal distance approximating twenty feet. Small differences in lateral separations of individual elements in the target give rise to stereopsis. In the space-eikonometer two transparencies are superimposed and movement of the levers results in lateral separation of the transparencies and stereopsis.

In the Howard-Dolman Peg test a binocular presentation is given and the slightly differing "retinal pictures" results in stereopsis with one peg being viewed as closer to the observer than the other.

The phenomena of Chromostereopsis has been classied as an illusion by some. Chromatic aberration of the eye plays a major role in the perception of depth when lights of two colors at the opposite ends of the spectrum are observed. The blue usually appears further away than the red.

A survey of the literature, indicates that little research has been made in the area of correlating the various tests of

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(3) Davson, Hugh, The Eye Volume 4 Visual Optics and the Optical Space Sense, Academic Press, New York, 1962, page 271-272.

(4) Adler, Francis, Physiology of the Eye Clinical Application, C. V. Mosby Company, St. Louis, 1959, page 771.

stereopsis used optometrically today. A correlation of the Ortho-rater and telebincoular did not seem to be available. Probably due to the fact' that these tests are suppose to be the "best possible" according to each manufacturer. A test by an unbiased observer did not seem to be available.

Correlating the telebinocular to stereopsis observed in the space-eikonometer also did not seem to be available. The major function of the space-eikonometer is not measurement of stereopsis, but detection and measurement of aniseikonia with the result that stereopsis is assumed before measurements of aniseikonia begin.

There has been very little written about chromostereopsis, probably because according to most it is an illusion. But chromostereopsis is a physical phenomenon-that is the effect when viewing two colors near opposite ends of the spectrum with one color appearing closer to the observer than the other color with the induced prism and the wavelenght of light. "There is no meaning in the statement that an apparent stereoscopic depth interval to a given objective depth. Probably, however, the two are related in some sort of a rank order psycho-physical parallelism"(5)

There has been a survey done by Monroe Hirsch comparing the Howard-Dolman Peg test to the telebinocular. It has been found: first, the results obtained from a stereoscope in comparing the relative position of two objects in space was of little value; second, it was found with the Howard-Dolman Peg test could equally be a reliable measure of corresponding points. Thus the Howard-Dolman Peg test maybe used to determine the presence and to estimate the degree of iseikonia.

Also Langlands and Warren found the correlation between the Howard Dolman Peg test and stereoscope was of a significance of +.343. Another paper also suggested that the distribution of thresholds obtained on a stereoscope is bimodal and perhaps this had a greater effect on retinal disparity

(5) Op. Cit., The Eye, page 370

and that scores obtained have influenced by this factor. "While the Howard Dolman test may be administered in such a manner as to yield valuable information concerning the prescence and degree of aniseikonia, no stereoscopic method at present employed can be used for this purpose."(6)

(6) Monroe, Hirsch, The Stereoscope as a Method of Measuring Distance Discrimination, Monograph 34, American Journal of Optometry and Archives of American Academy or Optometry, Foshay Tower, Minneapolis, Minnesota, Oct. 1947, page 4.

DATA

Subject		Pd	Ortho rater	Space Eikonometer		Telebinocular	Chromo-stereopsis		Howard-Dolman cm	
1.	NM	62	F	1 red	1 bk	90	5 BO	2 BI	0	+1.1
2.	DW	59	all	4 red	2 bk	100	18 BO	6 BI	+3.5	-4.
3.	SL	63	no response	3 red	2 bk	100	6 BO	0	0	-3.
4.	RH	64	all	2.2red	1 bk	95	6 BO	0	0	+2
5.	RC	64	all	.7red	1 bk	100	2 BO	3 BO	+4	-1
6.	DN	64	all	0	3 bk	95	24 BO	3 BI	+1	-8
7.	TS	58	F	1 red	1 bk	95	10 BO	14 BI	+1	-3.5
8.	GW	62	F G H	.5red	4 bk	90	14 BO	6 BI	0	+3
9.	JC	64	all	3 red	.7 bk	90	14 BO	1 BO	+1.5	-1.5
10.	BH	62	all	1 red	1 bk	100	8 BO	4 BO	+5	-1
11.	RH	64	all	1.5red	.5bk	95	1 BI	8 BI	+1	-3.5
12.	SVH	63	all	.5red	.5bk	90	6 BO	6 BI	+3	-4.5
13.	GE	64	F	.5red	.6bk	100	11 BO	8 BO	+1	-1
14.	GJ	61	H	.2red	.2bk	95	4 BO	0	+2	-1
15.	ST	60	D H	.5red	1.5bk	100	3 BO	5 BI	0	-3
16.	DC	64	D F G H	0	.7bk	100	6 BO	1 BO	-2	0
17.	KS	64	F H	.6red	0	100	4 BI	16 BI	0	-1.5
18.	JP	60	F	.7red	.2bk	95	6 BO	1 BI	+.2	-4.7
19.	BH	68	all	1 red	1 bk	100	2 BO	6 BI	+.8	-2
20.	JS	64	all	1.5red	1 bk	100	8 BO	0	+1.2	-1
21.	RB	64	C G	1.5red	1.5bk	100	0	8 BI	+2	-1
22.	DL	58	all	1.5red	1.5bk	100	9 BO	0	+5	-1
23.	EL	68	F H	.5red	.5bk	95	4 BI	8 BI	+4	-3.5
24.	DW	65	F H	1.0red	.5bk	95	2 BO	½ BI	+2.9	-3.3
25.	DC	62	F G	1.0red	.5bk	95	2 BO	2 BI	+5.	-2.5
26.	VS	66	G	.5red	.5bk	95	10 BO	4 BI	+1	-1
27.	GS	58	B D H	.5red	2. bk	95	8 BO	4 BO	+2	0
28.	RE	60	E F G H	0 red	1 bk	95	16 BO	5 BO	0	-1
29.	VC	62	all	1 red	1 bk	100	6 BO	5 BO	+1.5	-1
30.	BB	64	all	.5red	.5bk	95	4 BO	6 BI	+1.7	-1.7

CALCULATIONS

In order to facilitate computations in determining the correlations amount the various tests - prism diopters were used as a base.

The manuals on the telebinocular and the Ortho-rater gave separations of the stereopsis tests in terms of minutes of angle. These readings were converted to degrees and then to prism diopters by the trigonometric function of tangents.

The Howard Dolman Peg Tests was converted into prism diopters by use of the formula:

$$\frac{d_{(near)} - d_{(far)}/2}{d^2} \times Pd$$

where $d_{(near)}$ was the closest peg and $d_{(far)}$ was the peg farthest away to first detectable depth. In this research d' was 5.64 meters as measured from the stationary peg to the eye of the observer. The $d_{(near)} - d_{(far)}$ was divided by two to give the average disparities then divided by 32 and multiplied by the pupillary distance of the observer in order to obtain the readings in prism diopters.

The Space Eikonometer calculations used the same formula as described for the Howard Dolman Peg test with the exception that actual instrument distances from the lenses to the slide (15.9 cm) and the lateral separation of the green lines (27 mm). Readings were taken in percent of 27 mm and divided by two to get the average disparity divided by .0253 multiplied by the pupillary distance to get prism diopters.

In order to obtain the prism diopter disparity on chromostereopsis, the refractive index of the various colors were utilized in an effort to find the amount of disparity. The index for the sodium line of the prism glass is 1.517, for the red 1.513 and for blue 1.528.

$$\frac{(1.528 - 1.00) - (1.513 - 1.00)}{1.517 - 1.00} = \frac{.015}{.517} \doteq 2.9\%$$

This 2.9% was multiplied by one half the total prism diopter differences found in the experiment to find stereopsis due to the action of the prisms.

T SCORES TELEBINOCULAR VERSUS ORTHO RATER

Subject		Pd	X	Y	D = X - Y	D^2
1.	NM	62	.209	.280	-.071	.005
2.	DW	59	.105	.280	-.175	.031
3.	SL	63	.105	~~10.500~~	~~-10.495~~	~~101.000~~
4.	RH	65	.157	.280	-.123	.015
5.	Rc	64	.105	.280	-.175	.031
6.	DN	64	.157	.280	-.123	.015
7.	TS	58	.157	.180	-.123	.015
8.	GW	62	.709	.553	+.156	.024
9.	JC	64	.157	.280	-.123	.015
10.	BH	62	.104	.280	-.175	.031
11.	RH	64	.157	.280	-.123	.015
12.	SVH	63	.209	.280	-.071	.005
13.	GE	64	.105	.280	-.175	.031
14.	GJ	61	.157	.344	-.287	.082
15.	ST	60	.105	.344	-.239	.057
16.	DC	64	.105	.553	-.448	.200
17.	KS	64	.105	.553	-.448	.200
18.	JP	60	.157	.280	-.123	.015
19.	BH	68	.105	.280	-.175	.031
20.	JS	64	.105	.280	-.175	.031
21.	RB	64	.105	.280	-.175	.031
22.	DL	58	.105	.280	-.175	.031
23.	EL	68	.157	.344	-.287	.082
24.	DW	65	.157	.344	-.287	.082
25.	DC	62	.157	.553	-.396	.156
26.	VS	66	.157	.280	-.123	.015
27.	GS	58	.157	.344	-.287	.082
28.	RE	60	.157	.785	-.628	.394
29.	VC	62	.157	.280	-.123	.015
30.	BB	64	.157	.280	-.123	.015
n = 29			$\Sigma X = 4.995$	$\Sigma Y = 10.04$	D = 5.810	$D^2 = 1.654$

T SCORES TELEBINOCULAR VERSUS ORTHO RATER

STEP I $\bar{D} = \frac{\Sigma D}{n} = \frac{5.810}{29} = .200$

STEP II $s^2 = \frac{\Sigma D^2}{n} - \bar{D}^2 = \frac{1.654}{29} - (.040)^2 = .017$

$s = \sqrt{.017} = .130$

STEP III $s_{\bar{D}} = \frac{s}{\sqrt{n-1}} = \frac{.130}{\sqrt{28}} = \frac{.130}{5.3} = .0246$

STEP IV $t = \frac{\bar{D}}{s_{\bar{D}}} = \frac{.200}{.0246} = 8.14$

Therefore: P = .01

T SCORES TELEBINOCULAR VERSUS CHROMOSTEREOPSIS

Subject		Pd	X	Y	D = X − Y	D^2
1.	[illegible]	62	.209	.087	.122	.015
2.	[illegible]	59	.105	.348	−.243	.057
3.	[illegible]	63	.105	.087	.026	.001
4.	[illegible]	65	.157	.174	.017	.001
5.	[illegible]	64	.105	.014	.081	.006
6.	[illegible]	64	.157	.392	−.235	.055
7.	[illegible]	58	.157	.348	−.191	.036
8.	[illegible]	62	.709	.290	.519	.268
9.	[illegible]	64	.157	.029	.128	.016
10.	[illegible]	62	.104	.087	.027	.001
11.	[illegible]	64	.157	.101	.056	.001
12.	SVH	63	.209	.175	.034	.001
13.	GB	64	.105	.043	.062	.001
14.	GJ	61	.157	.058	.099	.001
15.	[illegible]	60	.105	.116	−.011	.000
16.	DO	64	.105	.073	.032	.000
17.	KB	64	.105	.175	.090	.001
18.	[illegible]	60	.157	.101	.056	.001
19.	ML	62	.105	.116	−.011	.000
20.	JT	64	.105	.116	−.011	.000
21.	ZD	64	.105	.116	−.011	.000
22.	[illegible]	58	.105	.130	−.025	.001
23.	[illegible]	66	.157	.055	−.102	.010
24.	DF	65	.157	.036	.121	.015
25.	BG	62	.157	.201	−.044	.001
26.	VS	66	.157	.058	.099	.001
27.	GS	58	.157	.058	.099	.001
28.	HE	60	.157	.150	.007	.000
29.	VC	62	.157	.130	.017	.000
30.	BB	64	.157	.145	.012	.000

n = 30 D = .840 D^2 = .291

T SCORES THREE BINOCULAR VERSUS CHROMOSTEREOPSIS

STEP I $\bar{D} = \frac{D}{n} = \frac{.840}{30} = .028$

STEP II $s^2 = \frac{D^2}{n} - \bar{D}^2 = \frac{.281}{30} - (.028)^2 =$

$.0097 - .0008 = .0089$

$s = \sqrt{.0089} = .094$

STEP III $s_{\bar{D}} = \frac{s}{\sqrt{n - 1}} = \frac{.094}{\sqrt{29}} = \frac{.094}{5.4} = .0175$

STEP IV $t = \frac{\bar{D}}{s_{\bar{D}}} = \frac{.028}{.0175} = 1.60$

Therefore: $P = .1$

T SCORES TELEBINOCULAR VERSUS HOWARD DOLMAN PEG TEST

Subject		Pd	X	Y	D = X - Y	D^2
1.	MI	62	.209	.011	.198	.039
2.	EW	59	.105	.069	.034	.001
3.	SL	63	.105	.029	.086	.001
4.	BH	65	.157	.021	.136	.018
5.	[illegible]	64	.105	.050	.055	.003
6.	LE	64	.157	.090	.067	.004
7.	[illegible]	58	.157	.041	.116	.135
8.	[illegible]	62	.709	.029	.680	.046
9.	JC	64	.157	.030	.127	.162
10.	BH	62	.104	.059	.045	.002
11.	RH	64	.157	.045	.059	.003
12.	SVH	63	.209	.074	.135	.182
13.	GE	64	.105	.020	.085	.007
14.	GJ	61	.157	.029	.128	.164
15.	ST	60	.105	.028	.077	.006
16.	DC	64	.105	.020	.085	.001
17.	KS	64	.105	.015	.090	.008
18.	JP	60	.157	.046	.111	.012
19.	BH	68	.105	.030	.075	.005
20.	JS	64	.105	.022	.083	.007
21.	RB	64	.105	.030	.075	.005
22.	DL	58	.105	.054	.051	.002
23.	EL	68	.157	.079	.078	.006
24.	DW	65	.157	.032	.125	.015
25.	DC	62	.157	.074	.085	.007
26.	VS	66	.157	.020	.137	.019
27.	GS	58	.157	.022	.135	.018
28.	RE	60	.157	.032	.125	.015
29.	VC	62	.157	.029	.009	.001
30.	BB	64	.157	.033	.124	.015

n = 30 D = 3.635 D^2 = .936

T SCORES TELEBINOCULAR VERSUS HOWARD DOLMAN PEG TEST

STEP I $\bar{D} = \frac{\Sigma D}{n} = \frac{3.635}{30} = .121$

STEP II $s^2 = \frac{\Sigma D^2}{n} - \bar{D}^2 = \frac{.936}{30} - .015 = .015$

$s = \sqrt{.015} = .122$

STEP III $s_{\bar{D}} = \frac{s}{\sqrt{n-1}} = \frac{.122}{\sqrt{29}} = \frac{.122}{5.4} = .122$

STEP IV $t = \frac{\bar{D}}{s_{\bar{D}}} = \frac{.121}{.023} = 5.25$

Therefore: $P = .01$

T SCORES   TELEBINOCULAR VERSUS SPACE EIKONOMETER

Subject	Pd	X	Y	D = X - Y	D^2
1. MM	62	.209	.068	.141	.020
2. DW	59	.105	.189	-.084	.007
3. SE	63	.105	.202	-.097	.009
4. [illegible]	65	.157	.112	.045	.002
5. [illegible]	64	.105	.061	.044	.002
6. [illegible]	64	.157	.412	-.255	.065
7. [illegible]	58	.157	.062	.095	.009
8. GW	62	.709	.742	-.033	.001
9. JC	64	.157	.126	.031	.009
10. BH	62	.104	.068	.036	.001
11. RH	64	.157	.051	.106	.011
12. SVE	63	.209	.034	.175	.031
13. GE	64	.105	.036	.069	.005
14. GJ	61	.157	.016	.141	.020
15. ST	60	.105	.081	.024	.006
16. DC	64	.105	.026	.079	.006
17. KS	64	.105	.021	.084	.007
18. JP	60	.157	.032	.124	.015
19. BH	68	.105	.073	.032	.001
20. JS	64	.105	.103	.002	.000
21. RB	64	.105	.103	.002	.000
22. DL	58	.105	.094	.011	.0001
23. [illegible]	68	.157	.036	.121	.014
24. DW	65	.157	.070	.087	.007
25. DC	62	.157	.033	.124	.015
26. VS	66	.157	.079	.078	.006
27. GS	58	.157	.078	.079	.006
28. RE	60	.157	.032	.125	.015
29. VC	62	.157	.066	.091	.008
30. BB	64	.157	.034	.123	.015

n = 30 $\Sigma D = 1.586$ $D^2 = .303$

SOC. II. TELEBINOCULAR VERSUS SPACE EIKONOMETER

STEP I $\bar{D} = \frac{\Sigma D}{n} = \frac{1.586}{30} = .053$

STEP II $s^2 = \frac{\Sigma D^2}{n} - \bar{D}^2 = \frac{.303}{30} - 2.52 =$

$.010 - 2.52 = 2.51$

$s = \sqrt{2.51} = 1.59$

STEP III $s_{\bar{D}} = \frac{s}{\sqrt{n - 1}} = \frac{1.59}{5.4} = .294$

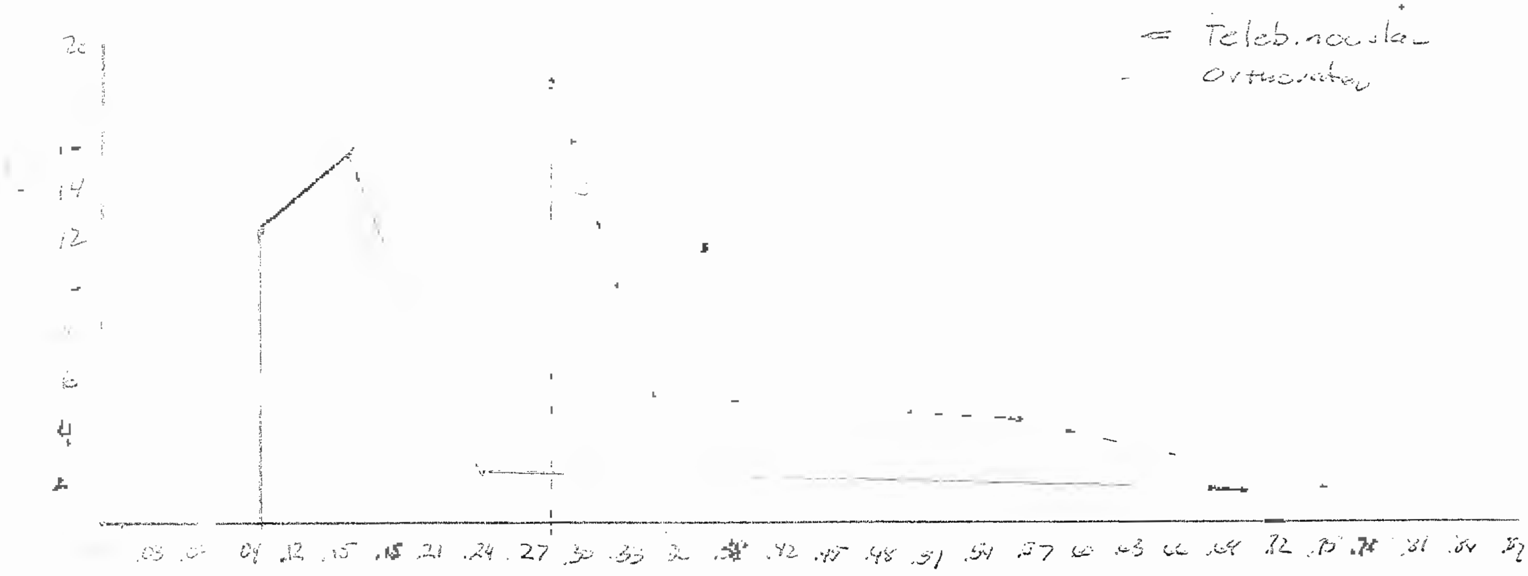
STEP IV $t = \frac{\bar{D}}{s_{\bar{D}}} = \frac{.053}{.294} = .18$

Therefore: $P = .9$

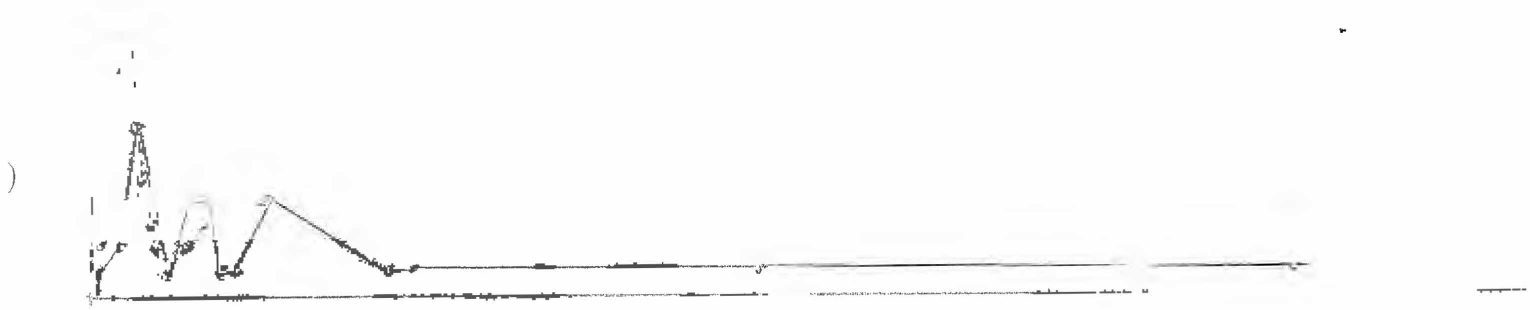
CONCLUSIONS

Comparing the stereopsis thresholds of the ortho-rater, and the Howard Dolman Peg test to the clinically rountine test, the telebinocular by the T Score calculations showed a greater than the one percent level of confidence. The Space Eikonometer figures appear to be very similar to the telebinocular, but the calculations do not seem to bear this out completely. The T Score calculations on the chromostereopsis indicate a ten percent level of confidence. This test seemed to be the most difficult from the standpoint of the subject. Some subjects reported great difficulty in seeing depth and several others experienced a "break" and saw two charts before seeing disparity when measuring from the equal point.

Most likely the differences could be found by repeating the same experiment with stricter control of variables such as: better testing procedures, targets, equipment, errors in measurement and individual responses.



Space Eikonometer
Howard Dolman



Chromostereopsis

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