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THE STEREOSCOPIC ANGLE AND ITS RELATIONSHIP TO THE STANDARD AIR FORCE TESTS FOR DEPTH PERCEPTION

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FOREWORD

This investigation was performed by members of the Physical-Physiological Optics Section of the Ophthalmology Branch, and Biometrics Branch, under task No. 775509, "Ophthalmological Aspects of Aerospace Flight."

The paper was submitted for publication on 2 June 1966. The data were collected and analyzed during the period from 1 November 1965 through 15 April 1966.

The authors express appreciation to the 96 basic airmen who volunteered to participate in this study, to Airman Third Class William E. Alley for technical assistance in performing the experiments, to Hans Bartholomew of the SAM Instrument Section for constructing the SAM-V, and to the staff at the Lackland Air Force Base Medical Processing Center for their cooperation in arranging for the tests.

This report has been reviewed and is approved.

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ABSTRACT

The three standard Air Force depth perception tests for pilot and observer qualification are the Vision Test Apparatus Near and Distant (VTA-ND), Verhoeff Stereopter (DPA-V), and Howard-Dolman apparatus (H-D).

The stereoscopic angle (η) for the VTA-ND is 25 seconds of arc, 32 seconds for the DPA-V, and 11 seconds for the H-D.

An enlarged Verhoeff (SAM-V) was utilized at equivalent calculated distances to compare with the three instruments under their individual parallactic angle conditions.

Data analysis showed the following: (1) Employment of the standard criteria for flying qualification resulted in the Verhoeff passing the greatest number, followed by the VTA-ND, and the H-D. Neither the Verhoeff nor H-D results statistically differed from those of the VTA-ND. (2) The SAM-V generally passed fewer subjects than the corresponding standard tests.

The results found with the standard Air Force tests are not a full measure of depth discrimination capability. A test concept is described which would incorporate a dynamic component into depth judgments.

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I. INTRODUCTION

An applicant for Air Force training as a pilot or observer is required to demonstrate depth appreciation during his physical examination. If he can show a stereoscopic acuity of 25 seconds (9) or better on the Vision Test Apparatus—Near and Distant (VTA-ND) (1), he is qualified in this attribute.

Failure in the above test transfers the candidate to trial with the Verhoeff Stereopter (DPA-V). Depth judgments at 1-m. distance subtending a stereoscopic angle (η) of 32 seconds (22) must be accomplished for eight consecutive presentations for initial test success.

Failure of one or more presentations requires 16 subsequent exposures, from which one or more incorrect responses direct the candidate to a Howard-Dolman (H-D) trial utilizing a 20-foot test distance. This test requires that the mean displacement of the movable rod must not vary in depth localization by more than 30 mm., corresponding to an 11-seconds (2) stereoscopic angle, in attempted alignment with the fixed rod.

The tests in this investigation were administered in accordance with the standard procedures outlined in Air Force Manual 160-1, "Medical Examination and Medical Standards" (3), with one exception: a headrest was used with the Howard-Dolman apparatus.

The VTA-ND utilizes a stereoscopic principle. It is an artificial test situation. Some individuals who fail may actually have good depth appreciation, but are unsophisticated users of this optical device. Those who demonstrate a pure stereopsis capability do not necessarily operate effectively in a natural three-dimensional environment.

Hofstetter (8) reports on a study in which a stereoscopic-type device was used, and the group with the fewer minor accidents scored higher in stereopsis. However, there was no statistically significant difference between the average scores in a serious-injury group and an accident-free group.

From a review of the literature (13, 19, 20) it is apparent that factors additional to stereopsis are in play during the DPA-V and H-D tests.

The Verhoeff device at the 1-m. test distance requires the employment of a 1-m. angle of convergence and 1 diopter of accommodation, for the test distance, by all subjects in this study.

Since the DPA-V testing is performed at the 1-m. distance, it does not necessarily follow that qualification in this instance can be transferred to the more distant requirements of the pilot. The pilot and aircraft observer would be restricted to an operating distance of a meter or less only when instrumentation reference or preoccupation with charts and writing so confined them.

Important extra-cockpit depth judgments must be made by the pilot during landing and takeoff, formation flying, and aerial refueling, in order to take corrective action to prevent collisions.

A principal objection by the authors in the use of the Howard-Dolman apparatus as the best index for depth testing at a distance, is the requirement that the two rods be positioned so that no difference in proximity to the observer is apparent. Stereoscopic acuity is determined by the just-noticeable-difference (J.N.D.) in relative depth that a normal binocular individual can discriminate between targets. The fact that an observer can place the movable rod at a mean variation of 30 mm. closer or farther than the fixed rod provides latitude about double that implied by the mean of 11-seconds stereoscopic angle, over the five determinations given for the test. The full range of deviation may be 60 mm which would allow a 22-seconds stereoscopic angle spread.

To this point, the stereoscopic angle has been the only factor considered for the Verhoeff and the Howard-Dolman tests. The paper by Sloan and Altman (20) explored the effect of conflicting size cues in the stereopter, and compared the test results with the standard Verhoeff and a special Verhoeff device where the bars were uniform in width. Statistically, they found a significant improvement in depth appreciation with the modified Verhoeff, making it evident that the standard Verhoeff instrument renders depth judgments more difficult.

The Howard-Dolman possesses the following attributes which may be additional to stereopsis in rod localization. In moving the peg closer to the testee, the angular subtense is increased, and the rod may appear larger than the fixed one. Retinal image size will decrease when the rod is moved farther from the observer than the position of the stable comparison peg.

Howard (10) and Hirsch et al. (7) investigated the significance of this size change, and concluded that this factor was inconsequential for threshold (J.N.D.) detection. However, Hirsch et al. found a significant effect upon the position of subjective equality.

Kinesthetic (hand-eye coordination) contributions to depth judgment have also been advanced, as secondary factors, in testing with the H-D apparatus. Sloan and Altman (20) used a pulley arrangement to offset the kinesthetic cue. Their results indicated that kinesthetic input was a negligible determinant in H-D results.

Motion parallax is produced by moving one's head laterally, and assessing the spatial localization of one object with respect to another by the resultant speed and direction of relative retinal image movements. Monocular motion parallax is a strong cue in depth judgment. However, binocular motion parallax may be an even greater discriminator (4, 20).

The standard Air Force method of administering the H-D test does not mechanically restrict the head movements of the examinee, but relies on the examiner to detect gross head movements, and to caution the violator when this occurs. Laboratory protocol with the H-D confines the subject's head in a chin-headrest combination (20).

In summary, the factors which individually are considered insignificant with the H-D, may in totality still influence the acute depth discrimination exhibited.

Of the three standard Air Force depth discrimination tests, the Verhoeff principle appears to be the least objectionable for natural binocular depth perception. Verhoeff (22) indicated that an expansion of his design would yield essentially the same results when tested over the same parallactic angle at the appropriate distance.

A model of the Verhoeff Stereopter (SAM-V), constructed at the USAF School of Aerospace Medicine, allows a 32-seconds stereoscopic angle to be subtended at a 3.14-m. placement from the observer.

Accommodation convergence was changed by this test procedure from the 1 diopter (DPT) 1 meter-angle (M.A.) *(used in Verhoeff test)*, to less than $^1/_3$ DPT $^1/_3$ M.A., respectively. The use of these functions for depth localization is considered to be negligible at the expanded test distance (6). Graham (6) stated that, "Convergence cues cannot be differentially effective for objects at distances greater than about 20 yards." Ludvigh (14) commented that since the subject cannot report on his condition of convergence, the convergence mechanism is not a cue to space judgment. Matsubayashi (15) reported that convergence is an influencing variable. Glezer's (5) results fail to show evidence of depth perception arising from changes in convergence. Ittelson (11) discounts convergence as a clue to apparent distance.

The use of the SAM-V was considered as a vehicle for studying depth judgments on all three standard tests, with the SAM-V being positioned at the equivalent distances for matching parallactic angles: 3.14 m. corresponding to the Verhoeff, 3.66 m. for the VTA-ND (group D), and 5.43 m. for the H-D apparatus.

II. METHODS

The 96 volunteer subjects who participated were basic airmen in the physical processing stage of induction into the U. S. Air Force at Lackland Air Force Base. The only criteria used in selection were based on VTA-ND measurements of visual acuity and phorias (1) which were required to be within limits for pilot and aerial observer training (3), and a high basic intelligence level. All men were between the ages of 17 and 22 years.

The subjects were divided into order 1 and order 2, and 48 members were in each classification. Order 1 was tested through the usual order of instrumentation as given to a subject who experienced difficulty in qualifying: VTA-ND, DPA-V, and H-D. Following this sequence, the SAM-V was employed at 3.14, 3.66, and 5.43 m. These three distances were randomized for each order, with 8 subjects being utilized in each of the six possible permutations of the three distances.

Order 2 was established to rule out the possible effects of learning due to previous exposure to the hand-held Verhoeff. The sequence for order 2 was the VTA-ND, SAM-V, H-D, and the DPA-V. Once again, all permutations of the SAM-V distances were employed.

The VTA-ND and Verhoeff testing were conducted in an examining room with approximately 20 ft.-c. (220 lux) of illumination at the working level. The other tests were accomplished in a standard Air Force eyelane with about 3 ft.-c. (33 lux) of lighting.

Pictorial illustrations of the devices and targets are shown in figures 1 to 5.

Each subject was given identical instruction by the same examiner for each of the devices. VTA-ND qualification required the identification of the ring which was stereoscopically displaced closer to the observer than the other four in each line, for all targets through group D. The testee was requested to select the deviant circle for all lines through group F. Group D corresponds to the standard 25-seconds parallactic angle, group E to 20-seconds, and group F to 15-seconds (9).

The DPA-V was administered at the 1-m. distance by the examiner, who hand-held the device, and imposed no head restraints upon the testee. The Verhoeff was transformer-powered to provide a consistent test luminance for all candidates. The brightness values in this instrument and in the H-D were not measured. The authors concur with the Verhoeff (22) statement that in stereoscopic judgments, "The character and the intensity of the light are unimportant within wide limits, even more so than for tests of the visual acuity."

Identification of the bar which was closer or farther than the other two from the observer, for eight presentations given, established depth discrimination for 32 seconds of stereoscopic angle if all were correctly named in the DPA-V.

A headrest was used in testing with the H-D, since the authors believed that motion parallax would be a major factor in depth judgment (18). The test distance was 20 feet (6 m.), and the subject was required to align the movable rod with the fixed one. A mean separation of 30 mm. or better, which has been historically given as 11 seconds of parallactic angle (2, 10, 20, 22) was necessary to pass this test.

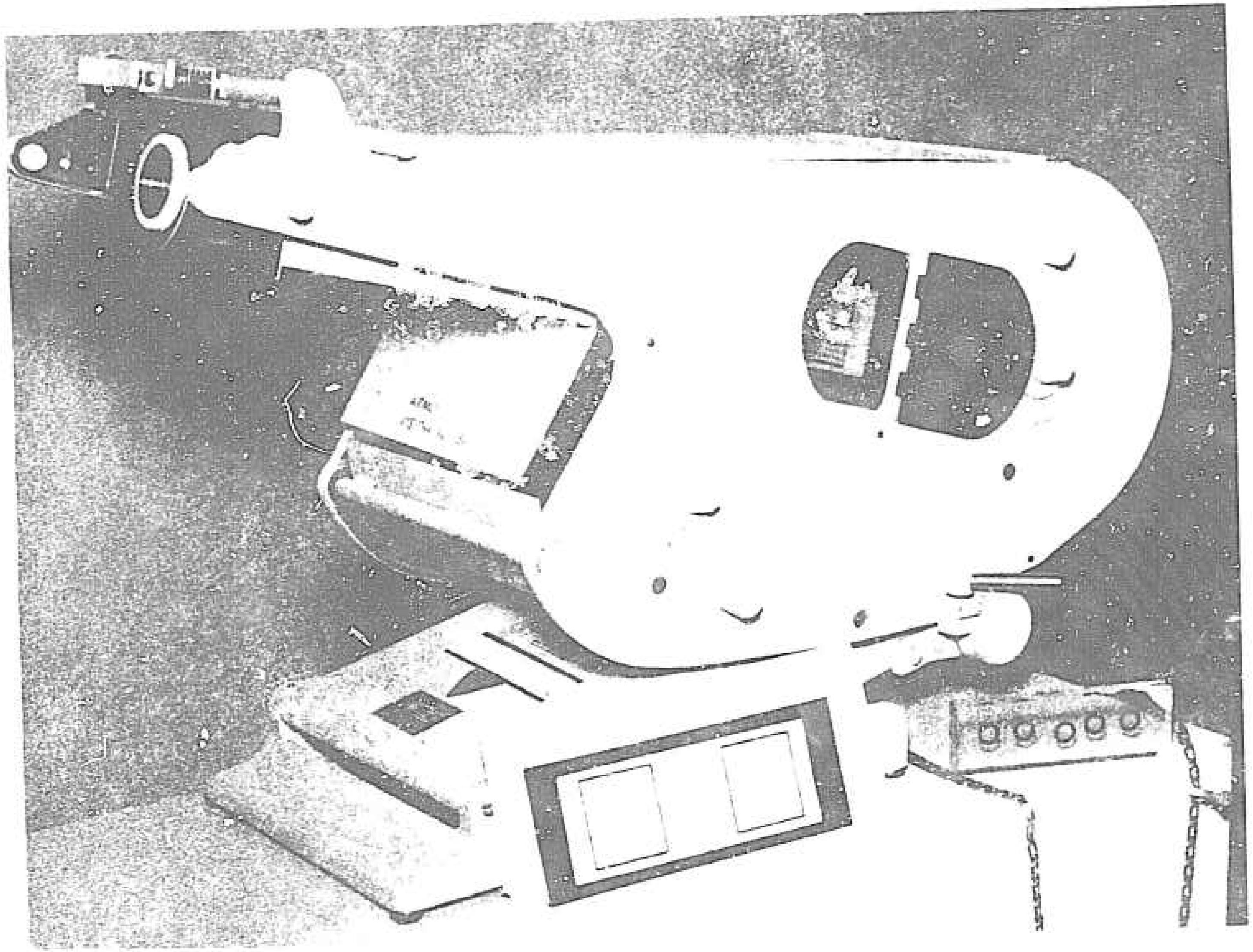

FIGURE 1

Armed Forces Vision Tester Near and Distant (VTA-ND). Stereoscopic slide and instruction plate are shown in front

FIGURE 2

Verhoeff Stereopter (DPA-V) hand held in testing position.

In order to discount the effect of pretest rod position upon the end-point judgment for alignment (23), the movable rod was set at some arbitrary distance behind the fixed rod in three of the trials, and in front, for the other two.

The examinee manipulated the string-pulley arrangement for rod alignment, and was required to completely release the cord after making his judgment.

If the subject failed on any of the standard tests, there was no opportunity given for repeating it, as is the usual procedure provided for in AFM 160-1 (3).

The SAM-V was used for comparative purposes with the three standard instruments. The headrest was used in this test. The SAM-V was placed on a stand with casters, and the test distances (3.14, 3.66, and 5.43 m.)

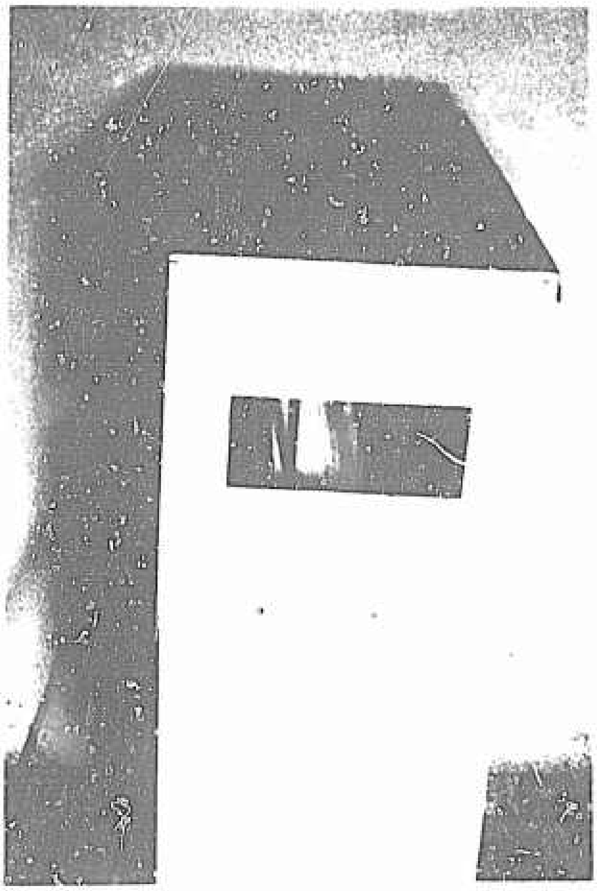

FIGURE 3

Howard Dolman apparatus (H-D). Hand-manipulated strings, and graduated scale are shown.

were marked on the eyelane floor. As suggested in the report by Niven et al. (16), this established a fixed, nonrotating base, so that the bars were exhibited in the frontal plane. The hand-held Verhoeff does not offer this rigidity of position.

III. RESULTS

First, statistical testing was done on the SAM-V data to determine whether the passing results were affected by the different permutations (six) of the three test distances. Each order was tested separately. On order 1 the subjects were tested on the SAM-V apparatus last (all three test distances), and on order 2 the SAM-V apparatus was used second (after VTA-ND). The passing results are given in table I for each permutation and order. Remember, eight different subjects were observed for each permutation on each order. Chi-square testing (21) on each order separately showed that the different permutations of the three SAM distances did not statistically affect the pass or fail results.

Since the permutations of the SAM-V distances did not affect the pass-fail results within each order, the total pass-fail results were compared between the two orders. See the bottom line for each order in table I. Chi-square testing showed that statistically more subjects passed the SAM-V tests for order 2 than for order 1 ($P < .01$). Thus, it appears that if there was a learning effect for order 1, it was offset by a greater fatigue effect. In subsequent testing the data for the different orders on SAM-V are tested separately.

The pass-fail results were also compared between the two orders on each of the three standard methods of testing stereopsis. The results are shown in table II. The chi-square testing showed that the pass-fail results were within statistical fluctuation between the two orders on each of the VTA-ND and H-D methods. However, for the Verhoeff method there was some indication that more subjects passed the test for order 2 than for order 1 ($P < .10$).

The Verhoeff result appears to contradict the SAM-V results. Remember the DPA-V method was used *second* in order 1 and *last* in order 2. If the fatigue explanation given for the SAM-V method was correct, then one would have expected order 2 for Verhoeff to show *fewer* passing the test rather than *more*.

Both SAM-V and DPA-V methods show more subjects passing order 2 than for order 1. One can attribute this to chance or perhaps to a learning factor gained by using the SAM-V earlier in the order which offsets the fatigue effect generated by repetition at the three test distances.

The pass-fail results for the combined orders are given in table III in three different 2 x 2 arrangements on the three standard methods.

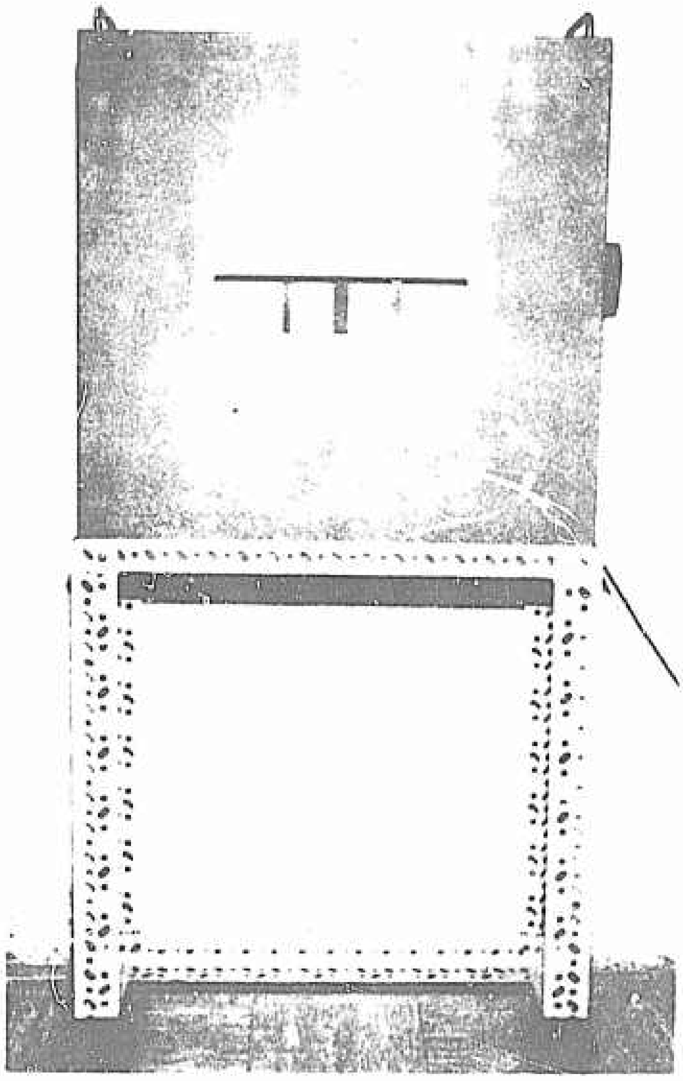

FIGURE 4

USAFSAM apparatus (SAM-V), an enlarged Verhoeff Stereopter.

Each 2 x 2 arrangement was tested separately, although the testing results are not completely independent of each other. Since each method was used on each of the same 96 subjects, the testing between methods is somewhat different from the previous testing between orders where *different* subjects were involved (21). The experimenters were interested in knowing whether the proportion of subjects passing was the same for each of the two methods being considered. The only figures involved in the testing are figures from the cells where the methods do not agree on the passing or failing. Since the total number of disagreements between the methods was small, an exact test was performed on these data using the binomial distribution. Results showed that the proportion of subjects passing the VTA-ND (group D, η = 25″) was essentially not different from the proportion of subjects

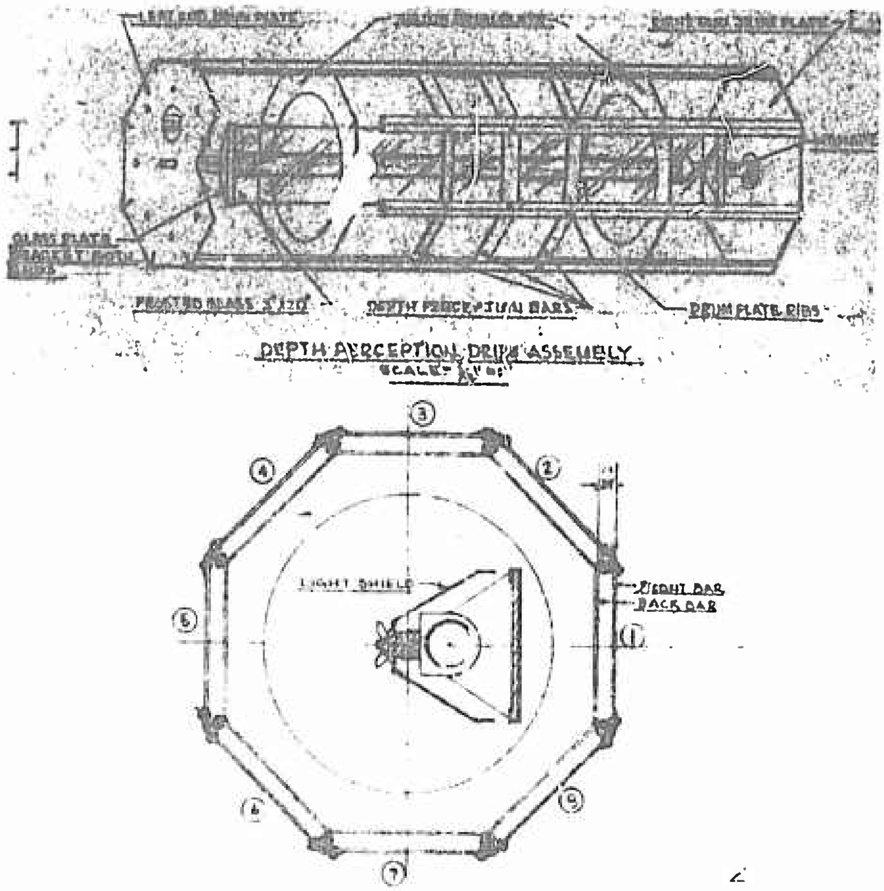

FIGURE 5

Schematic of component parts of SAM-V apparatus.

pass for the Verhoeff (η = 32″) or the H-D method (η = 11″). There was some indication that more subjects passed the Verhoeff than the H-D ($P < .10$).

The pass-fail results are given in 2 x 2 arrangements for each SAM-V distance with each of the three standard methods on each order separately in table IV. The proportion of subjects passing SAM-1 (3.14 m.) was significantly less than the proportion of subjects passing on any of the three methods for order 1 ($P < .01$). On order 2, the proportion of subjects passing SAM-1 was essentially the same as the proportion for the standard methods.

The proportion of subjects passing SAM-2 (3.66 m.) was less than the proportion of subjects passing on any of the three methods for any order. All tests were statistically significant at the .001 level except VTA-ND order 2 ($P < .05$) and H-D order 2 (not significant).

The proportion of subjects passing SAM-3 (5.43 m.) was statistically *less* than the proportion of subjects passing on any of the three methods for any order ($P < .001$). Only 4 of the 96 subjects passed SAM-3.

On each order in table V, the proportion of subjects passing SAM-1 was significantly greater than the proportion passing SAM-2 ($P < .01$). Of course, each of these SAM-V test distances passed significantly more subjects than the SAM-3 distance ($P < .001$). Thus, as the η's decreased on the SAM-V testing, the proportion of subjects passing, decreased.

TABLE I

Passing results on the three distances of SAM-V for each permutation within order

Order	Permutation	Passing results: All three	Both 1 and 2	Either 1 or 2*	None
1	1 2 3†	1	1	1	5
	1 3 2	0	2	3	[illegible]
	2 1 3	0	2	3	3
	2 3 1	0	4	2	2
	3 1 2	1	3	2	2
	3 2 1	0	2	5	1
	Total	2	14	16	16
2	1 2 3	1	3	3	1
	1 3 2	0	8	0	0
	2 1 3	0	4	3	1
	2 3 1	0	7	1	0
	3 1 2	1	4	1	2
	3 2 1	0	6	1	1
	Total	2	32	9	5

*Few passed 2 without passing 1.
†1 - 3.14 m.
2 - 3.66 m.
3 - 5.43 m.

TABLE II

Pass-fail results for each order on each standard method of testing stereopsis

Method	Order	Results: Pass	Fail
VTA	1	41	7
	2	42	6
H-D	1	40	8
	2	40	8
Verhoeff	1	41	7
	2	46	2

TABLE III

Pass-fail results (orders combined) in three 2 x 2 arrangements of the three standard methods

VTA \ Verhoeff	Pass	Fail
Pass	80	3
Fail	7	6
Verhoeff \ H-D	**Pass**	**Fail**
Pass	77	10
Fail	3	6
VTA \ H-D	**Pass**	**Fail**
Pass	76	7
Fail	4	9

TABLE IV

Pass-fail results for each SAM distance with each standard method per order

Order	Method \ SAM	(1) 3.14 m. Pass	(1) 3.14 m. Fail	(2) 3.66 m. Pass	(2) 3.66 m. Fail	(3) 5.43 m. Pass	(3) 5.43 m. Fail
1	Verhoeff						
	Pass	29	12	18	23	2	39
	Fail	1	6	0	7	0	7
	VTA						
	Pass	29	12	16	25	2	39
	Fail	1	6	2	5	0	7
	H-D						
	Pass	28	12	17	23	2	38
	Fail	2	6	2	7	0	8
2	Verhoeff						
	Pass	43	3	34	12	2	44
	Fail	0	2	0	2	0	2
	VTA						
	Pass	40	2	33	9	2	40
	Fail	3	3	1	5	0	6
	H-D						
	Pass	39	1	32	8	2	38
	Fail	4	4	2	6	0	8

TABLE V

Pass-fail comparisons between the SAM distances per order

Order	SAM-1 \ SAM-2	Pass	Fail	SAM-1 \ SAM-3	Pass	Fail	SAM-2 \ SAM-3	Pass	Fail
1	Pas	16	14	Pass	2	28	Pass	2	16
	Fail	2	16	Fail	0	18	Fail	0	30
2	Pass	34	9	Pass	2	41	Pass	2	32
	Fail	0	5	Fail	0	5	Fail	0	14

Table VI shows the pass-fail results of H-D and Verhoeff (both orders) for the subjects who passed the VTA-ND and also for the subjects who failed VTA-ND. From this, one can see that the three methods agreed on a total of 79 (74 + 5) or 82% of the subjects tested. Following the conventional AF order of testing only 13 subjects would have taken the Verhoeff after failing the VTA-ND. Of these, only 6 would have taken the H-D test. However, there was some indication that the H-D method passed fewer subjects than the Verhoeff, and also the proportion passing was essentially the same for the Verhoeff and VTA-ND methods. So, under the conditions of the experiment, the conventional sequence of testing is not too meaningful.

A reason for including order 2 in the experiment was to see what the results would look like for SAM-V if it were to follow the VTA-ND. Since the SAM-V test distances generally passed a smaller proportion of the subjects than the Verhoeff and H-D methods did, it is felt that in the long run SAM-V would qualify very few additional subjects over the VTA-ND.

All of the results given above are dependent on the pass or fail criteria for the different methods.

The proportion of subjects passing the VTA-ND through at least group C was compared with the Verhoeff results since the η's were quite comparable (η = 30″ and η = 32″, respectively.) Statistical results showed no significant difference in proportion of "passes" between these two outcomes. However, there was some indication ($P < .10$) that the proportion of subjects passing VTA-ND through group F was smaller than the proportion passing the H-D (η = 15″ and η = 11″, respectively). The results are shown in table VII.

TABLE VI

Pass-fail results on H-D and Verhoeff methods (both orders) on subjects who passed and failed VTA separately

VTA	Verhoeff \ H-D	Pass	Fail
Pass	Pass	74	6
	Fail	2	1
Fail	Pass	3	4
	Fail	1	5

TABLE VII

Pass-fail results (orders combined) in a 2 x 2 arrangement of VTA-C (through group C) and Verhoeff and also of VTA-F and H-D

VTA-C \ Verhoeff	Pass	Fail
Pass	82	4
Fail	5	5
VTA-F \ H-D	**Pass**	**Fail**
Pass	66	6
Fail	15	10

A total of 86 subjects passed the VTA through group C (η = 30″), 83 through group D (η = 25″), 81 through group E (η = 20″), and 72 through group F (η = 15″).

Nine subjects failed the Verhoeff by having a wrong response on one or more of the eight trials. The following shows a distribution of the number of trials that were missed:

Number of trials missed	*Frequency*
1	1 (Subj. No. 24, order 1)
2	2
3	0
4	1
5	3
6	1
7	1
8	0

Considering that the H-D mean distance variation allows an alignment error of double the resultant, the following comparisons are made: (1) The "η" for a 35 mm. mean variation in the H-D test is computed to be 13 seconds of arc. Assuming that the spread from the fixed bar can vary over 70 mm., this would really represent 26 seconds of arc. This comparison is made with the VTA-ND in table VIII. A similar analysis is made for the 45 mm. mean

TABLE VIII

Pass-fail results (orders combined) in a 2 x 2 arrangement of VTA-D (through group D) and H-D (35 mm. mean variation); also, of Verhoeff and H-D (45 mm. M. V.)

VTA-D 25″ \ H-D(35 mm.) 26″	Pass	Fail
Pass	76	7
Fail	5	8
DPA-V 32″ \ H-D(45 mm.) 33″	**Pass**	**Fail**
Pass	81	6
Fail	5	4

variation (M.V.). By doubling the 16.5 seconds of arc, which this distance represents, the 33-seconds resultant is compared with the Verhoeff in table VIII. The proportion of subjects passing was essentially the same for the two methods compared in each table.

The above results [illegible] ate support of the statement of Ogle [illegible] and Jameson and Hurvitch (12) that the [illegible]reoscopic angle is independent of distance, provided all monocular cues to depth are eliminated.

The bar graph in figure 6 shows a comparison of the results of the four methods. The clear and shaded areas reveal the numbers of passes and failures, respectively, for each of the methods. Where multiple η's are shown within a bar, the [illegible] line is used to separate passes and failures. The η's represent the stereoscopic angles in seconds of arc.

Table IX shows a frequency distribution of the average of the absolute deviations from alignment for the H-D method on the 56 subjects. The distribution manifests a rather

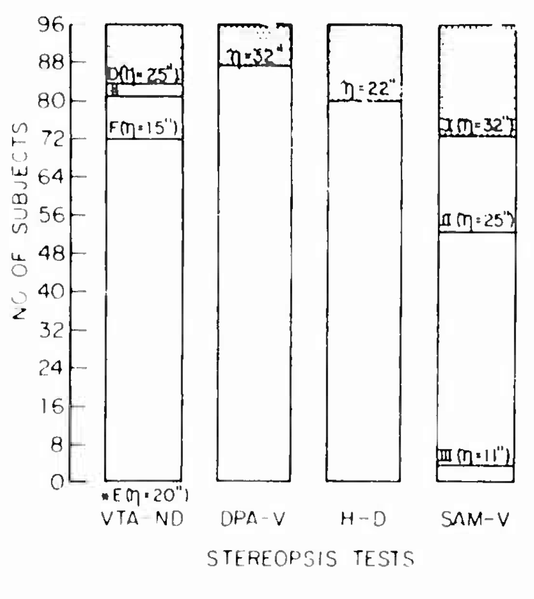

FIGURE 6

Bar graph showing comparison of four stereopsis [illegible]. Shaded [illegible] number of [illegible] passes [illegible] respectively, for the stereoscopic [illegible] each test.

clear separation between the subjects who passed the test and those who did not.

A listing of the pass-fail results for each method on each subject is given in tables X and XI. A sample stereopsis data sheet is shown in figure 7.

IV. CONCLUSIONS

Testing with the standard Air Force depth apparatus produced results that were not statistically different.

Since the VTA-ND incorporates other visual screening tests in its battery, continued use of the device is recommended as the prime method of the three for stereopsis qualification. Some individuals, however, experience difficulty with stereoscopic-viewing devices; therefore, the Verhoeff is offered as the backup depth test.

TABLE IX

Frequency distribution of the average of the absolute deviations for the H-D method

Average deviation intervals (mm.)	Frequency
0-5	6
5-10	12
10-15	24
15-20	16
20-25	12
25-30	10
30-35	1
35-40	4
40-45	1
45-50	3
50-55	0
55-60	2
60-65	1
65-70	0
70-75	0
75-80	2
80-85	0
85-90	0
90-95	1
95-100	0
100	1

TABLE X

Listing of pass-fail results for order 1. (1 Pass; 0 Fail)

Subject	Method						H-D av. dev. (mm.)
	VTA*	VER	H-D	SAM-1	SAM-2	SAM-3	
1	0 —	1	0	0	0	0	45.80
2	0B	0	0	0	0	0	90.20
3	1F	1	1	1	0	0	21.80
4	1F	1	1	1	1	0	24.00
5	1F	1	1	1	1	1	7.60
6	1F	1	1	0	0	0	27.60
7	1F	1	0	0	0	0	59.00
8	0B	0	1	0	0	0	19.80
9	1F	1	1	1	1	0	4.00
10	1F	1	1	0	1	0	20.60
11	1F	1	1	0	0	0	7.80
12	1F	1	1	0	0	0	17.20
13	1F	0	0	0	0	0	44.20
14	1E	1	1	1	0	0	15.00
15	1F	1	1	1	1	0	25.80
16	1F	1	1	1	0	0	9.60
17	0—	0	0	0	0	0	62.80
18	0C	1	1	1	1	0	13.00
19	1F	1	1	0	0	0	12.20
20	1F	0	1	1	0	0	16.00
21	1F	1	1	1	0	0	4.00
22	1F	1	1	1	1	0	11.00
23	1E	1	1	1	0	0	28.20
24	1E	0	1	0	0	0	19.20
25	1E	1	1	1	1	0	20.00
26	1F	1	0	1	0	0	38.60
27	1D	1	1	0	0	0	16.20
28	1F	1	1	1	1	0	22.80
29	1F	1	1	0	0	0	12.40
30	1F	1	1	1	1	0	6.40
31	1F	1	1	1	0	0	22.20
32	1F	1	1	1	1	0	4.60
33	1F	1	0	1	1	0	38.00
34	0B	0	0	0	0	0	56.60
35	1F	1	1	1	1	0	14.20
36	1F	1	1	1	1	1	26.20
37	1D	1	1	1	1	0	18.60
38	1F	1	1	1	0	0	18.60
39	1E	1	1	1	0	0	4.80
40	1F	1	1	0	0	0	12.40
41	1F	1	1	1	1	0	15.40
42	1F	1	1	1	0	0	11.40
43	1E	1	1	0	0	0	20.40
44	1F	1	1	1	0	0	24.40
45	1F	1	1	1	0	0	21.80
46	0—	1	1	0	1	0	24.60
47	1F	1	1	1	0	0	12.40
48	1F	1	1	1	1	0	19.40

*Letters indicate the highest group passed by the subject on VTA-ND.

TABLE XI

Listing of pass-fail results for order 2. (1 = Pass; 0 = Fail)

Subject	Method: VTA*	VER	H-D	SAM-1	SAM-2	SAM-3	H-D av. dev. (mm.)
1	1F	1	0	0	0	0	75.20
2	1F	1	1	1	0	0	26.40
3	1F	1	1	1	1	1	7.40
4	1F	1	1	1	0	0	13.80
5	1F	1	1	1	1	0	12.60
6	1F	1	1	1	1	0	21.40
7	1F	1	1	1	1	0	27.00
8	1F	1	1	1	0	0	11.60
9	1F	1	1	1	1	0	16.80
10	1F	1	1	1	1	0	9.20
11	1F	1	1	1	1	0	28.80
12	1F	1	1	1	1	0	12.60
13	1F	1	1	1	1	0	18.80
14	1F	1	1	1	1	0	9.20
15	1F	1	1	1	1	0	11.60
16	1D	1	1	1	1	0	6.20
17	1F	1	1	1	1	0	18.40
18	1F	1	1	1	0	0	11.80
19	1F	1	0	1	1	0	78.40
20	1F	1	1	1	1	0	26.80
21	1F	1	1	1	0	0	16.00
22	1F	1	1	1	1	0	12.60
23	1F	1	1	0	0	0	9.00
24	1F	1	1	1	0	0	14.80
25	1F	1	1	1	1	0	15.60
26	1F	1	1	1	1	0	14.60
27	1E	1	1	1	1	0	20.80
28	1F	1	1	1	1	0	17.40
29	1F	1	1	1	1	0	14.20
30	1F	1	1	1	1	0	13.00
31	1F	1	1	1	1	0	27.20
32	0—	1	0	1	0	0	45.40
33	0C	0	0	0	0	0	47.20
34	1F	1	1	1	1	0	5.00
35	0—	1	1	0	1	0	15.00
36	0—	0	0	1	0	0	35.20
37	0C	1	0	1	0	0	105.80
38	1E	1	1	1	1	1	11.00
39	1F	1	1	1	1	0	4.80
40	1F	1	1	1	1	0	7.80
41	1E	1	0	1	1	0	35.40
42	1F	1	1	1	1	0	8.00
43	1F	1	1	1	1	0	8.40
44	1F	1	1	1	1	0	22.60
45	1F	1	1	1	0	0	12.00
46	1F	1	1	1	1	0	26.00
47	1F	1	1	1	1	0	10.20
48	0B	1	0	0	0	0	32.00

*Letters indicate the highest group passed by the subject on VTA-ND.

14 DEC. 65.
(AC 8 W.).

Name: JONES, JOHN J. | Organization: FLT 0014/SQ 3725 BMTS (Flt./Sq.)

Serial No.: AF 12625232 | Phone: SQ. C.O.

Age: 19 | P.D.: 66/63 | Subject No.: 16

Order of testing: VTA, Verhoeff, H-D, SAM V ✓

VTA, SAM V, H-D, Verhoeff ____

VTA

	1.	2.	3.
B.	✓	✓	✓
C.	✓	✓	✓
D.	✓	✓	✓
E.	✓	✓	✓
F.	✓	✓	✓

Verhoeff

1. ✓
2. ✓
3. ✓
4. ✓
5. ✓
6. ✓
7. ✓
8. ✓

Howard-Dolman < 3 (BEHIND), 2 (FRONT)

1. 10 mm
2. 40 mm
3. 22 mm
4. 15 mm
5. 27 mm

Total 114 mm

Avg. 23 mm

SAM V

Order	1	3	2
	3.14	3.66	[illegible] 5.43
1.	✓	✓	X
2.	✓	✓	✓
3.	✓	✓	✓
4.	✓	✓	X
5.	✓	X	✓
6.	✓	✓	X
7.	✓	✓	✓
8.	✓	X	X

Visual Acuity

20 ft. R. 20/20 L. 20/17

13 in. R. 20/20. L. 20/17

Phorias

Vertical: 20 ft: ORTHO.

Horizontal: 20 ft: 1 ESO.

13 in: 2 EXO.

FIGURE 7

Sample stereopsis score sheet for each of the four methods tested.

The Howard-Dolman qualified fewer subjects than either of the other two standard methods. It is therefore recommended that this instrument be eliminated as a terminal requirement.

Contrary to Verhoeff's (22) expectation, the SAM-V at an equivalent stereoscopic angle passed a smaller number of subjects than the DPA-V. The examinees were restricted by a headrest with the SAM-V, and this was not required with the DPA-V. Additionally, the DPA-V was hand-held, while the SAM-V was positioned on a stable platform (16). It is believed that these differences in test procedures might account in part for the differences in the results.

The stereopsis tests presently employed are static. True depth judgments, particularly by the pilot, are almost always of a dynamic nature. It is considered that a dynamic test for stereopsis be devised which involves, for example, the alignment of a target and a probe, in motion, in tri-dimensional space. The concept is similar to the operation of an air-to-air refueling system. The stereoscopic angular (η) subtense recommended for the target would be 32 seconds of arc, comparable to that in the Verhoeff test (22).

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13. ABSTRACT

The three standard Air Force depth perception tests for pilot and observer qualification are the Vision Test Apparatus--Near and Distant (VTA-ND), Verhoeff Stereopter (DPA-V), and Howard-Dolman apparatus (H-D).

The stereoscopic angle (η) for the VTA-ND is 25 seconds of arc, 32 seconds for the DPA-V, and 11 seconds for the H-D.

An enlarged Verhoeff (SAM-V) was utilized at equivalent calculated distances to compare with the three instruments under their individual parallactic angle conditions.

Data analysis showed the following: (1) Employment of the standard criteria for flying qualification resulted in the Verhoeff passing the greatest number, followed by the VTA-ND, and the H-D. Neither the Verhoeff nor H-D results statistically differed from those of the VTA-ND. (2) The SAM-V generally passed fewer subjects than the corresponding standard tests. The results found with the standard Air Force tests are not a full measure of depth discrimination capability. A test concept is described which would incorporate a dynamic component into depth judgments.

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Depth perception						
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Armed Forces Vision Tester (VTA-ND)						
Verhoeff Stereopter (DPA-V)						
Howard-Dolman apparatus (H-D)						
USAFSAM Stereopter (SAM-V)						

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