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ARMY MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

REPORT NO. 70
3 December 1951

BINOCULAR STEREOPTIC ACUITY AND SPATIAL LOCALIZATION AS CRITERIA FOR THE EVALUATION OF CONTACT LENSES*

*A joint project under AMRL Project No. 6-95-20-001, Subtask Relationship Between Optical Aids and Perception in Visual Observation, and AMRL Project No. 6-64-12-028, Subtask, Contact Lens Studies.

MEDICAL RESEARCH AND DEVELOPMENT BOARD
OFFICE OF THE SURGEON GENERAL
DEPARTMENT OF THE ARMY

REPORT NO. 70

BINOCULAR STEREOPTIC ACUITY AND SPATIAL LOCALIZATION AS CRITERIA FOR THE EVALUATION OF CONTACT LENSES*

by

E. A. Alluisi, 1st Lt, MSC, G. S. Harker, Psychologist,
J. M. Enoch, 2nd Lt, MSC, R. A. Wickersham, 2nd Lt, MSC,
and J. L. McGraw, Major, MC.

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ABSTRACT

BINOCULAR STEREOPTIC ACUITY AND SPATIAL LOCALIZATION AS CRITERIA FOR THE EVALUATION OF CONTACT LENSES

OBJECT

To provide an exemplary experimental evaluation of two contact lenses with measures of binocular stereoptic acuity and of spatial localization obtained with a stereoptometer as criteria.

To provide a preliminary test of the hypotheses that changes in binocular stereoptic acuity and changes in spatial localization take place when contact lenses are worn.

RESULTS

Binocular stereoptic acuity (a measure of the variable ranging error) was defined in this study as the standard deviation of 10 rangings made with a stereoptometer on a target at 3.02 meters. These scores were analyzed by the analysis of variance technique. There were no significant differences attributable to any of the major effects (subjects, lenses, lengths of time the lenses were worn), or minor effects (interactions).

Spatial localization (a measure of the constant ranging error) was defined in this study as the arithmetic mean of 10 rangings made with a stereoptometer on a target at 3.02 meters. When these scores were analyzed by the analysis of variance technique, significant differences in total performance were found in only one minor effect--the interaction of subjects with the lenses they wore. The three subjects differed significantly in total performance when wearing spectacles, when wearing Dallos fluidless contact lenses, and when wearing Obrig fluid contact lenses. While wearing spectacles, two of the three subjects ranged the target significantly nearer than while wearing either of the contact lenses. The third subject showed no significant differences in spatial localization when the different lenses were worn.

CONCLUSIONS

An exemplary experimental evaluation of two contact lenses has been presented.

A preliminary test has been made of the hypotheses that changes in binocular stereoptic acuity and changes in spatial localization take place when contact lenses are worn. The hypothesis concerning binocular stereoptic acuity is neither strengthened nor weakened by the results because the absolute values of all these scores obtained were too great to be considered due to anything other than to weaknesses in apparatus and procedure. The hypothesis concerning spatial localization appears tenable in light of the findings of some statistically significant differences between mean rangings when contact lenses were worn.

After modification as recommended, both the apparatus and the procedure should be suitable for the experimental evaluation of contact lenses with measures of binocular stereoptic acuity and of spatial localization as criteria.

RECOMMENDATIONS

Measures of binocular stereoptic acuity and of spatial localization should be included in the total evaluation of contact lenses. In such a study, the number of subjects, measurements, targets, and distances involved should be increased above those used in this pilot study.

Certain modifications in the apparatus and procedure of this study should be made before they are used in an experimental evaluation of contact lenses.

Submitted by:
E. A. Alluisi, 1st Lt, MSC
G. S. Harker, Psychologist
J. M. Enoch, 2nd Lt, MSC
R. A. Wickersham, 2nd Lt, MSC
J. L. McGraw, Major, MC

Approved: Ray G. Daggs
RAY G. DAGGS
Director of Research

Approved: Carl F. Tessmer
CARL F. TESSMER
Lt. Colonel MC
Commanding

BINOCULAR STEREOPTIC ACUITY AND SPATIAL LOCALIZATION AS CRITERIA FOR THE EVALUATION OF CONTACT LENSES

I. INTRODUCTION

Possible differences among contact lenses may be classified roughly into four categories: physicial, optical, physiological, and psycho-physiological. The first three categories include such factors as the material structure of the lenses, the refractive status of the lenses, and the corneal clouding caused by the wearing of the lenses. The psycho-physiological category includes such criteria as the development of "haze" and "chromatic halo" in the wearer's visual field, visual acuity performance, color vision performance, the development of photophobia, and the wearer's performance in binocular depth perception.

In the military situation, binocular depth perception is best characterized by performance with a binocular stereoscopic range finder. As such, it may be broken down into two components: binocular stereoptic acuity and spatial localization. The former may be used as an expression of the variable error in range finding, and the latter as an expression of the constant error. With respect to contact lenses, the concrete importance of these criteria is seen in the questions: Does the wearing of contact lenses (rather than spectacles) alter the binocular stereoptic acuity (the variability of ranging) of the wearer? Does the wearing of contact lenses (rather than spectacles) result in a change in the wearer's spatial localizations (mean rangings)?

The hypothesis that changes both in binocular stereoptic acuity and in spatial localization might take place when contact lenses are worn would seem consistent with the fact that physiological changes do take place in the cornea when contact lenses are worn. This pilot study was undertaken as a preliminary test of this hypothesis. It was undertaken also to provide a "shake-down" of the apparatus and of the experimental procedure, and to provide an exemplary experimental evaluation of two contact lenses with measures of binocular stereoptic acuity and of spatial localization obtained with a stereoptometer as criteria.

II. EXPERIMENTAL

The availability of only three suitable subjects for the experiment, as well as the plan to make only a pilot study, dictated the necessity of using an experimental design suitable to small sampling techniques. The three-factor analysis of variance design used was considered adequate for these needs.

A. Apparatus

Because a report (1) will be submitted describing in its entirety the "stereoptometer," the apparatus description will be limited to the minimum necessary for understanding the experimental procedure.

The stereoptometer is basically a binocular stereoscopic range finder devoid of optical magnification and of increased base. The instrument consists of two surplus USAF reflex gun sights, each modified by the addition of a 4-millimeter diaphragm. One sight is mounted in a fixed position on a frame, the other is mounted on a bearing which allows rotation about the eye cup in a horizontal arc. Lateral movement provides adjustment for differing interpupillary distances. For this study, the reticle consisted of a golden-orange circle, the diameter of which subtended 15 minutes of visual arc at the plane of the eye cups.

The observer binocularly views the target through the sights, fusing the two indefinitely projected reticle patterns into a single reticle pattern projected to a determinable radial distance. The observer then rotates the movable sight until the fused reticle pattern is seen to be at the same radial distance as the target. The tangent of the angle of rotation of the one sight with respect to the other is then read from a thousandth-inch dial gauge placed 9.060 inches from the center of the point of rotation. Appropriate trigonometric calculations are made to determine the "range" of the target. These calculations follow the formula:

$$\text{Range} = \frac{(9.06)\ (\text{PD})}{(\text{Gauge Reading})}$$

where PD is the interpupillary distance of the observer (an estimation of his internodal-point distance). With the gauge readings expressed in inches, the range will be expressed in the same units as is the PD. All calculations are based on these transmuted linear-ranging data, not on the original tangential data.

B. Target and Field of View

A solid, round, chrome-plated steel rod 9.0 inches long with a diameter of .375 inch was placed at a point 3.02 meters from the plane of the eye cups (the estimated position of the nodal points of the observer's eyes). This rod was attached to a tripod which supported it vertically so that the top of the rod stood at a position 1.40 meters from the floor level. The eye cups of the stereoptometer were centered 1.33 meters from the floor level. The reticle patterns as projected were placed so as to be seen at 20 minutes of visual arc above the top of the target--this adjustment was made with the aid of a standard Army Ordnance double collimator. Target background was provided by a black screen of low reflectance. The level of illumination, at the position of the target, as measured by a Macbeth illuminometer, was 38 foot-candles; at the position of the eye cups it was 27 foot-candles.

C. Subjects

Three subjects were used. Table 1[1] shows the ages and refractive information on these subjects.

D. Lenses

The spectacles used were standard Army issue, based on cycloplegic refractions. The Dallos lenses were fluidless glass contact lenses, very carefully fitted to sclera and cornea for capillary clearance. These lenses are fenestrated with a small, circular vent which is usually surrounded by an air bubble of small size. Fluid circulates under the lenses in capillary thicknesses. The Obrig lenses were standard plastic-type fluid contact lenses. They feature a large corneal section and good limbal clearance. In fitting, the eye was first molded, a casting was made from this mold, the lenses were formed from this casting, and final adjustments were made after trial on the eye. The solution used with these fluid lenses was 1-1/2 per cent $NaHCO_3$ in distilled water. Both the Dallos and the Obrig lenses will be more fully described in a later report (2).

E. Measures and Design

The interpupillary distance (PD) measure used was the arithmetic mean of 25 measurements per subject taken on an NDRC interpupillometer (3). The three optical aids were used during a period of three days by the three subjects in a balanced Latin Square order of presentation. On each day, rangings were made by each subject eight times between 0800 hours and 1630 hours at hourly intervals except at noon, when no measurements were taken. Additional rangings were made by all subjects 30 minutes before the experimental run (20 minutes before insertion of contact lenses when they were worn), and 30 minutes after the experimental run (10 minutes after removal of contact lenses when worn). In all cases these "before" and "after" rangings were made while wearing spectacles. There was a constant 10-minute time lag between subjects at each time of measurement. Each subject ranged 15

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[1] All Tables appear in the Appendix.

times at each sitting. Of these 15 rangings, the first 3 and last 2 were disregarded in all calculations as a control for "warm-up" and for "end-effect." Thus, the calculations are based on the 10 rangings numbered 4th through 13th on each trial of 15 rangings.

III. RESULTS AND DISCUSSION

A. Binocular stereoptic acuity (the variable ranging error) was defined in this study as the standard deviation in centimeters of 10 rangings made with a stereoptometer on a target at 3.02 meters radial distance. Binocular stereoptic acuity thus defined differs from the Howard-Dolman definition (4) which measures variability about the "true" target distance, including both the variable and constant ranging errors in a single error term.

1. Because a "haze" as well as a "chromatic halo" appears in the field of view of the wearer of contact lenses as a function of the length of time during which the lenses are worn, it was hypothesized that binocular stereoptic acuity scores would differ as a function of the lengths of time the contact lenses were worn. Table 2 presents the binocular stereoptic acuity scores made under the experimental conditions. Table 3 presents the summary of an analysis of variance of these data.

a. This analysis indicates that there were no significant differences in the major effects, i.e., not among subjects, among the lenses worn, nor among the lengths of time the lenses were worn.

b. The analysis shows also that there were no significant differences in the minor effects, i.e., no interactions of subjects with lenses worn, of subjects with the lengths of time the lenses were worn, nor of lenses worn with the lengths of time these lenses were worn.

c. These results seem to indicate that there is no correlation between "haze" and binocular stereoptic acuity. Paradoxically, however, they might be due to the low level of ambient light falling on the eyes. It is believed that the experiment should be repeated with a higher level of ambient illumination (e.g., 100 foot-candles). In this connection, the 4-mm diaphragms in the eye cups of the apparatus might be enlarged or completely abandoned.

2. Because differential "hazes" develop with the wearing of different lenses, it was hypothesized that the obtained binocular stereoptic acuity scores would differ significantly if the wearing of different types of lenses were introduced as an interpolated activity. The 8-hour interval was used because this length is sufficient to produce an appreciable "haze" with the Obrig lens, little "haze" with the Dallos lens, and

no noticeable "haze" with spectacles. The rangings made (while wearing spectacles) 30 minutes before the experimental presentations and 30 minutes after the experimental presentations will be called, respectively, the "before" and the "after" rangings. The lenses worn during the experimental presentations will be called the interpolated lenses. Table 4 presents the binocular stereoptic acuity scores made under "before" and "after" conditions. Table 5 presents the summary of an analysis of variance of these data. There were no significant differences in major or minor effects.

3. It was further hypothesized that although there were no differences between the "before" and the "after" binocular stereoptic acuity scores, and although there were no differences among the measurements obtained with the various lenses under the experimental conditions, there might yet remain a difference between the averaged "before-after" measurements and those of any one of the experimental presentations. Table 6 presents the arithmetic means of the binocular stereoptic acuity scores made by each subject per experimental condition, and by each subject for the averaged "before-after" conditions. Table 7 presents the summary of an analysis of variance of these data. This analysis indicates that there were no significant differences in binocular stereoptic acuity scores among subjects, nor among the averaged "before-after" measurements and the three separate measurements taken during the experimental presentations.

4. Since the three preceding analyses have yielded negative results, one would be led to predict no differential binocular stereoptic acuity performances with different contact lenses except for two considerations, the first of which (ambient illumination) has been discussed in paragraph 1c, above. The second is the absolute values of the binocular stereoptic acuity scores obtained (e.g., 12-154 cm in Table 2, representing approximate parallactic angular standard deviations of 160-1380 seconds). These are too great to be considered representative of the subjects' binocular stereoptic abilities. It is believed that they may be bettered (lowered) by making the following changes in apparatus and procedure:

a. Provide a head rest and a chin cup in the apparatus to better stabilize the subject's head and eyes.

b. Modify the stereoptometer to allow symmetrical vergence of both right and left reticle beams instead of the present possible vergence of the right beam only. This would provide phenomenally true radial movement of the reticle image instead of the present phenomenal movement from far-right to near-left.

c. Provide a more structured target and field of view to insure subjective stability of the field. This is thought to be important in that any subjects available for an evaluatory study such as this would, of necessity, have visual defects perhaps augmented by abnormal phorias and suppressions. For these anomalies a well structured field is necessary for fused binocular vision.

B. Spatial localization was defined in this study as the arithmetic mean in centimeters of 10 rangings made with a stereoptometer on a target at 3.02 meters radial distance. The difference between the "true" target distance and the spatial localization of the target is the constant ranging error.

1. Because of the different optical magnifications given by spectacles and contact lenses (as a function of their different corrective planes), it was hypothesized that there would be significant differences in the spatial localizations (mean rangings) made with the different lenses. Table 8 presents the spatial localization scores made under the experimental conditions. Table 9 presents the summary of an analysis of variance of these data as far as the general analysis could be carried.

a. This analysis indicates that, in the major effects, no general analysis of the significance of differences among subjects, and among lenses, could be computed because of a significant but non-homogeneous minor effect (S x L). There were, however, no significant differences in the third major effect, i.e., among lengths of time the lenses were worn.

b. The analysis shows also that, in the minor effects, there is a significant F-ratio attributable to the interaction of subjects with lenses. However, the cause for the significance of the F-ratio cannot be assigned to the differences among the 9 "subject by lenses" totals of Table 8 because the variances of the 9 "subject by lenses" rows are not homogeneous.[2] There were no significant differences in the other minor

[2] Bartlett's test for homogeneity of variance was computed for the variances of the 9 "subject by lenses" rows of Table 8. This test yielded a corrected Chi-square of 31.45. For 8 degrees of freedom, a Chi-square of 26.10 is associated with a probability of .001. Thus, the hypothesis of homogeneity of variance for the particular rows tested is rejected at less than the 0.1 per cent level of confidence.

effects, i.e., no interactions of subjects with lengths of time the lenses were worn, nor of lenses with lengths of time they were worn.

c. Table 10 summarizes the analyses of variance of the data of Table 8 for three separate types of lenses. The cause for the significance of the F-ratios cannot be assigned to the differences among the respective totals since the variances of the rows (subjects) within each of the three sections of Table 8 was found to be non-homogeneous.[3] Table 10 indicates, however, that the subjects differed significantly in performance while wearing each of the optical aids.

d. Table 11 presents the subject totals of the 9 major rows of Table 8. Table 12 presents the summaries of analyses of variance for the spatial localization scores of each of the three subjects.

(1) Section A indicates that subject 1 ranged quite differently when wearing the different lenses. Since the variances of subject 1's mean rangings with the three lenses are homogeneous,[4] the significance of the F-ratio can be attributed to the differences among his spatial localization score totals. Table 13 shows that, while wearing spectacles, this subject ranged the target significantly nearer than he did while wearing either of the contact lenses; and that, while wearing the Obrig fluid lenses, he ranged it significantly nearer than he did while wearing the Dallos fluidless lenses.

(2) Section B indicates that subject 2's spatial localization scores with the three lenses did not differ significantly among themselves.

(3) Section C indicates that subject 3 ranged differently when wearing the different lenses. Since the variances of subject 3's mean rangings with the three lenses are homogeneous,[4] the significance of the F-ratio can be attributed to the differences among his spatial localization score totals. Table 14 shows that, while wearing spectacles, this subject ranged

[3]The corrected Chi-squares resulting from Bartlett's test for homogeneity of variance for the three sections were as follows: Spectacles, Cor X^2 = 9.962 ($p < .01$); Dallos lenses, Cor X^2 = 9.598 ($p < .01$); Obrig lenses, Cor X^2 = 9.551 ($p < .01$).

[4]The corrected Chi-squares resulting from Bartlett's test for homogeneity of variance for the variances of the rangings of subjects 1 and 3 were as follows: Subject 1, Cor X^2 = 1.02 ($p > .50$); Subject 3, Cor X^2 = 2.17 ($p > .30$).

the target significantly nearer than he did while wearing either of the contact lenses. The difference between his Dallos ranging and his Obrig ranging, although in the same direction as with subject 1, is not a significant difference.

2. Because of the different optical magnifications given by spectacles and contact lenses (as a function of their different corrective planes), and because differential "hazes" develop with the wearing of different lenses, it was hypothesized that the obtained spatial localization scores (mean rangings) would differ significantly if the wearing of different types of lenses were introduced as an interpolated activity. Table 15 presents the spatial localization scores made under the "before" and the "after" conditions. Table 16 presents the summary of an analysis of variance of these data. There were no significant differences in major or minor effects.

C. Since there have been no significant differences in either binocular stereoptic acuity or spatial localization resulting from the "before-and-after" measurements, it seems appropriate to conclude that these measurements may be omitted from any future replication.

IV. SUMMARY

A. With binocular stereoptic acuity (the variable ranging error) defined as the standard deviation in centimeters of 10 rangings made with a stereoptometer on a target at 3.02 meters:

1. Analysis of performance during the experimental presentations revealed no significant differences in either major or minor effects.

2. Analysis of performance measured while wearing spectacles 30 minutes before, and again 30 minutes after, the experimental presentations revealed no significant differences in effects.

3. Analysis of the arithmetic means of the binocular stereoptic acuity scores made by the three subjects under each of the three experimental conditions, and of the averaged "before-after" measurements, revealed no significant differences in either major or minor effects.

B. With spatial localization defined as the arithmetic mean in centimeters of 10 rangings made with a stereoptometer on a target at 3.02 meters:

1. Analysis of performance during the experimental presentations revealed a significant but non-homogeneous minor effect, the interaction of subjects with types of lenses worn. Subsequent analyses revealed:

a. The subjects differed significantly in total performance when wearing spectacles, when wearing the Dallos lenses, and when wearing the Obrig lenses.

b. While wearing spectacles, two of the three subjects ranged the target significantly nearer than while wearing either of the contact lenses. The third subject showed no significant differences in spatial localization when the different lenses were worn.

2. Analysis of performance measured while wearing spectacles 30 minutes before, and again 30 minutes after, the experimental presentations revealed no significant differences in either major or minor effects.

C. The following alterations in apparatus and procedure have been indicated for any replication:

1. Apparatus

a. Provision of head rest and chin cup.

b. Removal or enlargement of 4-mm diaphragms.

c. Provision of symmetrical vergence of both reticle beams.

2. Procedure

a. Provision of a high level of ambient illumination at the eye cups of the apparatus.

b. Provision of a more structured target and field of view.

c. Discontinuance of the "before" and the "after" measurements.

V. CONCLUSIONS

A. An EXEMPLARY experimental evaluation of two contact lenses has been presented. Had this been an ACTUAL evaluation, it would have been concluded that:

1. In terms of binocular stereoptic acuity as defined, the three optical aids used do not differ significantly. They are, therefore, of equal acceptability with this criterion.

2. In terms of spatial localization as defined, no evaluation can be made from the obtained data, but the indications are that significant differences in total performance exist--these attributable to the interaction of wearers with types of lenses worn.

B. A preliminary test has been made of the hypotheses that changes in binocular stereoptic acuity and changes in spatial localization take place when contact lenses are worn.

1. The hypothesis concerning binocular stereoptic acuity is neither strengthened nor weakened by the results because the absolute values of all these scores obtained were too great to be considered due to anything other than to weaknesses in apparatus and procedure.

2. The hypothesis concerning spatial localization appears tenable in light of the findings of some statistically significant differences between mean rangings when contact lenses were worn.

C. After modification as recommended, both the apparatus and the procedure should be suitable for the experimental evaluation of contact lenses with measures of binocular stereoptic acuity and of spatial localization as criteria.

VI. RECOMMENDATIONS

A. Measures of binocular stereoptic acuity and of spatial localization should be included in the total evaluation of contact lenses. In such a study, the number of subjects, measurements, targets, and distances involved should be increased above those used in this pilot study.

B. The following modifications in the apparatus and procedure of this study should be made before they are used in an experimental evaluation of contact lenses:

1. Apparatus

a. Provision of head rest and chin cup.

b. Removal or enlargement of 4-mm diaphragms.

c. Provision of symmetrical vergence of both reticle beams.

2. Procedure

a. Provision of a high level of ambient illumination at the eye cups of the apparatus.

b. Provision of a more structured target and field of view.

c. Discontinuance of the "before" and the "after" measurements.

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APPENDIX

TABLE I

AGES AND REFRACTIVE DATA OF SUBJECTS

Subject No.	Age (yrs)	PD (mm)	Visual Acuity*						Spectacle Correction	
			Uncorrected			Corrected				
			OD	OS	OU	OD	OS	OU	OD	OS
1	19	65.1	20/200	20/200	20/200	$20/20^{-1}$	$20/20^{-1}$	$20/20^{-1}$	+7.50= -1.25x170	+8.00= -1.25x15
2	20	66.8	20/300	20/200	20/200	20/15	20/15	20/15	-3.25	-2.75= -0.75x180
3	23	69.9	20/200	20/200	20/200	20/15	20/15	20/15	-2.75= -0.75x120	-2.75= -0.75x60

*The test of visual acuity used was the Landolt-C at 12 foot-lamberts target brightness.

TABLE 2

BINOCULAR STEREOPTIC ACUITY SCORES* OF 3 SUBJECTS UNDER 3 EXPERIMENTAL CONDITIONS OVER A 490-MINUTE PERIOD

Conditions (Lenses)	Subjects	Minutes since insertion of contact lenses								Total
		10	70	130	190	310	370	430	490	
Spectacles (S)	1	78	50	56	28	50	32	43	30	367
	2	36	36	24	34	46	66	70	78	390
	3	62	22	27	36	39	37	154	42	419
Spectacle	Total	176	108	107	98	135	135	267	150	1176
Dallos Lenses (I)	1	26	25	42	74	44	32	48	29	320
	2	35	21	28	20	36	53	51	24	268
	3	66	67	34	65	66	26	29	35	388
Dallos	Total	127	113	104	159	146	111	128	88	976
Obrig Lenses (II)	1	44	14	31	34	45	45	32	45	290
	2	51	41	54	48	26	98	32	34	384
	3	12	28	23	28	131	49	31	41	343
Obrig	Total	107	83	108	110	202	192	95	120	1017
GRAND TOTAL		410	304	319	367	483	438	490	358	3169

*Standard deviation of 10 rangings, in centimeters.

TABLE 3

ANALYSIS OF VARIANCE OF DATA OF TABLE 2

Source of Variation	Sum of Squares	df	Variance Estimate	F	F* necessary for p = .05
Subjects (S)	636	2	318	0.526	3.34
Lenses (L)	930	2	465	0.768	3.34
Minutes worn (M)	3894	7	556	0.919	2.36
S x L	994	4	248	0.411	2.71
S x M	7270	14	519	0.858	2.06
L x M	8990	14	642	1.061	2.06
S x L x M	16943	28	605	---	---
Total	39657	71	---	---	---

*F's in this and following tables are from (5), pp. 410-413. Figures given under "p = .05" are the 5 per cent points for the distribution of F with the given degrees of freedom (df).

TABLE 4

BINOCULAR STEREOPTIC ACUITY SCORES*
OF 3 SUBJECTS WEARING SPECTACLES BEFORE
AND AFTER THE EXPERIMENTAL PRESENTATIONS

Subject No.	Before Experimental Presentations			After Experimental Presentations			Total
	Experimental Conditions			Experimental Conditions			
	S	I	II	S	I	II	
1	28	36	42	21	43	101	271
2	72	18	52	52	45	52	291
3	47	48	47	62	23	59	286
Total	147	102	141	135	111	212	848

*Standard deviation of 10 rangings, in centimeters. S - Spectacles; I - Dallos fluidless lenses; II - Obrig lenses.

TABLE 5

ANALYSIS OF VARIANCE OF DATA OF TABLE 4

Source of Variations	Sum of Squares	df	Variance Estimate	F	F necessary for p = .05
Subjects (S)	36	2	18	0.044	6.94
Interpolated Lenses (L)	1633	2	816	1.990	6.94
Before-After (BA)	257	1	257	0.627	7.71
S x L	2086	4	521	1.271	6.39
S x BA	332	2	166	0.405	6.94
L x BA	621	2	310	0.756	6.94
S x L x BA	1641	4	410	---	---
Total	6606	17	---	---	---

TABLE 6

ARITHMETIC MEANS OF BINOCULAR STEREOPTIC ACUITY SCORES*
MADE BY 3 SUBJECTS UNDER 3 EXPERIMENTAL CONDITIONS
AND "BEFORE-AND-AFTER" THE EXPERIMENTAL RUNS

Subjects	B-A	Experimental Conditions			Total
		S	I	II	
1	45.2	45.9	40.0	36.2	167.3
2	48.5	48.8	33.5	48.0	178.8
3	47.7	52.4	48.5	42.9	191.5
Total	141.4	147.1	122.0	127.1	537.6

*Standard deviations of 10 rangings, in centimeters.

B-A - Means of the 6 "before-after" measurements made by each subject while wearing spectacles; data of Table 4.

S - Spectacles; I - Dallos fluidless lenses; II - Obrig fluid lenses; these are means of the 8 measures made by each subject under each of the 3 experimental conditions; data of Table 2.

TABLE 7

ANALYSIS OF VARIANCE OF DATA OF TABLE 6

Source of Variation	Sum of Squares	df	Variance Estimate	F	F necessary for p = .05
Subjects (S)	73.26	2	36.63	1.60	5.14
Lenses (L)	139.11	3	46.37	2.03	4.76
S x L	137.09	6	22.85	---	---
Total	349.46	11	---	---	---

TABLE 8

SPATIAL LOCALIZATION SCORES* MADE BY 3 SUBJECTS UNDER 3 EXPERIMENTAL CONDITIONS OVER A 490-MINUTE PERIOD ON A TARGET 302 CENTIMETERS DISTANT

Conditions (Lenses worn)	Subjects	Minutes since insertion of contact lenses								Total
		10	70	130	190	310	370	430	490	
Spectacles (S)	1	306	303	306	303	303	299	296	294	2410
	2	314	310	299	297	284	331	317	321	2473
	3	296	285	280	287	280	285	298	285	2296
Spectacles Total		916	898	885	887	867	915	911	900	7179
Dallos Lenses (I)	1	314	318	318	319	324	315	323	321	2552
	2	305	302	306	305	304	297	291	301	2411
	3	314	324	303	299	308	305	328	296	2477
Dallos Total		933	944	927	923	936	917	942	918	7440
Obrig Lenses (II)	1	317	310	311	312	314	309	314	317	2504
	2	320	313	294	299	304	294	286	302	2412
	3	304	299	290	290	323	305	298	308	2417
Obrig Total		941	922	895	901	941	908	898	927	7333
GRAND TOTAL		2790	2764	2707	2711	2744	2740	2751	2745	21952

*Arithmetic means of 10 rangings in centimeters

TABLE 9

ANALYSIS OF VARIANCE OF DATA OF TABLE 8.

Source of Variation	Sum of Squares	df	Variance Estimate	F	F necessary for p = .05* or .01#
Subjects (S)	1615	2	807.5	( )	3.34*
Lenses (L)	1435	2	717.5	( )	3.34*
Minutes worn (M)	560	7	80.0	1.03	2.36*
S x L	2310	4	577.5	7.41	4.07#
S x M	1021	14	72.93	0.94	2.06*
L x M	1189	14	84.93	1.09	2.06*
S x L x M	2175	28	77.68	---	---
TOTAL	10305	71	---	---	---

( ) No F ratio computed since the S x L term is significant.
* The 5 per cent point for the distribution of F with the given df.
# The 1 per cent point for the distribution of F with the given df.

TABLE 10

SUMMARY BY LENS OF ANALYSIS OF VARIANCE OF DATA OF TABLE 8

	Source of Variation	Sum of Squares	df	Variance Estimate	F	F necessary for p = .05* or .01#
A. Spectacles	Subjects (S)	2012	2	1006	10.37	6.51#
	Minutes worn (M)	678	7	97	1.00	2.77*
	S x M	1361	14	97	---	---
	Total	4051	23	---	---	---
B. Dallos Lens	S	1244	2	622	9.15	6.51#
	M	252	7	36	0.53	2.77*
	S x M	948	14	68	---	---
	Total	2444	23	---	---	---
C. Obrig Lens	S	669	2	334	5.30	3.74*
	M	819	7	117	1.86	2.77*
	S x M	888	14	63	---	---
	Total	2376	23	---	---	---

TABLE 11

SUMS BY SUBJECT OF SPATIAL LOCALIZATION SCORES* MADE BY 3 SUBJECTS UNDER 3 EXPERIMENTAL CONDITIONS OVER A 490-MINUTE PERIOD ON A TARGET 302 CENTIMETERS DISTANT**

Subject	Minutes since insertion of contact lenses								Total	Sub-totals		
	10	70	130	190	310	370	430	490		S	I	II
1	937	931	935	934	941	923	933	932	7466	2410	2552	2504
2	939	925	899	901	892	922	894	924	7296	2473	2411	2412
3	914	908	873	876	911	895	924	889	7190	2296	2477	2417
Total	2790	2764	2707	2711	2744	2740	2751	2745	21952	7179	7440	7333

* Arithmetic means of 10 rangings, in centimeters.

** Data of Table 8.

S - Spectacles; I - Dallos lenses; II - Obrig lenses.

TABLE 12

SUMMARY BY SUBJECT OF ANALYSIS OF VARIANCE OF DATA OF TABLE 11

	Source of Variation	Sum of Squares	df	Variance Estimate	F	F necessary for p = .05* or .01#
A. Subject 1	Lenses (L)	1304	2	652	40.75	6.51#
	Minutes worn (M)	63	7	9	0.56	2.77*
	L x M	229	14	16	---	---
	Total	1596	23	--	---	---
B. Subject 2	L	315	2	158	1.17	3.74*
	M	719	7	103	0.76	2.77*
	L x M	1890	14	135	---	---
	Total	2924	23	---	---	---
C. Subject 3	L	2125	2	1062	11.93	6.51#
	M	798	7	114	1.28	2.77*
	L x M	1247	14	89	---	---
	Total	4170	23	---	---	---

TABLE 13

SIGNIFICANCE OF DIFFERENCES BETWEEN
MEAN SPATIAL LOCALIZATION SCORES OF SUBJECT 1

Lenses	Means (cm)	Differences Tested	F	p
S	301.25	S-I	77.55	<.001
I	319.00	S-II	37.99	<.001
II	313.00	I-II	13.26	<.01

S - Spectacles; I - Dallos fluidless contact lenses; II - Obrig fluid contact lenses.

TABLE 14

SIGNIFICANCE OF DIFFERENCES BETWEEN
MEAN SPATIAL LOCALIZATION SCORES OF SUBJECT 3

Lenses	Means (cm)	Differences Tested	F	p
S	287.00	S-I	23.08	<.01
I	209.625	S-II	11.49	<.05
II	302.125	I-II	1.818	>.05

S - Spectacles; I - Dallos fluidless contact lenses; II - Obrig fluid contact lenses.

TABLE 15

SPATIAL LOCALIZATION SCORES*
OF 3 SUBJECTS WEARING SPECTACLES
BEFORE AND AFTER THE EXPERIMENTAL PRESENTATIONS

Subject No.	Before Experimental Presentations			After Experimental Presentations			Total
	Experimental Conditions			Experimental Conditions			
	S	I	II	S	I	II	
1	293	304	312	313	316	310	1848
2	304	307	312	307	293	301	1824
3	295	306	300	280	294	300	1775
Total	892	917	924	900	903	911	5447

* Arithmetic means of 10 rangings, in centimeters.
S = Spectacles; I = Dallos fluidless lenses; II = Obrig lenses.

TABLE 16
ANALYSIS OF VARIANCE OF DATA OF TABLE 15

Source of Variation	Sum of Squares	df	Variance Estimate	F	F necessary for p = .05
Subjects (S)	461	2	230	4.26	6.94
Interpolated Lenses (L)	159	2	80	1.48	6.94
Before-After (BA)	20	1	20	0.37	7.71
S x L	175	4	44	0.81	6.39
S x BA	333	2	166	3.07	6.94
L x BA	51	2	25	0.46	6.94
S x L x BA	217	4	54	---	---
Total	1416	17	---	---	---