EFFECT OF TRAINING ON ACUITY OF PERIPHERAL VISION

by

Frank N. Low

A report on research conducted at the School of Medicine, University of North Carolina, with the cooperation of the U. S. Navy, by means of a grant-in-aid from the National Research Council Committee on Selection and Training of Aircraft Pilots, from funds provided by the Civil Aeronautics Administration.

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LETTER OF TRANSMITTAL

NATIONAL RESEARCH COUNCIL

2101 Constitution Avenue, Washington, D. C.
Division of Anthropology and Psychology

Committee on Selection and Training of Aircraft Pilots

September 26, 1946

Dr. Dean R. Brimhall
Director of Research
Civil Aeronautics Administration
Room 3895, Commerce Building
Washington 25, D. C.

Dear Dr. Brimhall:

Attached is a report entitled The Effect of Training on Acuity, by Frank N. Low, submitted by the Committee on Selection and Training of Aircraft Pilots with the recommendation that it be included in the series of Technical Reports of the Division of Research, Civil Aeronautics Administration.

Earlier experiments conducted by the Committee suggested that peripheral vision played a significant role in pilot performance, particularly during the approach and landing.[1,2] It therefore seemed fitting to undertake research directed towards the more exact and reliable measurement of individual differences in acuity of peripheral vision and towards investigating the possibility of improving peripheral vision through training. The attached report is devoted to a discussion of the results of such experiments. Of particular interest in this report are the findings concerning the improvement of peripheral vision with training. These suggest the need of further experimentation designed especially to determine the transfer of training of the type recommended in this report to the actual flying situation.

Cordially yours,

Morris S. Viteles, Chairman
Committee on Selection and
Training of Aircraft Pilots
National Research Council

MSV:pd

[1] Tiffin, J., and Bromer, J. Analysis of eye fixations and patterns of eye movement in landing a Piper Cub J-3 airplane. Washington, D. C.: CAA Division of Research, Report No. 10, February 1943.

[2] Pfaffmann, C. Progress reports on the study of visual depth perception in aviation, supplement to Tiffin, J., and Bromer, J. Op. cit.

FOREWORD

The course of systematic training reported here is an outgrowth of earlier research in peripheral vision conducted under grants-in-aid from the Committee on Aviation Medicine. The present study, conducted under the auspices of the Committee on Selection and Training of Aircraft Pilots, represents an extended investigation to answer certain questions posited by this earlier research.

Acknowledgment and thanks are due to Dr. R. C. Rogers, formerly of the Editorial Staff of the Committee on Selection and Training of Aircraft Pilots, for aid and advice in the design of the investigation, to the Naval Commands at Chapel Hill, North Carolina, to the administrative offices of the University of North Carolina, and to students and others for making possible the successful completion of this project.[1]

[1]The author is now connected with the Department of Anatomy, Johns Hopkins Medical School, Baltimore, Maryland.

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SUMMARY

This report is concerned with a course of systematic training of peripheral vision carried out under the auspices of the National Research Council Committee on Selection and Training of Aircraft Pilots. Such training was believed to be of value since problems encountered in the landing and take-off of aircraft suggested that peripheral visual acuity might at times be a critical factor determining pilot performance.

The apparatus employed in the investigation was a hand-operated perimeter with a primary arm supported from the base, which determined the meridian along which the test object could be set, and a secondary arm supported by the primary arm which determined the angular deviation of the object from the line of vision. The end of the secondary arm supported an attachment with a shutter which provided for the rapid exposure of test objects.

The test objects consisted of Landolt Broken Circles in fourteen sizes, four types of airplane silhouettes each in five sizes, and Isolated Forms composed of four isolated small objects, three squares and one circle, arranged on the circumference of an imaginary parent circle.

In the training regime an initial test (acuity) was given with a check test every fourth period thereafter. In the intervening periods there was practice with airplane silhouettes. When working with the airplane silhouettes the subjects identified the direction the plane was pointing according to the criterion of four consecutive correct answers before two misses. The identifications were begun 20 degrees from the line of vision and the plane moved out 10 degrees upon successful identification. This was repeated until the subject failed. The test object was then moved 5 degrees inward to get a reading accurate to 5 degrees. The greatest angular deviation at which the subject was successful was recorded. When the procedure was completed for one eye the operator and subject changed places.

Special tests included in the training regime were the Rotated Meridians Test (the subject was tested with circles on meridians located halfway between the meridians tested and trained), the Night Visual Acuity Test (in which the circle test was run under scotopic conditions), and the Rapid Recognition Test (in which the circle test was run with a shutter in the line of peripheral vision -- exposures for all determinations being set at 1/5 second).

The transfer techniques used in the training regime included 1) the Isolated Forms described above, 2) ten tries at identifying the break in a No. 10 circle at 90 degrees from the line of vision on the "out" and "down and out" meridians in each eye, and (3) the Non-perimetric Binocular Test. In the latter test the subject fixated a button 15 degrees to the right and then 15 degrees to the left. When fixating 15 degrees above and then below, ten tries were given with a size No. 5 circle.

The subjects were naval and civilian students enrolled at the University of North Carolina in a course designed for the testing and training of peripheral visual acuity. The 43 subjects were divided into two groups. Group II (N = 25) received one less period than Group I (N = 18). A Rapid Recognition Test was given to Group II on Period 2. Certain of the transfer tests given at the beginning and end of the course were allocated to the two groups at different periods. Group II received a Non-perimetric Binocular Transfer Test on the last period.

Three types of scores were derived (acuity, millimeter variability, and percentile steadiness scores), and the averages of these scores for the eight straight tests for the two groups (N = 43) were compared. The curve for the acuity scores appeared to improve rapidly and then indicated a tendency to level off. The curve for the millimeter variability scores showed the same form as the acuity scores curve so that the curve for the percentile steadiness scores tended to be flat. Data for the special tests and transfer tests (Rapid Recognition Test, Night Visual Acuity Test, Rotated Meridians Test, Tests with No. 10 Circle at 90 degrees, Non-perimetric Binocular Test, and the Monocular Transfer Test) indicated that improvement in peripheral visual acuity under each of these test conditions occurred.

Correlations of acuity, millimeter variability, and percentile steadiness scores derived from the eight straight tests were obtained for the two groups (N = 43). The findings indicated that:

1. Correlations of the acuity scores of the first straight test with subsequent straight tests were all significant at the 1% level of confidence, with the exception of the correlation of the eighth straight test with the first, where the r did not reach an acceptable level of significance.

2. Correlations of the acuity scores with the mm. variability scores on the same test were all significant, ranging from .47 to .78. These correlations showed little tendency to improve during the course of training.

3. The r's of the acuity scores with the percentile steadiness scores on the same test did not reach an acceptable level of significance.

4. The mm. variability scores showed significant test-retest correlations in 4 out of 6 cases, but none of the coefficients was high.

5. The mm. variability scores correlated with the percentile steadiness scores on the same test with significant coefficients in all cases.

6. The percentile steadiness scores failed to correlate with each other significantly, either on a test-retest basis or in terms of the relationship of the initial score to those of any subsequent test.

The scores of the special tests conducted toward the end of the training procedure were correlated with the scores of the 8th straight (final) test. Acuity with rotated meridians correlated .85 with the acuity of the 8th test, while acuity with rapid recognition correlated with acuity on the 8th test with an r of .74. It was observed that acuity with rapid recognition correlated .63 with night visual acuity, suggesting the possibility of substituting the easily acquired rapid recognition scores for the difficult-to-obtain night visual acuity measures.

EFFECT OF TRAINING ON ACUITY OF PERIPHERAL VISION

INTRODUCTION

The fundamental phenomena associated with the acuity of peripheral vision were investigated by workers of the German school during the latter half of the 19th century. The nucleus of their findings has been reviewed by Duke-Elder[1] in his reference Textbook of Ophthalmology. Their work was mainly qualitative and very small numbers of subjects were used.

The unusual demands of modern aviation on pilot efficiency has revived interest in peripheral visual function. Problems encountered in the landing and take-off of aircraft have suggested that peripheral visual acuity may at times be a critical factor determining pilot performance. This new interest led to the development of a standardized measure of peripheral acuity. The results of these studies have been reported in two groups of 100 subjects each, the first measured with photopic illumination[2] and the second with scotopic illumination.[3] These tests established the normal distribution of scores to be expected in an unselected group of subjects, and have served, with occasional modification, as the measures of our subjects' peripheral acuity in the present study.

An interesting feature of practical importance discovered by the earlier workers was the tendency for peripheral acuity to improve through practice. Dobrowolsky and Gaine[4] reported improvement up to the end of the sixth week through daily practice periods. Would this increased acuity be sufficient to improve performance? Could a satisfactory technique for this be devised? The writer undertook the training of a small group of five subjects under the sponsorship of the Committee on Aviation Medicine (CMR-OSRD). The improvement proved to be quantitatively great but unfortunately slow, the process being unfinished after seventeen daily one-hour sessions of practice. Could the technique be adapted for the training of large groups of individuals? Do the results of the training transfer to other situations, both in and out of the laboratory, to night visual acuity, to practical conditions in outside life? This report deals with an investigation conducted under the auspices of the National Research Council Committee on Selection and Training of Aircraft Pilots to answer these questions with particular reference to the possible usefulness of it in the training of pilots.

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[1] Duke-Elder, Sir W. S. Textbook of ophthalmology. St. Louis: C. V. Mosby Co., 1944.

[2] Low, F. N. The peripheral visual acuity of 100 subjects. Am. J. Physiol., 140, 83, 1943.

[3] Low, F. N. The peripheral visual acuity of 100 subjects under scotopic conditions. Am. J. Physiol., 146, 21, 1946.

[4] Dobrowolsky, W., & Gaine, [illegible]. Pfluger's Arch. f. d. ges. Physiol., 12, 411, 1876.

APPARATUS

The apparatus used in earlier research has been described in a previous report.[5] It consisted of a 25 centimeter perimeter with an attachment for constant illumination. Tests were run in a black booth, the operator wearing black gown and gloves. In the investigation reported here, an improved design of this equipment was employed since the nature of the problem and previous experiences with technique made clear the need for an instrument which would facilitate the changes in targets and test objects.

The improved perimeter was hand operated and so constructed that it included attachments consisting of a shutter for the rapid exposure of test objects. The machine consisted essentially of a primary arm mounted on a bearing which was tilted downward and forward at an angle of 10 degrees. The primary arm was roughly circular and supported a secondary arm at a bearing which was directly above the subject's head when the instrument was in zero position. The secondary arm supported the test object 25 centimeters from the subject's eye. A blind was located between the test object and the subject's eye. The secondary arm rotated around the bearing which connected it with the primary arm in such a manner as to describe a meridian. The meridian was altered by rotating the primary arm which was fitted with a dial indicating its position. The secondary arm would then rotate in whatever meridian specified by this "set" and the angular deviation of the test object from the line of vision was indicated by a dial mounted high on the primary arm. The portion of the secondary arm holding the test object was so constructed that when a test object was inserted into the holder it could be placed in any of the four possible positions by the operator's hand, which was concealed from the subject by a large shield. The blind which either obscured or revealed the test object could also be operated from behind the shield. During the setting of a test object it was not necessary for the operator to reach in front of the test object or to interfere with the line of the subject's vision. The test object was illuminated by a 60-watt Mazda lamp, which was mounted on the secondary arm which moved with it, thus insuring an absolutely constant source of illumination throughout the test. Both arms were counter-weighted.

The end of the secondary arm was constructed to hold a rod, which supported a photographic shutter in such a manner that the shutter was always in the line of peripheral vision. This attachment provided for controlling time of exposure of objects used in the speed of recognition tests.

Test objects employed were as follows:

1. Circles. Each unit of apparatus was equipped with a set of Landolt Broken Circles (rings) of fourteen sizes (see Table 1), photographically printed in black on white paper. The photographs were 75 millimeters

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[5] Low, F. N. Proposed design of an experimental investigation of the training of peripheral visual acuity. 1943. Design in the files of the Committee on Selection and Training of Aircraft Pilots.

TABLE 1

DATA ON BROKEN CIRCLES USED IN TESTING

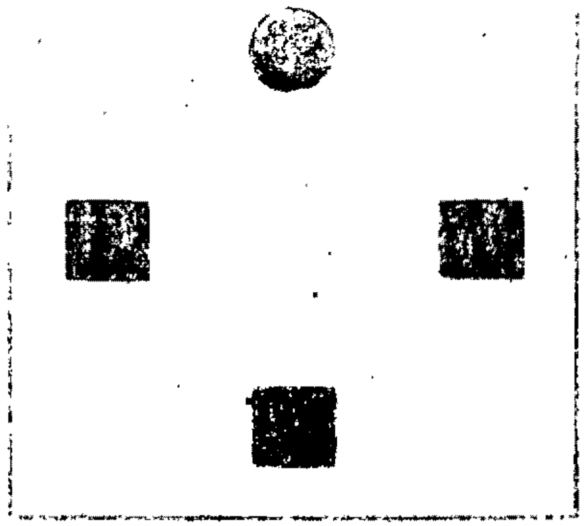
No.	Equivalent Used in Summation	Width of Break in Circle (mm.)	Diameter of Circle (mm.)
¼	.13*	.25	1.25
½	.40	.55	2.75
1	.73	.90	4.5
1½	1.2	1.4	7.0
2	1.7	1.9	9.5
2½	2.2	2.4	12.0
3	2.6	2.8	14.0
4	3.5	4.1	20.5
5	4.5	4.8	24.0
6	5.3	5.7	28.5
7	6.2	6.7	33.5
8	7.2	7.6	38.0
9	8.3	8.9	44.5
10	9.3	9.7	48.5
10x	10.4		

*For example, .13 represents the value midway between zero and .25; .40 the value midway between .25 and .55, etc.

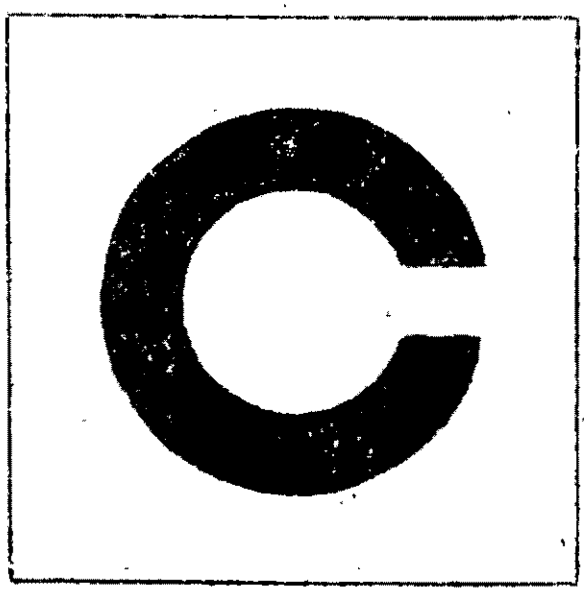
square, with the circle in the center, and pasted on a metal target which fitted into the target holder on the end of the secondary arm.

2. Airplane Silhouettes. A set of four types of airplane silhouettes each in five sizes (50 mm., 25 mm., 10 mm., 5 mm., and 2½ mm.) accompanied a unit of equipment. The four types of planes, selected arbitrarily, differed considerably in general form. They were selected with reference to the greatest possible range of difficulty, as revealed by preliminary experimentation.

3. Isolated Forms. Each unit of apparatus was equipped with a special set of test objects for transfer studies (see Figure 1). The test object selected for these transfer studies consisted of four isolated small objects, three squares and one circle, which were arranged on the circumference of an imaginary parent circle. The criterion of discrimination was a signaling of the position of the small circle as distinguished from the small squares of the same diameter. This discrimination involved an analysis of isolated forms and a distinction between their respective shapes. In the present investigation test objects of this type arranged around imaginary parent circles of 25 millimeters and 10 millimeters in diameter were used in the manner described on page 8.



Isolated Points
(50 mm. size - 25 mm. and 10 mm. sizes were used in study)



No. 10 Circle
(Actual size used at 90 degrees in study)

FIGURE 1

TARGETS USED FOR TRANSFER STUDIES

Other items of apparatus employed in the investigation were the following:

1. Fixation Buttons. These consisted of a white circle 10 millimeters in diameter with black center, with the Roman numerals I, II, III, and IIII arranged around the center point in positions which corresponded to the four positions of the test object. For the experimental work on night vision, a special self-luminous fixation button of the same design was employed.[6] The active element was an orange self-luminous material recently developed, believed to have a negligible effect on dark adaptation, but bright enough to stimulate central vision.

2. Dark Adaptation Goggles. During the 30-minute period of dark adaptation required before entering the darkened room for night visual acuity tests, the subjects wore Polaroid Dark Adaptor Lens (non-polarizing XDA8FAP).

3. Shutters. Ilex No. 4 Universal shutters were employed. Short cable releases were attached and the shutters could be timed for permanent exposure or for exposures of 1, 1/2, 1/5, 1/10, 1/25, 1/50, and 1/100 of a second.

4. Apparatus for Binocular Transfer Test. A cardboard carrier, 300 millimeters square, was constructed to hold a set of Landolt circles of the same sizes as used on the perimeter. When inserted the black circle appeared in the center of the carrier which was faced with white photographic paper. The carrier was mounted so that it could be revolved, the break in the circle pointing up, down, right, or left. It was brightly illuminated and fixation buttons were placed above, below, to the right, and to the left so the test objects would be 15 degrees from the line of vision of a subject seated 175 centimeters distant.

The laboratory layout in which the testing and training were done was constructed with overhead supports from which black cloth was draped from a height of 7 feet to 1 foot from the floor. The draping was so compartmented as to provide a series of booths 46 inches wide and 43 inches deep. In each booth was a black table with a perimeter. The test objects on the table were concealed from the view of the subject by blinds of cardboard covered with black cloth. Efforts were made to keep the visible portion of the table top clear of objects which might provide non-homogeneous surrounds. The subjects sat facing into the booth, the operator standing in it. At times, unfortunately, this made it difficult for the instructor to check fixation.

SUBJECTS

The subjects were naval and civilian students at the University of North Carolina, enrolled in a course designed for the testing and training

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[6] These self-luminous fixation buttons were prepared by the U. S. Radium Corporation.

of peripheral visual acuity. Group I, including Subjects 1 to 19, was trained in twice-weekly laboratory periods from July to October, 1944. Subject 20 was a volunteer who was trained with Group I at the rate of four laboratory periods weekly during July and August, 1944. No special tests were taken by her. Group II, including Subjects 21 to 47, was trained from November, 1944, to February, 1945. Late registration in the second group necessitated "make-up" laboratories. The actual time in training was about two weeks less for Subjects 24 to 47 and for Subjects 21 to 23, who commenced training at the beginning of the trimester. Of the 47 subjects comprising Groups I and II, 43 completed the course. The precise difference between the training of the two groups is to be found in Appendix B.

PROCEDURES

Testing and Training Techniques. The testing procedure has been described in an earlier study.[7] An operator's manual describing the testing method is included in Appendix A. It contains a description of the hand-operated quantitative perimeter and is sufficiently detailed to make test operation possible, provided an instrument is available for examination during the reading of the manual.

Appendix B contains the score sheets for the progressive tests and training periods as they were used in the training course, as well as a brief description of the training techniques. The regime provided for an initial test (acuity) with a check test every fourth period thereafter. In the intervening periods there was practice with airplane silhouettes. The type and size of the planes and the meridians to be trained have been specified on the training sheets in Appendix B.

When working with the airplane silhouettes the subjects identify the direction the plane is pointing, according to the criterion of four consecutive correct answers before two misses. The identifications are begun at 20 degrees from the line of vision and the plane is moved outward 10 degrees upon successful identification. This is repeated until the subject fails. The test object is then moved 5 degrees inward to get a reading accurate to 5 degrees. The greatest angular deviation at which the subject is successful is recorded on the training sheet. This general procedure is followed until all of the specified operations have been completed for one eye. Operator and subject then change places.

Special tests[8] included in the training regime were as follows:

1. Rotated Meridians. The subjects were tested with circles on meridians located half way between the meridians normally tested and trained. (See Figure 2.) A 30 degree point on the nasal horizontal meridian

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[7]Low, F. N. Op. cit. (See footnote 2 of this report.)

[8]Score sheets for these tests are found in Appendix B.

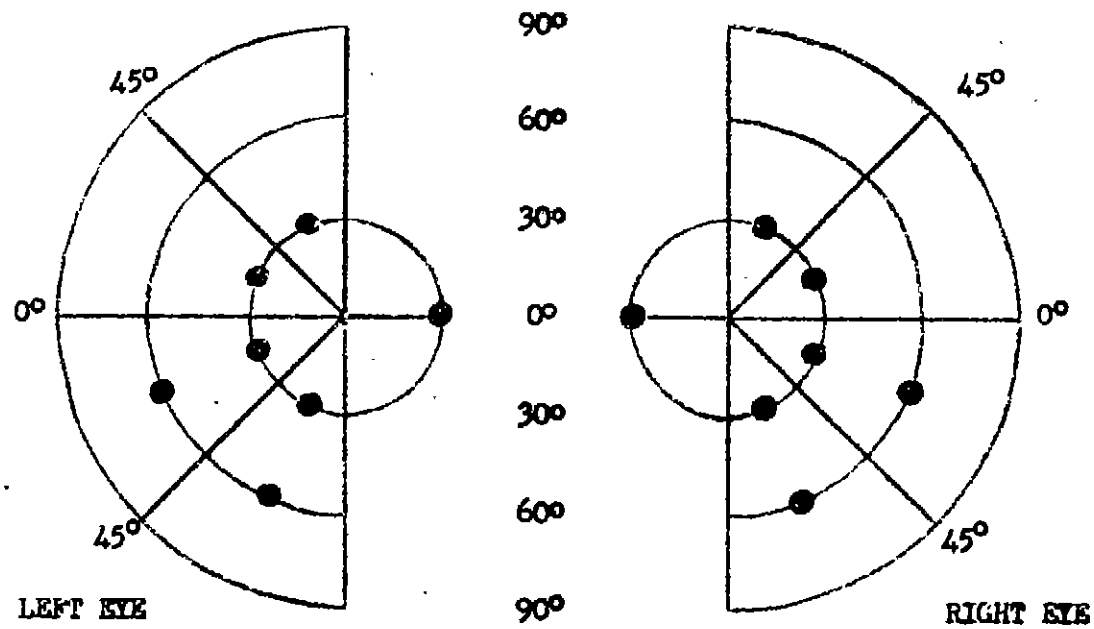

FIGURE 2

SOLID CIRCLES ARE POINTS ON THE RETINA AT WHICH MEASURES ARE OBTAINED ON THE ROTATED MERIDIAN TEST was included.

2. Night Visual Acuity. The usual circle test was run under scotopic conditions. The illumination was reduced to scotopic range and was set with a photometer.

3. Rapid Recognition. The usual circle test was run with a shutter in the line of peripheral vision. Exposure for all determinations was set at 1/5 second.

The technique used for these tests was the same as for a normal circle test (acuity) except for the indicated changes.

The following transfer studies[9] were included in the training regime:

1. Isolated Forms. Test objects consisting of three squares and a circle (see Figure 1) were arranged on four points of an imaginary parent circle. This type of test object with parent circle diameters of 25 mm. and 10 mm. was used on the temporal horizontal meridians. The test object was started at 20 degrees and "pushed outward" with the technique described for training with airplane silhouettes. The subjects signaled the position of the circle. This was done with both sizes in each eye.

2. No. 10 Circle at 90 Degrees. Each subject was given ten tries at identifying the position of the break in a No. 10 circle at 90 degrees from the line of vision on the "out" and "down and out" (45 degrees) meridians in each eye. The score for each point was the number of correct answers, 40 being a perfect score.

3. Non-perimetric Binocular Test. The subject was seated 175 cm. from a 300 mm. white square, with circle test objects in its center. Acuity was measured by the usual success criteria with the subject first fixating on the button 15 degrees to his right and then 15 degrees to his left. When fixating 15 degrees above and then below, ten tries were given with a size No. 5 circle. Twenty was a perfect score for these two points.

The Training Course. The training course used in this experiment consisted essentially of an initial circle test on the first period and a check test every fourth period thereafter. On the intervening groups of three periods each the subjects were trained with airplane silhouettes. Modifications of this general pattern were necessary to accommodate transfer tests. Differences in the number of periods available also necessitated some differences between the two groups.

The two groups received the same general training but differed in detail. Group II received one less period. A rapid recognition test was given to Group II on Period 2, the remainder of the training and testing periods being displaced. Group II did not have periods corresponding to

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[9] Score sheets for these tests are found in Appendix B.

Periods 24 or 25. Certain of the transfer tests given at the beginning and end of the course were given to the two groups on different periods. Group II received a non-perimetric binocular transfer test on the last period. These distinctions between the training of the two groups are indicated in the schema (see page 36) and on the training sheets in Appendix B.

The plane types, sizes, and meridians used on each period are specified on the score sheets in Appendix B. These were chosen with reference to the ability of the groups trained. The first group of three training periods are so chosen that failure does not occur until the test object is far removed from the line of vision. Succeeding groups, of three training periods each, have plane types and sizes of such difficulty that the point of failure gradually approaches the line of vision. Periods 14 to 16 present great difficulty, failure occurring near the line of vision. In other words, the task of the average subject has been increased in difficulty more rapidly than his acuity improves. The result of this is that his point of failure gradually approaches the line of vision. The choice of plane type and size has also been adjusted to the restricted field on the "up," "down," and "up and out" meridians. Here smaller sizes are necessary to cause failure within the field, thus providing a sure tax on the subject's ability.

In designing future applications of the training regime a thorough investigation of plane type, size, and meridian should be undertaken. Too large sizes for any stage of the training will cause the subject to run the test object out of his field. Too small sizes will cause failure at the least deviation possible (20 degrees). Both of these errors destroy the effectiveness of the training, the aim being to run the subject from sure success to sure failure.

A questionnaire (see Appendix C) on the subjective effects of the training was filled out by Group I near the middle of the course. The same questionnaire was filled out by Group II at the end of the course.

The laboratory periods were two hours long. Early in the course when the technique was unfamiliar and transfer tests were included the technique took longer than two hours. Later in the course many subjects were finished in less than the allotted time.

RESULTS

Derivation of Acuity Scores. The primary measure of the subject's ability to resolve detail in the periphery is a summation of the equivalents of 14 individual measures of this ability, taken during a single test. In the 100 subjects previously reported[10] this score averaged 47.9 with extremes at 13.2 (best) and 111 (worst). The present group of 43 subjects, tested before training when their scores were comparable to the original group of 100, averaged 44.4 with extremes at 26.5 and 72.0 as indicated in

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[10] Low, F. N. Op. cit. (See footnote 2 of this report.)

Table D-1, Appendix D. Similar tests were made every fourth period during the training regime and are called "straight" tests to distinguish them from other Landolt circle tests made under differing conditions such as rapid recognition, night visual acuity, etc. The progress of the trainees in developing better acuity is indicated in the concluding page of Table D-1, Appendix D. The final acuity scores averaged 13.3, representing 334% of the starting score. This measure, however, is linear or one-dimensional. The area of the smallest break (or circle) that can be identified, being two dimensional, is a truer index of the subject's ability since it represents the retinal area stimulated by the test object. On this basis of calculation it is found that, after training, a subject can identify simple form in a retinal area only one-eleventh the size of the minimum area necessary for successful stimulation before training. Or, given stimulation of the same retinal area necessary for perception of simple form before training, the trained subject should be able to make out eleven times as much detail. In the practical sense the trained subject should be eleven times as efficient in his responses to peripheral stimuli, other conditions being the same, as an untrained individual.

The extremes of performance in acuity are represented in subjects T-35 (best) and T-34 (worst). T-35 reached about 1200 per cent of his own starting score indicating an efficiency one hundred forty-four times as great. T-34 reached 159 per cent of the starting score indicating an efficiency barely 2½ times as great. The frequency distributions of these acuity scores before and after training are presented in Figure 3. There is only a slight overlap between the distributions of these scores before and after training. The progress of the mean acuity scores during the progress of the training regime is presented, along with other data, in Figure 4.

Derivation of Millimeter Variability Scores. During the progress of the testing, there was a noticeable fluctuation of the subject's efficiency between successive points tested. A subject would do very well on one point and very poorly on another. This was so arresting that an attempt to extract a measure of it was made. It was assumed that the acuity of any one point bore a constant relationship to the total score of the subject. This was found to be true with the mean scores in several different groups of subjects. Therefore, the numerical relation of the average score on each point to the average total score was calculated. The total score was known to be the most reliable figure. Therefore, when the total score of any subject was multiplied by this numerical relationship for any point an estimate of the score that this subject should have gotten on this particular point was obtained. The subject would have gotten this score if it had not been for the spontaneous fluctuation which characterized his performance. Therefore, the difference between the subject's recorded score and the calculated score (derived from a mean numerical relationship as above) is a measure of the degree of fluctuation during the testing of that point. This measure of fluctuation has been calculated for each of the fourteen points constituting an acuity test. A summation of these fourteen fluctuation scores has been called the "millimeter variability" of the subject and is an index of how much he wavered during the

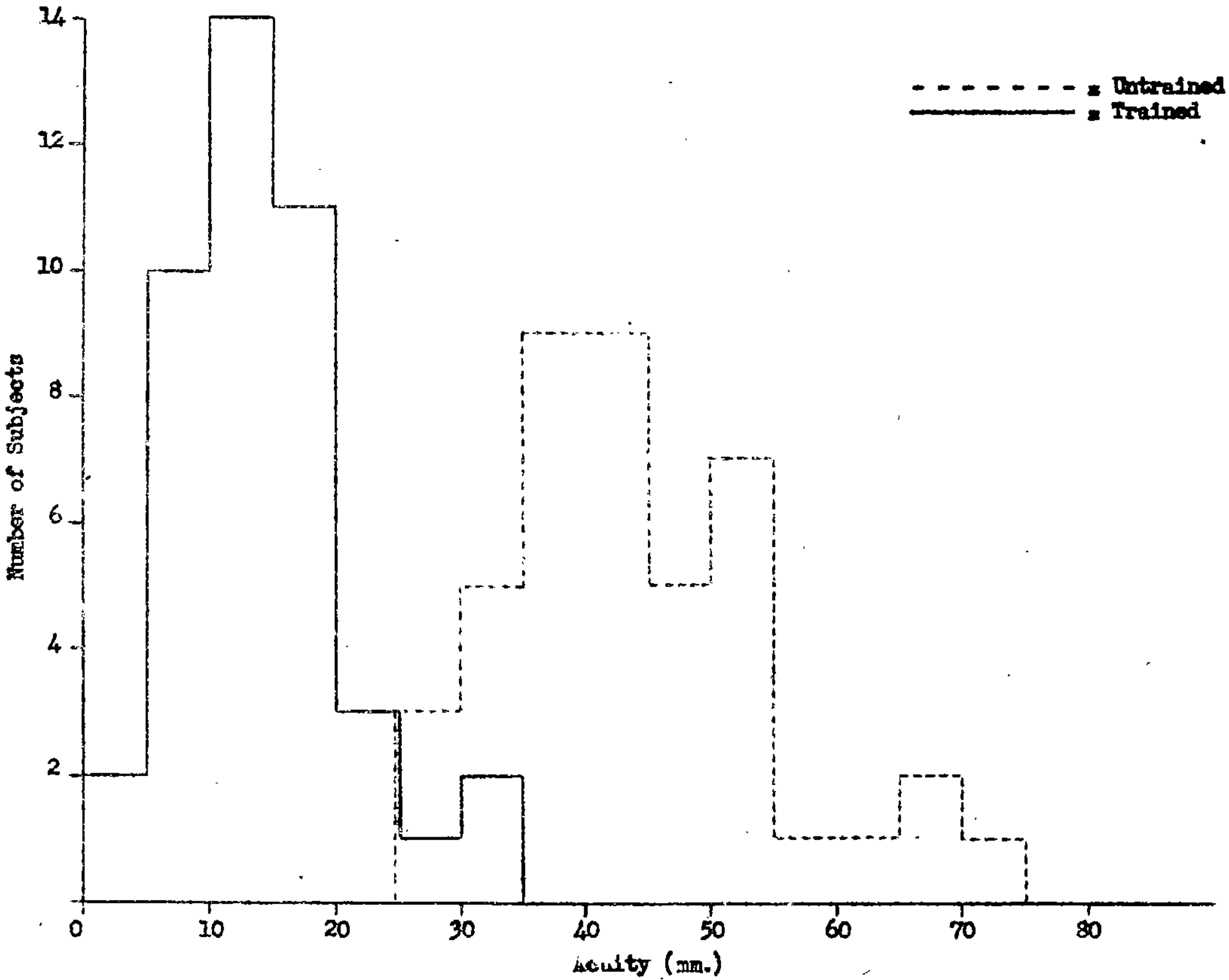
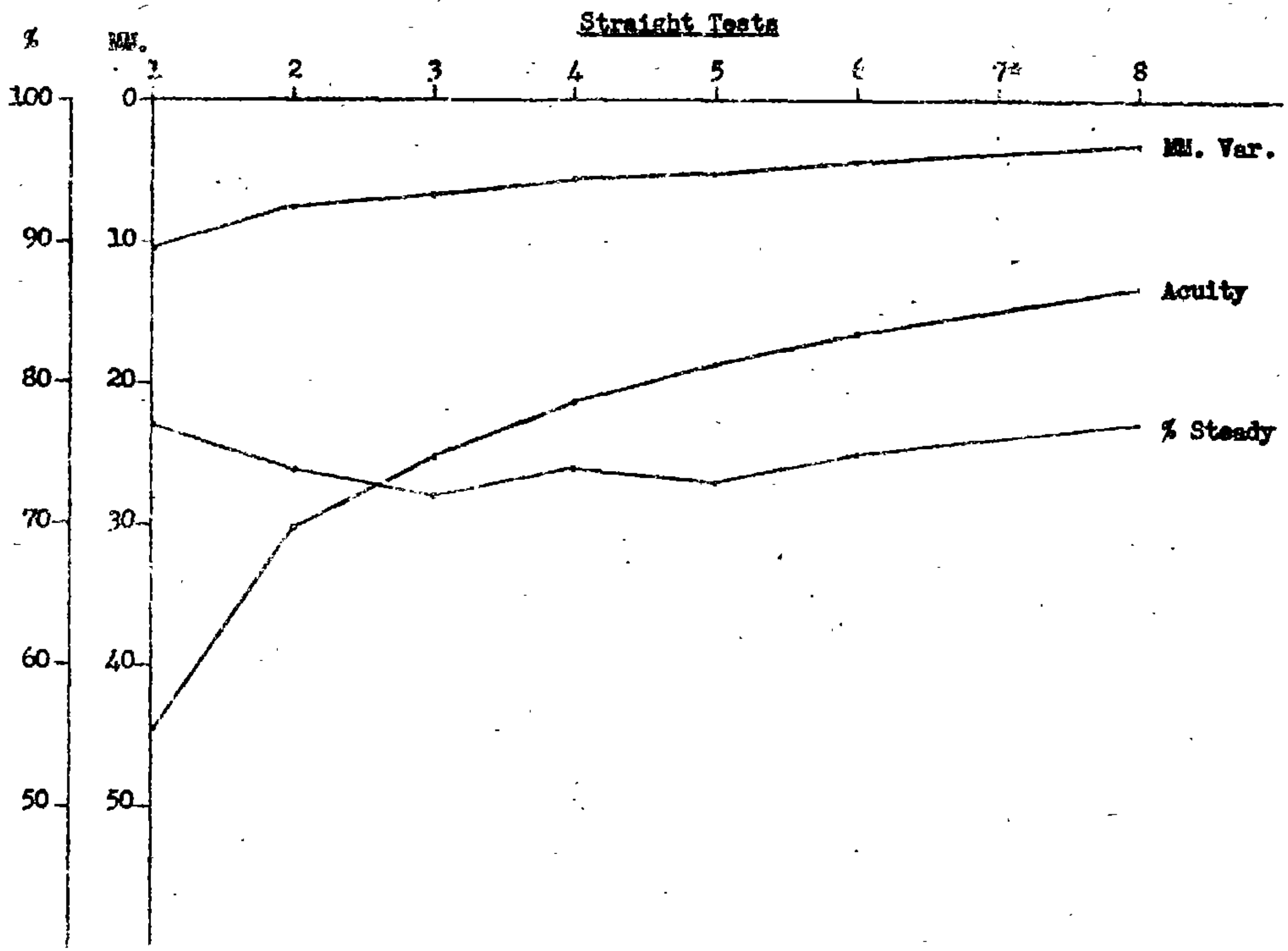


FIGURE 3

FREQUENCY OF ACUITY SCORES FOR 43 SUBJECTS BEFORE AND AFTER TRAINING



*Test 7 was taken by only 18 subjects and is not included in the curve.

FIGURE 4

ACUITY, MM. VARIABILITY, AND PERCENTILE STEADINESS SCORES ON EIGHT PROGRESSIVE TESTS
(N = 43)

test. The mm. variability scores for each subject on each test are presented in Table D-1, Appendix D. These scores averaged 10.3 mm. on the first test and gradually decreased as the acuity improved (Figure 4).

The Percentile Steadiness Score. Since the mm. variability scores and the acuity scores are both measured in millimeters they are comparable to each other. For instance in test No. 1 subject T-1 showed an acuity of 44.5 mm. and fluctuated 14.1 mm. during the testing of fourteen points. The fluctuation was 32% of the acuity. Subtracting from 100 the subject is then understood to have been 68% steady. This measure, called the percentile steadiness, has been calculated for all subjects in all of the straight tests and is presented in Table D-1, Appendix D. It averaged 77% in the first test and exactly the same in the last test (Figure 4).

Comparison of the Three Types of Scores. A comparison of these three types of score in our group of 43 subjects with the same scores in the original 100 subjects is to be found in a footnote to Table D-1, Appendix D. Both the acuity and mm. variability scores were slightly better in the present group but the percentile steadiness measure was exactly the same.

The relationship of these three types of score to each other during the progress of the training regime is presented in Figure 4. The acuity scores improved rapidly at first and then showed a tendency to asymptote. The mm. variability scores showed so much the same behavior that the percentile steadiness scores, which represent the relation between the two, change only 5% throughout the entire regime. The persistance of the mm. variability scores throughout the regime reveals fluctuating efficiency to be a fundamental of peripheral visual performance rather than a phenomenon traceable to the unpracticed nature of the peripheral retina.

Data on Special Tests and Transfer Tests. Table D-2, Appendix D, represents the results of certain special tests and transfer tests.

1. The Rapid Recognition Test. In the rapid recognition test, with the time of exposure limited to 1/5 second, 25 subjects before training showed a mean acuity of 76.7, a mean mm. variability of 15.2, and an average percentile steadiness score of 80.4%. After training these same 25 subjects, tested by the same technique showed an acuity of 41.3 and were 78.6% steady. The improvement in rapid recognition of simple form had improved to 186% of its starting value but the steadiness remained about the same. No training under conditions of rapid recognition was done in the interim and these results are interpreted to indicate successful transfer of this ability as a result of training with test objects presented for unlimited exposure.

2. Night Visual Acuity Test. The night visual acuity of 42 trained subjects averaged 37.4, with a mean mm. variability of 6.1. The average percentile steadiness was 84.2%. There are no night visual acuity scores

for these subjects before training because of the technical difficulty of obtaining such measures in unpracticed operators. However, these scores are indirectly comparable to our initial group of 100 untrained subjects whose mean acuity was 70.1, mm. variability 11.2, and percentile steadiness 83.8%. On the basis of comparison between 100 untrained subjects and another group of 42 trained subjects the trained subjects showed an improvement to 187% of normal. The closely similar percentile steadiness of these two groups resembles that encountered in other types of scores. It is concluded that night visual acuity has been improved by training under photopic illumination.

3. Rotated Meridians Test. The scores for the special test in which the meridians tested were so rotated as to be half way between the meridians used on the straight tests show a mean acuity score of 7.3 in 42 trained subjects. No scores for this test are available from untrained subjects but in difficulty the test is comparable to the usual acuity test. On the basis of known isopters for all meridians the difficulty should be comparable. It is believed that the low acuity scores here, indicated that all areas of the peripheral retina have been improved by the training regime. There has been no restriction of improvement to the meridians actually worked by the technique.

4. Tests with No. 10 Circle at 90 Degrees. Table D-2, Appendix D, also presents the results of tests with a No. 10 circle at 90 degrees. The subjects were given ten tries at identifying the position of a No. 10 circle at 90 degrees on two meridians, "out" and "down and out," in each eye. A perfect score was 40. Before training 42 subjects averaged seventeen correct answers. After training the same group averaged twenty-eight correct answers, an increase of nine. Thus it is concluded that the improvement in peripheral acuity extended to areas as far removed as 90 degrees from the line of vision.

5. Non-Perimetric Binocular Transfer Test. Table D-2, Appendix D, also includes the results of the non-perimetric binocular transfer test. Only 25 subjects of Group II received this test. The results are comparable to an unselected group of twenty-two untrained subjects who took the same test. At 15 degrees to the left on the horizontal meridian the trained subjects showed a mean binocular acuity of 2.8 mm. (measurement of break in circle) as compared to 7.2 mm. for the untrained group. At 15 degrees to the right on the horizontal meridian the trained subjects showed a mean binocular acuity of 2.5 mm. which compared with 4.5 mm. in the untrained group. When given ten tries with a No. 5 circle at both 15 degrees above and 15 degrees below the line of vision, with a possible perfect score of 20, the trained group averaged eighteen and the untrained group averaged thirteen. It is concluded that the effects of the training transferred successfully to binocular acuity by virtue of the favorable comparison of scores with those of an untrained group.

6. Monocular Transfer Test. Table D-3, Appendix D presents the results of the monocular transfer test using two sizes of isolated forms

consisting of three squares and one circle on the horizontal meridian. These test objects were "pushed outward" until failure both before and after training, no practice with comparable test objects being undertaken during the regime. In 42 subjects in the left eye the 25 mm. size was successfully identified, on the average, 17 degrees farther from the line of vision after training than before. In the right eye for the same size the average score was 18 degrees farther from the line of vision after training than before. For the 10 mm. size the left eye averaged 9 degrees better and the right eye 10 degrees better after training than before. It is concluded that the improvement in simple form acuity transferred successfully to unfamiliar test objects used in a perimetric laboratory situation.

Statistical Analysis. Previous to the collection of the present data from the subjects of the training regime the scores of the original groups of test subjects were correlated by means of the Pearson product-moment method.[11] Eye-to-eye correlation of the acuity scores in 100 day vision subjects gave a reliability of .91. Similar correlation of night visual acuity scores gave a reliability of .84.[12] Correlations of individual point scores with total scores in the photopic acuity group yielded coefficients ranging from .60 to .77. The night vision group yielded similar coefficients ranging from .44 to .78. These figures point to an ever present source of error in the determinations, a fact which led to the extraction of the mm. variability and percentile steadiness scores which have been previously discussed. Eye-to-eye correlation of the mm. variability scores in the photopic group indicated a reliability of .61 for this measure. This lower coefficient was interpreted to be due to an intrinsic tendency to change in this measure, a supposition which was borne out by the correlations of the training data reported below.

The acuity, mm. variability, and percentile steadiness scores of the training group were subjected to a similar analysis. The results of this work are presented in Table 2. It should be noted that in a sample of 43 cases r would have to exceed .30 to be significant at the 5% level and .39 to be significant at the 1% level.

The correlations of the acuity scores in consecutive straight tests may be interpreted as test-retest reliability. Between the first and second tests the coefficient of .62 contrasts markedly with the .91 obtained from eye-to-eye correlation based on previous test scores. This contrast implies a day-to-day change in the ability of the subjects in greater quantitative degree than occurs during the three-quarters of an hour or so normally taken to perform the test. However, this test-retest coefficient rose to .85 toward the end of the regime so that it

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[11] Low, F. N. Some characteristics of peripheral visual performance. Am. J. Physiol., 146, 573, 1946.

[12] Low, F. N. Op. cit. (See footnote 3 of this report.)

TABLE 2

CORRELATIONS OF ACUITY, MM. VARIABILITY, AND PER CENT STEADINESS SCORES
DERIVED FROM THE EIGHT STRAIGHT TESTS
(N = 43)

		Acuity (Straight Tests)								MM. Variability (Straight Tests)								Per Cent Steadiness (Straight Tests)							
		1	2	3	4	5	6	7*	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Acuity (Straight Tests)	1		.62	63	.54	.48	.39		.28	.55								-.04							
	2			.80							.63								-.29						
	3				.77							.47								-.32					
	4					.89							.57								-.11				
	5						.86							.70								.16			
	6								.86						.78								.09		
	7																								
	8																.83								.15
MM. Variability (Straight Tests)	1										.32	.16	.18	.16	.22		-.05	.70							
	2											.43							.51						
	3												.54							.51					
	4													.17							.48				
	5														.59							.51			
	6																.65						.56		
	7																								
	8																								.59
Per Cent Steadiness (Straight Tests)	1																		[illegible]	[illegible]	[illegible]	.06	-.13		-.11
	2																			.25					
	3																				-.17				
	4																					.30			
	5																						.25		
	6																								.16
	7																								
	8																								

*Test 7 was taken by only 18 subject and is not included.

nearly equaled the original eye-to-eye correlation. This indicates that the day-to day fluctuation in acuity has diminished as a result of the training.

Correlations of the acuity scores of the first test with subsequent tests show significant correlations up to the 6th test, the coefficient .39 just reaching the 1% confidence level. The correlation of the 8th test with the 1st test is .28 and is not significant at the 5% level of confidence. Thus the initial acuity score of any subject is not an index of his eventual accomplishment.

The correlations of the acuity scores with the mm. variability scores on the same test are all significant, ranging from .47 to .78. These correlations show little tendency to improve during the course of the training regime.

Correlations of the acuity scores with the percentile steadiness scores in the same tests do not show significant correlations. This lack of correlation emphasizes the independence of the percentile steadiness scores from the acuity scores and indicates that fluctuation of efficiency may be great or small in proportion to acuity whether the latter be large or small.

The mm. variability scores show significant test-retest correlations in 4 out of 6 cases, but none of the coefficients are high. This is in keeping with the low reliability of the mm. variability scores reported above, which was interpreted to be due to intrinsic changeability of this function.

The mm. variability scores correlate with the percentile steadiness scores in the same test with significant coefficients in all cases.

The percentile steadiness scores fail to correlate with each other significantly either on a test-retest basis or on the basis of the relationship of the initial score to those of any subsequent test.

Thus the acuity scores are the most reliable measures, subject to the least fluctuation. The steadiness of the subject is the least reliable feature of his performance. It cannot be predicted in individuals, but for the groups it changes little throughout the regime. The mm. variability scores, which are quantitatively somewhat dependent on the acuity measures correlate significantly with these measures.

The original test scores (acuity) have been correlated with external circumstances such as age, sex, time of day, operator, etc.[13] No significant coefficients were obtained. This has led to the conclusion that the fluctuations of efficiency noticed in the subjects during the testing and confirmed by later statistical analysis are both intrinsic and spontaneous, not being influenced by external conditions.

The scores of the special tests conducted toward the end of the regime were correlated with the scores of the 8th straight (final) test

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[13] [illegible] (See footnote [illegible] of this report.)

The acuity with rotated meridians correlated .85 with the acuity of the 8th test, which was comparable to the coefficient of correlation of the 6th and 8th tests. Acuity with rapid recognition correlated with acuity on the 8th test with an r of .74. The acuity with rapid recognition correlated .63 with night visual acuity. The latter correlation suggested a ready substitution of the easily acquired rapid recognition scores for the difficult-to-obtain night visual acuity measures. The coefficient is about the same as the test-retest reliability in day vision, which is .62. However, the coefficient of correlation in untrained subjects between photopic rapid recognition and night visual acuity may be less than the figure observed in trained subjects, since the photopic test-retest reliability in these subjects at this stage is .86.

Correlations between the mm. variability and percentile steadiness scores in the above group of special tests with the same types of score in the 8th straight test yielded coefficients in the same range as correlations of the same type of score reported above for the various straight tests.

<u>Subjective Effects</u>. During the progress of the training regime the subjects discussed differences in peripheral perception noticed in everyday life outside the laboratory. These discussions were spontaneous and were not solicited in any way. Midway in the progress of the regime (Group I) these comments became so persistent that the questionnaire found in Appendix C was presented. The same questionnaire was presented to Group II at the end of their regime. Changes in peripheral perception outside of the laboratory were noticed by 41 out of 42 subjects. Thirty subjects were sure that the new perceptual experiences were intrusive, forcing themselves on awareness rather than occurring as a result of thinking about the training course or by self-testing. Four subjects were doubtful about this and 7 were certain that the changes occurred only when thinking about the training. Among these 42 subjects, 31 noticed a difference when walking on the street, 23 noticed a difference in sports, and 20 noticed a difference in reading. Various other situations in which changes were noticed were mentioned by 29 subjects. Among these were, marching in drill, seeing better at night, and driving an automobile. In all, one hundred three situations involving change were reported. All but two of these were interpreted by the subjects themselves to be helpful rather than detrimental to their general welfare.

<u>Retention of the Effects of the Training</u>. It was occasionally possible to check test trainees weeks or months after the training regime had been completed. The results varied considerably in both time elapsed and percentile retention. Too few cases were recorded to draw conclusions but at least 50% of the improvement was retained in all cases measured.

<u>Effects on Central Vision.</u> The Snellen index of thirteen of the trainees taken before and after the training showed no changes that could be attributed to the regime. Ten subjects measured 20/20 or better both before and after training. Two declined and one improved.

DISCUSSION

The results of this investigation can be summarized by the statement that the attempt to train peripheral visual acuity by a course of controlled practice has been very successful. By linear measurement our final measure of 334% of the starting scores is, in itself, an impressive figure. Nevertheless, a two-dimensional measurement, dealing with the area on the retina stimulated by the test object is a more suitable criterion for judgment, since the projection of the image on the retinal mosaic is the physical cause of the stimulation. Considered in this truer two-dimensional aspect the results of the training are still more impressive. After training it is necessary, in the average subject, to stimulate a retinal area only one-eleventh the size necessary for stimulation before training. Or, if the same retinal area necessary for perception of simple form before training were stimulated, after training the subject could perceive eleven times as much detail.

The above figures in themselves indicate an extensive quantitative change. They are further enhanced by the results of the transfer tests. Tests were made to check the transfer of improvement effects to (1) retinal areas not worked by the technique, (2) night visual acuity, (3) rapid recognition of simple form, (4) unfamiliar test objects, (5) retinal areas 90 degrees from the line of vision, (6) non-perimetric binocular acuity, and (7) conditions of everyday life outside the laboratory. All of these transfer studies were successful. In no case was there doubt that the trained subjects excelled untrained ones in situations involving acuity of peripheral visual perception.

The effects of the training noticed by the subjects outside the laboratory are a strong recommendation for the probable practical value of the technique. It is notable here that in most subjects, the new perceptual experiences were intrusive, occurring without forethought. This indicates strongly that the subjects had become aware of peripheral visual stimuli of which previously they had not been aware, a fact arguing strongly in favor of the practical value of the technique for pilots whose peripheral perception is frequently taxed in the performance of routine duties. The writer considers that the success of the laboratory transfer tests, coupled with the encouraging evidence furnished by the trainees' experience outside the laboratory, justifies the conclusion that a general transfer of the observed increase in efficiency to all situations involving peripheral visual stimuli has been accomplished to the extent of producing a practical increase in the efficiency of response to such stimuli.

During the progress of this investigation a motorized quantitative perimeter was constructed to facilitate the testing of peripheral visual acuity with moving test objects. It proved impractical to check the transfer of the improvement to acuity with moving test objects directly with the training group here reported. Since the completion of this investigation the writer has measured the peripheral motion acuity in 50 subjects with this apparatus, acquired on loan from the Committee on

Selection and Training of Aircraft Pilots. The results of this investigation[14] will appear shortly in the American Journal of Physiology.

The failure to observe eye-to-eye improvement during the motion acuity tests raised the question of transfer of improvement of stationary acuity, as reported in this study, to moving stimuli. Suspecting that the failure to improve depended on the limitation of time of exposure of the stimulus inherent to its movement, the scores of the rapid recognition tests with stationary test objects were reexamined. It was found that there was no eye-to-eye improvement here either. Nevertheless, there was distinct improvement in rapid recognition scores in the same subjects before and after training. It was, therefore, concluded that the limitation of time of exposure inherent in both rapid recognition and motion acuity prevented the subject from "working out" his impression of the test object. However, it was considered probable that practice with stationary test objects would transfer successfully to moving test objects in spite of failure of eye-to-eye improvement, just as it did in the rapid recognition tests. Further supporting evidence is the successful transfer to conditions of outside life where stimuli are more apt to be in movement rather than stationary. An interesting implication of these observations is the unlikelihood of success if moving test objects had been used in the present investigation.

A further point of interest is observed when one considers the customary use of peripheral vision. Under photopic conditions the peripheral retina is used for initial perception of stimuli only. Little or no attempt is made to analyze detail. Instead, the object perceived is fixated with central vision for analysis of detail by a retinal area of incomparably greater acuity. The important thing is to become conscious of the peripheral stimulus, and it seems, from the subjective data, that this ability has been improved by the training regime. This, in turn, suggests that the peripheral retina be interpreted as an unpracticed sensory area. In all probability, the basic reason for its unpracticed nature is the greater and more useful acuity to be found in central vision, to the use of which eye and head movements are well adapted.

In night vision, on the other hand, no comparable central area of great acuity exists. The fovea is blind and the area of greatest acuity

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[14]Briefly, the results of the measurement of peripheral motion acuity in 50 subjects are as follows: The test showed a reliability of .82. Peripheral motion acuity was about 60% as strong as the acuity of comparable retinal areas measured with stationary test objects. Peripheral motion acuity showed little or no tendency toward eye-to-eye improvement during the test. There was very little difference between motion acuity measured with inswinging test objects and that measured with outswinging test objects. The inner 3 to 5 degrees of excursion is the critical area for form perception regardless of whether the test object is inswinging or outswinging. The phenomena, such as mm. variability and percentile steadiness, observed in the measurement of motion acuity are essentially the same as those previously observed in the measurement of stationary acuity.

located 10 to 15 degrees from it is not quantitatively very much greater than outlying areas. Here, peripheral acuity itself is the useful function and any improvement in it, such as has been observed in this study, should be much more useful to the individual than a comparable increase in photopic peripheral acuity.

Certain theoretical and practical implications concerning visual function have arisen indirectly from this study. Early in the preliminary studies the close similarity of day and night visual acuity, differing only as 7 to 5 in the presence of a 1 to 2,000,000 difference in brightness[15] was noticed, this being a corroboration of data already known for simple acuity. Further similarity became evident in the mm. variability and percentile steadiness scores under the two levels of illumination. Essentially the same phenomena seemed to apply to both photopic and scotopic measures. Still further and more impressive similarity became evident in two distinct phenomena (1) the transfer of improved photopic acuity to scotopic acuity, and (2) the significant correlation between photopic rapid recognition scores and scotopic acuity scores. Much work has been done on night vision problems with a tendency to regard the phenomena here as clearly separated from other visual phenomena. It would seem that considerable economy might be achieved if peripheral perception were regarded as a common perceptual phenomenon, regardless of brightness levels, but subject, of course, to the limitations of well established phenomenon of dark adaptation. It has been indicated in this report that both the measurement and training of night visual acuity could be accomplished without reverting to the awkward, time consuming, and expensive conditions of literally working in the dark.

In conclusion it may be said that peripheral visual acuity has been successfully trained. It has been demonstrated that the technique, although slow, is applicable to large groups of subjects. The basic feature of the technique is the functional improvement of an unpracticed sensory area through forced practice. The fundamental requirements of the method are (1) the forcing of peripheral interpretation by perimetric apparatus and (2) the exposure of stationary stimuli long enough to give the subject an opportunity to work out his impression of the stimulus. The extent of the improvement is great and its practical value to the subject apparent.

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[15] Low, F. N. Op. cit. (See footnote 3 of this report.)

APPENDIX A

OPERATOR'S MANUAL OF TESTING PROCEDURES

APPENDIX A

OPERATOR'S MANUAL OF TESTING PROCEDURES

APPARATUS

<u>The Quantitative Perimeter</u>. This instrument is used for testing and training peripheral visual acuity. It consists essentially of (1) a primary arm supported from the base which determines the meridian along which the test object can be set, and (2) a secondary arm supported by the primary arm which determines the angular deviation of the test object from the line of vision. A primary dial rotates with the primary arm and a secondary dial rotates with the secondary arm.

When the dials are at zero, both arms determine a vertical plane which passes through both eye piece and fixation button. Unless otherwise specified the apparatus is described in zero position. The primary dial is the lower one near the base and can be set by rotating force applied to it. The secondary dial is at the top of the instrument and can be set by force applied to the secondary arm after the primary dial has been set.

A counterweight for the secondary arm, consisting of a pipe-length and iron weight, screws into this arm opposite the lamp socket. For hand operation the cylindrical weight should be firmly adjusted at the far end of the pipe.

The mechanism at the free end of the secondary arm is designed for presentation of the stimuli. A circular shield obscures the operator's hand. Two small wheels are mounted behind the shield. The upper wheel controls the position of the test object, and is constructed so that only four positions are possible. It turns a shaft which supports a target holder on the opposite side of the shield. The lower wheel controls a blind which either covers or presents the test object.

The targets are square sheets of metal with two copper pins on the back. The primary pin is long, and is centered on the back of the target. The secondary pin is short, and off-center.

A target is placed on the instrument by inserting its primary pin into the centered hole in the target holder. While applying slight pressure to the target the upper wheel should be rotated until the secondary pin coincides with a marginal notch in the target holder. The target will then slip into position and rotate with the upper wheel. In placing the target in position, the primary pin displaces a ball bearing which is spring-pressed into the tube. The pressure on the bearing can be adjusted by turning a laterally placed screw. This mechanism is designed to prevent auditory cues caused by the turning of the target. Sometimes a target which is silent for one angular deviation and meridian may make a clinking sound at another. Increasing the pressure on the ball bearing should eliminate this. The targets should be handled by the pins or the edges at all times.

The test objects are photographically printed and pasted on the targets. The size of the test object is printed on the back of the target. It roughly corresponds to the width of the break in the circle in millimeters.

The fixation button is pasted on a detachable mount which fits into the end of a slit copper tube. The tube is inserted into the center hole passing through the axis of rotation of the primary arm, so that Number I on the fixation button is above and vertical. The surface of the fixation button should be approximately flush with the flat surface of the primary arm. The button will then turn with the primary arm so that there is always easy identification of the position of the break in the test object with reference to its corresponding number (i.e., I, II, III, or IIII).

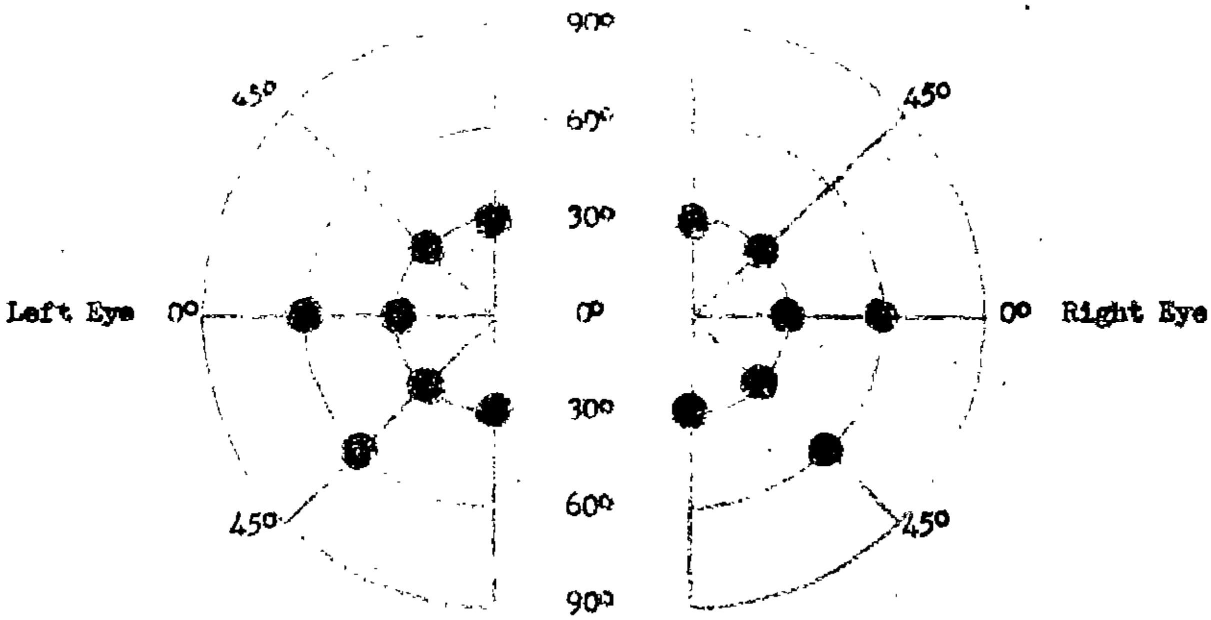
__Accessory Apparatus.__ This has been described in an earlier study.[15] The present apparatus has eliminated most of these items. The testing should be done in a three-sided booth of black cloth, the ideal dimensions of which are 4 feet 6 inches wide and 3 feet 6 inches deep. Black cloth should be draped from a height of 7 feet to close to the floor. The instrument is set on a table in the center of the booth. It is placed so that the subject faces the operator, who stands in the back of the booth behind the table. The cloth on the sides should extend laterally as far as the subject's field of vision (100°+). The top of the table should be black. It has been found that black gown and gloves for the operator are not necessary. If the operator stands still during determinations the distraction of his visible presence is negligible.

TESTING

The test for peripheral acuity consists of the measurement of simple form acuity at fourteen points (areas) of the visual periphery. All points are located in the temporal half, as distinguished from the nasal half of the visual field (see Figure 5). The order of testing the points, their position, and the dial readings on the instrument are as follows:

Order	Meridian	Angular Deviation	Primary Dial	Secondary Dial
1	Out (horizontal)	30°	0°	30°
2	Out (horizontal)	60°	0°	60°
3	Down & out (45° below horizontal)	30°	45°	30°

[15] Low, F. N. __Op. cit.__ (See footnote 2 of this report.)



(The meridians on which the points are tested are 45° apart; angular deviations of the points from the line of vision are 30°, and 60°.)

FIGURE 5

SOLID CIRCLES REPRESENT POINTS TESTED
ON TEMPORAL VISUAL FIELDS

Order of testing continued:

Order	Meridian	Angular Deviation	Primary Dial	Secondary Dial
4	Down & out (45° below horizontal)	60°	45°	60°
5	Down (vertical)	30°	90°	30°
6	Up (vertical)	30°	90°	30°
7	Up & out (45° above horizontal)	30°	45°	30°

The left eye is always tested first. The procedure is repeated on the right eye.

When testing either eye, the first point requires the primary dial of the instrument to be set at 0 degrees and the secondary dial at 30 degrees, care being taken that the test object is in the temporal field (as distinguished from nasal field) of the eye being tested. Care should be taken to avoid nasal placement of the test object. On points 5 and 6 the primary dial should be set so that the lamp is on the side of the blind eye.

The measure of acuity for each point is derived by decreasing (or increasing) the size of the test object presented. The technique is as follows: a target (4 for 30 degrees, 7 for 60 degrees) is placed on the instrument and covered with the blind. It is set randomly and presented by turning the blind. The subject, with fixated eye, signals (verbally or by tapping with a pencil) the position of the break by matching it with the numbers around the perimeter button. The target is covered, reset randomly, and re-presented. The "success" criterion is <u>four consecutive correct answers before the second wrong one</u>. If successful, the next smallest test object is tried, and so on to failure. If the original size tried is failed, the size is progressively increased to a "success" performance.

The sizes specified for starting are so chosen as to be above the threshold of acuity for the majority of individuals. With experience in the operation of this test, the choice of starting size can be modified to fit the subject. However, it is desirable to keep the starting size well above the expected threshold because of spontaneous fluctuation in the subject's ability to evaluate peripheral stimuli. When setting the test object randomly it is best to turn it slowly with firm grip as this avoids the auditory cues which result from too rapid revolution.

The smallest "success" size is entered on the score sheet in the proper box. It is corrected to an equivalent as indicated below:

Target No.	¼	½	1	1½	2	2½	3	4	5
Equivalent	.13	.4	.7	1.2	1.7	2.2	2.6	3.5	4.5

Target No.	6	7	8	9	10	10x
Equivalent	5.3	6.2	7.2	8.3	9.3	10.4

If size No. 10 is failed, 10x is entered in the score box and translated to the arbitrary equivalent, 10.4.

The following instructions may be given the subject:

"The instrument used for this test is a perimeter. It is designed to measure your ability to see and recognize objects which appear outside of your direct line of vision, i.e., it is to test your ability to recognize objects which appear to the side without moving your eyes to look directly at them. You will sit facing the 'perimeter button.' Look straight at it during the test. Closer to you, in line with the perimeter button, are an eye piece and a chin rest. The operator will assist you in bringing your head forward so that the eye piece lightly touches the lower lid of the eye being tested.

Now adjust the chin rest to help steady your head. Be sure to keep your head facing directly forward and at an even keel. Look directly at the perimeter button and don't move your eye.

The operator will put a broken circle (which looks very much like a capital C) in the target holder. When this circle is revealed to you it will be off to one side. Without moving your gaze from the perimeter button you will signify in what direction the break in the circle is pointing. Notice the numbers I, II, III, and IIII around the perimeter button. The break in the circle will correspond to the position of one of these numbers. If it points in the same direction as I, tap once on the table with your pencil. If it corresponds to number II, tap twice, etc. If you are not certain you must guess. A wrong answer is better than none at all. Don't move your eye, even after you have answered.

The operator will gradually reduce the size of the circle until you can't give correct answers any more. Then another point will be tested the same way. After one eye is tested on 7 points, the other eye will be tested. Relax as much as possible without moving your head and DON'T MOVE YOUR EYE."

It has been found that a verbal condensation of the above directions by the operator, demonstrating at the perimeter, is both shorter and more satisfactory than having the subject read the instructions. It is advisable to check the subject's comprehension of the matching of test object position with fixation button numbers. This can be done by revealing sample positions to be identified by unrestricted binocular central vision before the test begins. A short rest between eyes is permissible. Should the subject wish to relax between points this may be permitted.

The fixation is best stressed before the test. It is the operator's duty to check fixation during the test. If the subject's eye shows voluntary movement (short, quick excursions) the test object should be covered and reset. The subject should be warned. Do not score any response in the presence of voluntary eye movement as either correct or incorrect. Discard it completely. Most subjects show satisfactory fixation. Others have considerable trouble learning the technique. Many subjects show a slow, irregular wandering of the eye, easily distinguishable from the rapid voluntary movement. Unless this is excessive it can be ignored.

Under no circumstances should a reading be discarded for any reason other than poor fixation. No matter how illogical or unexpected a wrong answer may be, it must always be counted when given in the presence of satisfactory fixation.

Many subjects tend to develop the habit of glancing at the test object immediately after giving the response. This should be discouraged, as it induces a tendency to "guess and then verify" rather than promote an attempt to evaluate the peripheral stimulus. It is also unwise to tell the subject whether he is right or wrong after each response, since this, too, encourages a guess with anticipated verification. In general, the better the fixation, the better the score. This should be impressed on the subject if fixation is poor.

The perimeter is so constructed that the line of vision has a 10 degree downward tilt toward the operator. This permits a forward tilt to the head which relieves neck fatigue. The side-to-side alignment of the head must be kept horizontal as any tilt rotates the eyeball and has the effect of altering the meridian.

Many subjects are easily distracted by extraneous light around the edges of the patch on the blind eye. It is well to relieve them when possible but this usually does not produce a noticeable difference in the acuity readings. The purpose of the patch is primarily to prevent binocular perception. Subjects who are easily distracted tend to blame this on any score they may suspect is poor. The real difficulty seems to be intrinsic to the subject rather than external.

SCORE SHEET

The appended score sheet (see Figure 6) is designed for use during the test. The boxes in the lower half of the sheet are so arranged as to provide a vertical column for each point score and its derivatives. Horizontal lines provide for the same score or derivative for each of the fourteen points. Above the empty boxes are specifications for eye, meridian, and angular deviation. Below the boxes the order of testing is indicated.

Date:____________________ Code No:____________

Name:____________________________________Age:________Time:__________________

Identification____

	V	%V
First (L)		
Second (R)		
Both		

Test No:______________

Period No:____________

Operator:_____________

		First Eye (LEFT)							Second Eye (RIGHT)						
		out		down & out		down	up	up & out	out		down & out		up	down	up & out
		30°	60°	30°	60°	30°	30°	30°	30°	60°	30°	60°	30°	30°	30°
RAW SCORE	1														
EQUIVALENT	2														
	3														
	4														
	5														
	6														
	7														
	8														
Order of Testing		1	2	3	4	5	6	7	8	9	10	11	12	13	14

Remarks:

FIGURE 6

SCORE SHEET

During the testing the smallest "success" size for each point is entered in horizontal line 1, and is known as the raw score. Later the raw scores are corrected to the equivalents listed on pp. 28, 29 and are entered in horizontal line 2. The sum of the equivalents for the seven points of each eye is entered in the left hand column of the nine-square box near the top of the sheet. The sum of the fourteen equivalents is the total score, which is entered in the lower left hand box opposite the word "Both."

MANAGEMENT OF APPARATUS

Primary Bearing. This is the bearing in which the primary arm is supported by the base. The friction is so adjusted that it will hold the primary arm in any position desired. If the bearing loosens, it can be tightened with pressure applied by a wood press. Some tightening can be achieved with the set-screws in the bearing.

Secondary Bearing. In this bearing the primary arm supports the secondary arm and the secondary dial. Friction is applied by a spring brake pressing against the lower surface of the secondary dial. This pressure can be adjusted by turning the screw facing downward on the upper part of the primary arm.

If the reading of the secondary dial gets out of adjustment, it can be corrected by manipulating the set-screws which control the relationship of the secondary arm to the secondary dial. Loosening the screws and setting both dial and arm at zero will give the proper set. The screws should be tightened while the dial and arm are being held in position.

Targets. The photographic paper on which the test objects are printed is pasted on the metal target with Duco Household Cement. The dissimilar surfaces, paper and metal, react differently to temperature and humidity changes. A tendency to peel may be evident, especially after abrupt weather changes or in the presence of dry artificial heat. The paper may be repasted wholly or in part with the above cement. Pressure after treatment is desirable.

APPENDIX B

THE TRAINING TECHNIQUE

APPENDIX B

THE TRAINING TECHNIQUE

The technique of the test for peripheral visual acuity, with a description of the apparatus used, is described in Appendix A. The training technique described below is a modification of the testing technique.

APPARATUS

The quantitative perimeter is employed. The test objects are airplane silhouettes. Four types of plane are represented, being designated as 1, 2, 3, and 4. Five sizes of each plane are provided. The sizes represent the width of the wingspread in millimeters and are designated 50, 25, 10, 5, and 2½ mm.

TRAINING

The Training Sheets in this Appendix include specifications as to plane number, plane size, and meridian to be trained. There are ten variations of the above variables which may be specified for the training of each eye.

Beginning with the right eye, the plane specified on line one should be set in the target holder. The instrument should be set at the specified meridian, by the method described under TESTING (see Appendix A). The secondary arm should be set at 20 degrees (the least angular deviation practical). The same success criterion as was used for the circles applies to the plane silhouettes. The subject signals the direction the plane points. Upon repeated presentation four consecutive correct answers must precede the second wrong one. When success is achieved the secondary arm is set so as to move the test object 10 degrees farther from the line of vision, the meridian remaining unchanged, and the procedure repeated until failure occurs. Then the angular deviation is reduced 5 degrees and another set of exposures is run. The subject's "score" is the greatest angular deviation at which he is successful, and is entered on the training sheet under "score" at the right end of the line specifying the procedure.

When the right eye of any subject has been trained according to specifications he becomes the operator and trains his former operator's right eye. Following this the left eye of each individual is trained in the same manner.

Occasionally a large size airplane silhouette can be successfully identified on the horizontal and the "down and out" meridians as far out as the visual field extends. This is usually 95 degrees. On other meridians the eyebrow and cheek limit the extent to which the test object can be displaced to remain visible. In all cases where this occurs the greatest angular deviation at which success has been achieved should be scored with the word "plus" added. When working with small silhouettes a subject sometimes cannot make a successful set of responses of 20 degrees. In such a case the score should read "20 minus."

In general, the training technique differs from the testing technique in that each plane silhouette is "pushed outward" along a meridian while the circles are identified in decreasing sizes in one location. Other rules of procedure, including those concerning eye movement, are the same for both techniques.

For purposes of reducing the necessity of paging through the score sheets in order to identify the procedures administered at the various periods to Groups I and II, the following schema of the testing and training program is presented with a brief description of the techniques:

Group I (N = 18)

Period	
1	1st Straight Test (isolated points No. 10 Circle Transfer)
2	
3	Training { sizes 50, 25, & 10; all meridians
4	
5	2nd Straight Test
6	
7	Training { sizes 25, 10, & 5; all meridians
8	
9	3rd Straight Test
10	
11	Training { sizes 10, 5, & 2½; all meridians
12	
13	4th Straight Test
14	
15	Training { sizes 5 & 2½; all meridians
16	
17	5th Straight Test
18	
19	Training { sizes 5, 2½, & 50; emphasis on down, up, and up and out meridians
20	
21	6th Straight Test
22	
23	Training { sizes 25, 10, & 5; all meridians
24	
25	7th Straight Test
26	Rotated Meridian Test
27	Night Visual Acuity Test
28	Rapid Recognition Test
29	8th Straight Test (isolated points, No. 10 Circle Transfer)

Group II (N = 25)

Period	
1	1st Straight Test (isolated points No. 10 Circle Transfer)
2	Rapid Recognition Test
3	
4	Training { sizes 50, 25, & 10; all meridians
5	
6	2nd Straight Test
7	
8	Training { sizes 25, 10, & 5; all meridians
9	
10	3rd Straight Test
11	
12	Training { sizes 10, 5, & 2½; all meridians
13	
14	4th Straight Test
15	
16	Training { sizes 5 & 2½; all meridians
17	
18	5th Straight Test
19	
20	Training { sizes 5, 2½, & 50, emphasis on down, up, and up and out meridians
21	
22	6th Straight Test
23	Training { sizes 25 & 10; all meridians
24	
25	Rotated Meridian Test
26	Night Visual Acuity Test
27	Rapid Recognition Test (isolated points, No. 10 Circle Transfer)
28	8th Straight Test (Non-perimetric binocular transfer test)

The two groups listed on the preceding page, although differing in certain detail, received as nearly the same training as possible under the circumstances of slight differences in the length of the academic quarters. Group I received 29 full periods of training. The general pattern was that of training with an acuity test every 4th period. Group II received 28 full periods with the same general pattern. However, at the request of the Committee on Selection and Training of Aircraft Pilots a rapid recognition test was inserted in period 2 in Group II. Then, because of the loss of this one period and a semester one period shorter, it was necessary to omit in Group II the periods corresponding to periods 24 (training) and 25 (7th straight test) of Group I. The various transfer tests are the same for each group with the exception of a non-perimetric binocular transfer test administered to Group II only (period 28). The short transfer tests have been given to the two groups at slightly different times, but in general, stand at the beginning and end of the training. Both groups received the same set of three special tests at the end of the training (rotated meridian, night visual acuity, and rapid recognition).

SCORE SHEETS FOR TESTING AND TRAINING REGIME

TESTING SHEET

Date:______________________ Code No:__________

Name:______________________________________ Age:________ Time:______________

Identification:____________________________________

TRANSFER TEST:

Isolated Points: (3 squares and a circle)

25 mm.: L

R

10 mm.: L

R

			V	%V
First	(L)			
Second	(R)			
Both				

Test No: 1 (Group I)*

Period No: 1 (Group I)

Operator:______________

		First Eye (LEFT)							Second Eye (RIGHT)						
		out		down & out		down	up	up & out	out		down & out		down	up	up & out
		30°	60°	30°	60°	30°	30°	30°	30°	60°	30°	60°	30°	30°	30°
RAW SCORE	1														
EQUIVALENT	2														
	3														
	4														
	5														
	6														
	7														
	8														
Order of Testing		1	2	3	4	5	6	7	8	9	10	11	12	13	14

Remarks:

Test No 1, Period No. 1, Group 1

TESTING SHEET

Date: ______________ Code No: __________

Name: ______________________________ Age: ________ Time: ______________

Identification: ______________________________

TRANSFER TEST:**

No. 10 circles (10 tries)

L (Out 90°
(Down & Out 90°

R (Out 90°
(Down & Out 90°

	V	%V
First (L)		
Second (R)		
Both		

Test No: 2 (Group II)*

Period No: 2 (Group II)

Operator: ______________

		First Eye (LEFT)							Second Eye (RIGHT)						
		out		down & out		down	up	up & out	out		down & out		down	up	up & out
		30°	60°	30°	60°	30°	30°	30°	30°	60°	30°	60°	30°	30°	30°
RAW SCORE	1														
EQUIVALENT	2														
	3														
	4														
	5														
	6														
	7														
	8														
Order of Testing		1	2	3	4	5	6	7	8	9	10	11	12	13	14

Remarks:

*No corresponding period in Group I
**Rapid recognition test (0.2 sec exposure)

TRAINING SHEET

Date: ____________________ Code No: ______________

Name: ____ Age: ________ Sex: ________
last first middle

Identification: ____

PERIPHERAL TRAINING - PLANE SILHOUETTES Period No: 2, (Group I)*

RIGHT EYE

Order	Plane No.	Size	Meridian	Score
1	1	50	Out	
2	1	25	"	
3	2	50	"	
4	2	25	"	
5	3	50	"	
6	3	25	"	
7	4	50	"	
8	4	25	"	
9				
10				

LEFT EYE

Order	Plane No.	Size	Meridian	Score
1	1	50	Out	
2	1	25	"	
3	2	50	"	
4	2	25	"	
5	3	50	"	
6	3	25	"	
7	4	50	"	
8	4	25	"	
9				
10				

Remarks: TRANSFER TEST:**

No. 10 circle (10 tries)

L (Out 90°
(Down & Out 90°

R (Out 90°
(Down & Out 90°

*Period No. 3, Group II

**Given in Period 2 for Group II

TRAINING SHEET

Date:____________________ Code No:________________

Name:____ Age:______ Sex:__________
last first middle

Identification:____

PERIPHERAL TRAINING - PLANE SILHOUETTES Period No: 3 (Group I)*

RIGHT EYE

Order	Plane No.	Size	Meridian	Score
1	1	50	Down & Out	
2	1	25	" "	
3	2	50	" "	
4	2	25	" "	
5	3	50	" "	
6	3	25	" "	
7	4	50	" "	
8	4	25	" "	
9				
10				

LEFT EYE

Order	Plane No.	Size	Meridian	Score
1	1	50	Down & Out	
2	1	25	" "	
3	2	50	" "	
4	2	25	" "	
5	3	50	" "	
6	3	25	" "	
7	4	50	" "	
8	4	25	" "	
9				
10				

Remarks:

*Period No. 4, Group II

TRAINING SHEET

Date:____________________ Code No:____________

Name:____ Age:________ Sex:________
last first middle

Identification:____

PERIPHERAL TRAINING - PLANE SILHOUETTES Period No: 4 (Group I)*

RIGHT EYE

Order	Plane No.	Size	Meridian	Score
1	1	25	Down	
2	1	25	Up	
3	1	25	Up & Out	
4	1	10	Down	
5	1	10	Up	
6	1	10	Up & Out	
7	4	25	Down	
8	4	25	Up	
9	4	25	Up & Out	
10				

LEFT EYE

Order	Plane No.	Size	Meridian	Score
1	1	25	Down	
2	1	25	Up	
3	1	25	Up & Out	
4	1	10	Down	
5	1	10	Up	
6	1	10	Up & Out	
7	4	25	Down	
8	4	25	Up	
9	4	25	Up & Out	
10				

Remarks:

*Period No. 5, Group II

TESTING SHEET

Date: ________________ Code No: __________

Name: ______________________________ Age: ________ Time: ______________

Identification: ______________________________

		V	%V
First (L)			
Second (R)			
Both			

Test No: 2 (Group I)*

Period No: 5 (Group I)

Operator: ______________

		First Eye (LEFT)							Second Eye (RIGHT)						
		out		down & out		down	up	up & out	out		down & out		down	up	up & out
		30°	60°	30°	60°	30°	30°	30°	30°	60°	30°	60°	30°	30°	30°
RAW SCORE	1														
EQUIVALENT	2														
	3														
	4														
	5														
	6														
	7														
	8														
Order of Testing		1	2	3	4	5	6	7	8	9	10	11	12	13	14

Remarks:

*Test No. 2, Period No. 5, Group II

TRAINING SHEET

Date:______________________ Code No:__________

Name:______________________________________Age:________Sex:__________
last first middle

Identification:____

PERIPHERAL TRAINING - PLANE SILHOUETTES Period No: 6 (Group I)*

RIGHT EYE

Order	Plane No.	Size	Meridian	Score
1	1	25	Out	
2	1	10	"	
3	2	25	"	
4	2	10	"	
5	3	25	"	
6	3	10	"	
7	4	25	"	
8	4	10	"	
9				
10				

LEFT EYE

Order	Plane No.	Size	Meridian	Score
1	1	25	Out	
2	1	10	"	
3	2	25	"	
4	2	10	"	
5	3	25	"	
6	3	10	"	
7	4	25	"	
8	4	10	"	
9				
10				

Remarks:

*Period No. 7, Group II

TRAINING SHEET

Date: ____________________ Code No: ____________

Name: ____ Age: ______ Sex: ______
last first middle

Identification: ____

PERIPHERAL TRAINING - PLANE SILHOUETTES Period No: 7 (Group I)*

RIGHT EYE

Order	Plane No.	Size	Meridian	Score
1	1	25	Down & Out	
2	1	10	" "	
3	2	25	" "	
4	2	10	" "	
5	3	25	" "	
6	3	10	" "	
7	4	25	" "	
8	4	10	" "	
9				
10				

LEFT EYE

Order	Plane No.	Size	Meridian	Score
1	1	25	Down & Out	
2	1	10	" "	
3	2	25	" "	
4	2	10	" "	
5	3	25	" "	
6	3	10	" "	
7	4	25	" "	
8	4	10	" "	
9				
10				

Remarks:

*Period No. 8, Group II

TRAINING SHEET

Date:__________________ Code No:____________

Name:__________________________________ Age:______ Sex:_______
last first middle

Identification:____________________________________

PERIPHERAL TRAINING - PLANE SILHOUETTES Period No: 8 (Group I)*

RIGHT EYE

Order	Plane No.	Size	Meridian	Score
1	1	10	Down	
2	1	10	Up	
3	1	10	Up & Out	
4	1	5	Down	
5	1	5	Up	
6	1	5	Up & Out	
7	4	10	Down	
8	4	10	Up	
9	4	10	Up & Out	
10				

LEFT EYE

Order	Plane No.	Size	Meridian	Score
1	1	10	Down	
2	1	10	Up	
3	1	10	Up & Out	
4	1	5	Down	
5	1	5	Up	
6	1	5	Up & Out	
7	4	10	Down	
8	4	10	Up	
9	4	10	Up & Out	
10				

Remarks:

*Period No. 9, Group II

TESTING SHEET

Date:________________ Code No:____________

Name:____________________________________Age:_________Time:________________

Identification:____

		V	%V
First (L)			
Second (R)			
Both			

Test No: 3 (Group I)*

Period No: 9 (Group I)

Operator:________________

		First Eye (LEFT)							Second Eye (RIGHT)						
		out		down & out		down	up	up & out	out		down & out		down	up	up & out
		30°	60°	30°	60°	30°	30°	30°	30°	60°	30°	60°	30°	30°	30°
RAW SCORE	1														
EQUIVALENT	2														
	3														
	4														
	5														
	6														
	7														
	8														
Order of Testing		1	2	3	4	5	6	7	8	9	10	11	12	13	14

Remarks:

*Test No. 4, Period No. 10, Group II

TRAINING SHEET

Date:________________ Code No:__________

Name:__________________________________ Age:______ Sex:______
last first middle

Identification:__________________________________

PERIPHERAL TRAINING - PLANE SILHOUETTES Period No: 10 (Group I)*

RIGHT EYE

Order	Plane No.	Size	Meridian	Score
1	1	10	Out	
2	1	5	"	
3	2	10	"	
4	2	5	"	
5	3	10	"	
6	3	5	"	
7	4	10	"	
8	4	5	"	
9				
10				

LEFT EYE

Order	Plane No.	Size	Meridian	Score
1	1	10	Out	
2	1	5	"	
3	2	10	"	
4	2	5	"	
5	3	10	"	
6	3	5	"	
7	4	10	"	
8	4	5	"	
9				
10				

Remarks:

*Period No. 11, Group II

TRAINING SHEET

Date: ______________ Code No: ______________

Name: ______________________________ Age: ________ Sex: ________
last first middle

Identification: ______________________________

PERIPHERAL TRAINING - PLANE SILHOUETTES Period No: 11 (Group I)*

RIGHT EYE

Order	Plane No.	Size	Meridian	Score
1	1	10	Down & Out	
2	1	5	" "	
3	2	10	" "	
4	2	5	" "	
5	3	10	" "	
6	3	5	" "	
7	4	10	" "	
8	4	5	" "	
9				
10				

LEFT EYE

Order	Plane No.	Size	Meridian	Score
1	1	10	Down & Out	
2	1	5	" "	
3	2	10	" "	
4	2	5	" "	
5	3	10	" "	
6	3	5	" "	
7	4	10	" "	
8	4	5	" "	
9				
10				

Remarks:

*Period No. 12, Group II

TRAINING SHEET

Date:________________ Code No:__________

Name:________________________________ Age:______ Sex:______
last first middle

Identification:________________________________

PERIPHERAL TRAINING - PLANE SILHOUETTES Period No: 12 (Group I)*

RIGHT EYE

Order	Plane No.	Size	Meridian	Score
1	1	5	Down	
2	1	5	Up	
3	1	5	Up & Out	
4	1	2½	Down	
5	1	2½	Up	
6	1	2½	Up & Out	
7	4	5	Down	
8	4	5	Up	
9	4	5	Up & Out	
10				

LEFT EYE

Order	Plane No.	Size	Meridian	Score
1	1	5	Down	
2	1	5	Up	
3	1	5	Up & Out	
4	1	2½	Down	
5	1	2½	Up	
6	1	2½	Up & Out	
7	4	5	Down	
8	4	5	Up	
9	4	5	Up & Out	
10				

Remarks:

*Period No. 13, Group II

TESTING SHEET

Date: ____________ Code No: ____________

Name: ______________________ Age: ________ Time: ____________

Identification: ______________________

	V	%V
First (L)		
Second (R)		
Both		

Test No: 4 (Group I)*
Period No: 13 (Group I)
Operator: ____________

		First Eye (LEFT)							Second Eye (RIGHT)						
		out		down & out		down	up	up & out	out		down & out		down	up	up & out
		30°	60°	30°	60°	30°	30°	30°	30°	60°	30°	60°	30°	30°	30°
RAW SCORE	1														
EQUIVALENT	2														
	3														
	4														
	5														
	6														
	7														
	8														
Order of Testing		1	2	3	4	5	6	7	8	9	10	11	12	13	14

Remarks:

*Test No. 5, Period No. 14, Group II

TRAINING SHEET

Date:____________________ Code No:__________

Name:______________________________________ Age:______ Sex:______
last first middle

Identification:____

PERIPHERAL TRAINING - PLANE SILHOUETTES Period No: 14 (Group I)*

RIGHT EYE

Order	Plane No.	Size	Meridian	Score
1	1	5	Out	
2	1	2½	"	
3	2	5	"	
4	2	2½	"	
5	3	5	"	
6	3	2½	"	
7	4	5	"	
8	4	2½	"	
9				
10				

LEFT EYE

Order	Plane No.	Size	Meridian	Score
1	1	5	Out	
2	1	2½	"	
3	2	5	"	
4	2	2½	"	
5	3	5	"	
6	3	2½	"	
7	4	5	"	
8	4	2½	"	
9				
10				

Remarks:

*Period No. 15, Group II

TRAINING SHEET

Date:____________________ Code No:__________

Name:______________________________ Age:______ Sex:______
last first middle

Identification:______________________________

PERIPHERAL TRAINING - PLANE SILHOUETTES Period No: 15 (Group I)*

RIGHT EYE

Order	Plane No.	Size	Meridian	Score
1	1	5	Down & Out	
2	1	2½	" "	
3	2	5	" "	
4	2	2½	" "	
5	3	5	" "	
6	3	2½	" "	
7	4	5	" "	
8	4	2½	" "	
9				
10				

LEFT EYE

Order	Plane No.	Size	Meridian	Score
1	1	5	Down & Out	
2	1	2½	" "	
3	2	5	" "	
4	2	2½	" "	
5	3	5	" "	
6	3	2½	" "	
7	4	5	" "	
8	4	2½	" "	
9				
10				

Remarks:

*Period No. 16, Group II

TRAINING SHEET

Date: ____________________ Code No: __________

Name: ______________________________ Age: ____ Sex: ______
last first middle

Identification: ______________________________________

PERIPHERAL TRAINING - PLANE SILHOUETTES Period No: 16 (Group I)*

RIGHT EYE

Order	Plane No.	Size	Meridian	Score
1	2	2½	Down	
2	2	2½	Up	
3	2	2½	Up & Out	
4	3	2½	Down	
5	3	2½	Up	
6	3	2½	Up & Out	
7	4	2½	Down	
8	4	2½	Up	
9	4	2½	Up & Out	
10				

LEFT EYE

Order	Plane No.	Size	Meridian	Score
1	2	2½	Down	
2	2	2½	Up	
3	2	2½	Up & Out	
4	3	2½	Down	
5	3	2½	Up	
6	3	2½	Up & Out	
7	4	2½	Down	
8	4	2½	Up	
9	4	2½	Up & Out	
10				

Remarks:

*Period No. 17, Group II

TESTING SHEET

Date:______________ Code No:____________

Name:______________________________ Age:______ Time:______________

Identification:______________________________

	V	%V
First (L)		
Second (R)		
Both		

Test No: 5 (Group I)*

Period No: 17 (Group I)

Operator:______________

		First Eye (LEFT)							Second Eye (RIGHT)						
		out		down & out		down	up	up & out	out		down & out		up	down	up & out
		30°	60°	30°	60°	30°	30°	30°	30°	60°	30°	60°	30°	30°	30°
RAW SCORE	1														
EQUIVALENT	2														
	3														
	4														
	5														
	6														
	7														
	8														
Order of Testing		1	2	3	4	5	6	7	8	9	10	11	12	13	14

Remarks:

*Test No. 6, Period No. 18, Group II

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TRAINING SHEET

Date: ______________________ Code No: __________

Name: ______________________________________ Age: ________ Sex: ________
last first middle

Identification: ______________________________________

PERIPHERAL TRAINING - PLANE SILHOUETTES Period No: 18 (Group I)*

RIGHT EYE

Order	Plane No.	Size	Meridian	Score
1	1	5	Down	
2	1	2½	"	
3	2	5	"	
4	2	2½	"	
5	3	5	"	
6	3	2½	"	
7	4	5	"	
8	4	2½	"	
9	1	50	Out	
10	1	50	Down & Out	

LEFT EYE

Order	Plane No.	Size	Meridian	Score
1	1	5	Down	
2	1	2½	"	
3	2	5	"	
4	2	2½	"	
5	3	5	"	
6	3	2½	"	
7	4	5	"	
8	4	2½	"	
9	1	50	Out	
10	1	50	Down & Out	

Remarks:

*Period No. 19, Group II

TRAINING SHEET

Date:____________________ Code No:__________

Name:____________________________________ Age:______ Sex:______
last first middle

Identification:____

PERIPHERAL TRAINING - PLANE SILHOUETTES Period No: 19 (Group I)*

RIGHT EYE

Order	Plane No.	Size	Meridian	Score
1	1	5	Up	
2	1	$2\frac{1}{2}$	"	
3	2	5	"	
4	2	$2\frac{1}{2}$	"	
5	3	5	"	
6	3	$2\frac{1}{2}$	"	
7	4	5	"	
8	4	$2\frac{1}{2}$	"	
9	2	50	Out	
10	2	50	Down & Out	

LEFT EYE

Order	Plane No.	Size	Meridian	Score
1	1	5	Up	
2	1	$2\frac{1}{2}$	"	
3	2	5	"	
4	2	$2\frac{1}{2}$	"	
5	3	5	"	
6	3	$2\frac{1}{2}$	"	
7	4	5	"	
8	4	$2\frac{1}{2}$	"	
9	2	50	Out	
10	2	50	Down & Out	

Remarks:

*Period No. 20, Group II

TRAINING SHEET

Date: ____________________ Code No: ____________

Name: ______________________________________ Age: ______ Sex: ________
last first middle

Identification: ____

PERIPHERAL TRAINING - PLANE SILHOUETTES Period No: 20 (Group I)*

RIGHT EYE

Order	Plane No.	Size	Meridian	Score
1	1	5	Up & Out	
2	1	2½	" "	
3	2	5	" "	
4	2	2½	" "	
5	3	5	" "	
6	3	2½	" "	
7	4	5	" "	
8	4	2½	" "	
9	3	50	Out	
10	3	50	Down & Out	

LEFT EYE

Order	Plane No.	Size	Meridian	Score
1	1	5	Up & Out	
2	1	2½	" "	
3	2	5	" "	
4	2	2½	" "	
5	3	5	" "	
6	3	2½	" "	
7	4	5	" "	
8	4	2½	" "	
9	3	50	Out	
10	3	50	Down & Out	

Remarks:

*Period No. 21, Group II

TESTING SHEET

Date:________________ Code No:____________

Name:__________________________________Age:________Time:________________

Identification:____

		V	%V
First	(L)		
Second	(R)		
Both			

Test No: 6 (Group I)*

Period No: 21 (Group I)

Operator:____________

		First Eye (LEFT)							Second Eye (RIGHT)						
		out		down & out		down	up	up & out	out		down & out		down	up	up & out
		30°	60°	30°	60°	30°	30°	30°	30°	60°	30°	60°	30°	30°	30°
RAW SCORE	1														
EQUIVALENT	2														
	3														
	4														
	5														
	6														
	7														
	8														
Order of Testing		1	2	3	4	5	6	7	8	9	10	11	12	13	14

Remarks:

*Test No. 7, Period No. 22, Group II

TRAINING SHEET

Date: ____________________ Code No: ____________

Name: ____ Age: ______ Sex: ________
last first middle

Identification: ____

PERIPHERAL TRAINING - PLANE SILHOUETTES Period No: 22 (Group I)*

RIGHT EYE

Order	Plane No.	Size	Meridian	Score
1	1	25	Out	
2	1	25	Down & Out	
3	1	25	Down	
4	1	25	Up	
5	1	25	Up & Out	
6	4	25	Out	
7	4	25	Down & Out	
8	4	25	Down	
9	4	25	Up	
10	4	25	Up & Out	

LEFT EYE

Order	Plane No.	Size	Meridian	Score
1	1	25	Out	
2	1	25	Down & Out	
3	1	25	Down	
4	1	25	Up	
5	1	25	Up & Out	
6	4	25	Out	
7	4	25	Down & Out	
8	4	25	Down	
9	4	25	Up	
10	4	25	Up & Out	

Remarks:

*Period No. 23, Group II

TRAINING SHEET

Date: ______________ Code No: __________

Name: ______________________________ Age: ______ Sex: ______
last first middle

Identification: ______________________________

PERIPHERAL TRAINING - PLANE SILHOUETTES Period No: 23 (Group I)*

RIGHT EYE

Order	Plane No.	Size	Meridian	Score
1	1	10	Out	
2	1	10	Down & Out	
3	1	10	Down	
4	1	10	Up	
5	1	10	Up & Out	
6	4	10	Out	
7	4	10	Down & Out	
8	4	10	Down	
9	4	10	Up	
10	4	10	Up & Out	

LEFT EYE

Order	Plane No.	Size	Meridian	Score
1	1	10	Out	
2	1	10	Down & Out	
3	1	10	Down	
4	1	10	Up	
5	1	10	Up & Out	
6	4	10	Out	
7	4	10	Down & Out	
8	4	10	Down	
9	4	10	Up	
10	4	10	Up & Out	

Remarks:

*Period No. 24, Group II

TRAINING SHEET

Date: ____________________ Code No: __________

Name: ______________________________________ Age: ______ Sex: ______
last first middle

Identification: ______________________________________

PERIPHERAL TRAINING - PLANE SILHOUETTES Period No: 24 (Group I)*

RIGHT EYE

Order	Plane No.	Size	Meridian	Score
1	1	5	Out	
2	1	5	Down & Out	
3	1	5	Down	
4	1	5	Up	
5	1	5	Up & Out	
6	2	5	Out	
7	2	5	Down & Out	
8	2	5	Down	
9	2	5	Up	
10	2	5	Up & Out	

LEFT EYE

Order	Plane No.	Size	Meridian	Score
1	1	5	Out	
2	1	5	Down & Out	
3	1	5	Down	
4	1	5	Up	
5	1	5	Up & Out	
6	2	5	Out	
7	2	5	Down & Out	
8	2	5	Down	
9	2	5	Up	
10	2	5	Up & Out	

Remarks:

*No comparable period for Group II

TESTING SHEET

Date:______________ Code No:____________

Name:______________________________ Age:________ Time:______________

Identification:____

		V	%V
First (L)			
Second (R)			
Both			

Test No: 7 (Group I)*

Period No: 25 (Group I)

Operator:____________

		First Eye (LEFT)							Second Eye (RIGHT)						
		out		down & out		down	up	up & out	out		down & out		down	up	up & out
		30°	60°	30°	60°	30°	30°	30°	30°	60°	30°	60°	30°	30°	30°
RAW SCORE	1														
EQUIVALENT	2														
	3														
	4														
	5														
	6														
	7														
	8														
Order of Testing		1	2	3	4	5	6	7	8	9	10	11	12	13	14

Remarks:

*No comparable test for Group II

TESTING SHEET

Date:______________ Code No:____________

Name:______________________________ Age:_______ Time:_____________

Identification:__________________________________

		V	%V
First (L)			
Second (R)			
Both			

Test No: 8 (Group I)*

Period No: 26 (Group I)

Operator:____________

		First Eye (LEFT)							Second Eye (RIGHT)						
		D&O 22.5°		D&O 67.5°		U&O 22.5	U&O 67.5	IN 0°	D&O 22.5°		D&O 67.5°		U&O 22.5	U&O 67.5	IN 0°
		30°	60°	30°	60°	30°	30°	30°	30°	60°	30°	60°	30°	30°	30°
RAW SCORE	1														
EQUIVALENT	2														
	3														
	4														
	5														
	6														
	7														
	8														
Order of Testing		1	2	3	4	5	6	7	8	9	10	11	12	13	14

Remarks: Rotated meridians as noted above

*Test No. 8, Period No. 25, Group II

TESTING SHEET

Date:_______________ Code No:____________

Name:__________________________________ Age:________ Time:____________________

Identification:____________________________________

		V	%V
First (L)			
Second (R)			
Both			

Test No: 9 (Group I)*

Period No: 27 (Group I)

Operator:______________

		First Eye (LEFT)							Second Eye (RIGHT)						
		out		down & out		down	up	up & out	out		down & out		down	up	up & out
		30°	60°	30°	60°	30°	30°	30°	30°	60°	30°	60°	30°	30°	30°
RAW SCORE	1														
EQUIVALENT	2														
	3														
	4														
	5														
	6														
	7														
	8														
Order of Testing		1	2	3	4	5	6	7	8	9	10	11	12	13	14

Remarks: Night Visual Acuity

*Test No. 9, Period No. 26, Group II

TESTING SHEET

Date:______________ Code No:____________

Name:____________________________ Age:_______ Time:____________

Identification__________________________________

TRANSFER TESTS:**

Isolated Points:
(3 squares and a circle)

25 mm.: L
R

10 mm.: L
R

No. 10 Circle:
(10 tries)

L (Out 90°
(Down & Out 90°

R (Out 90°
(Down & Out 90°

		V	%V
First	(L)		
Second	(R)		
Both			

Test No: 10 (Group I)*

Period No: 28 (Group I)

Operator:____________

		First Eye (LEFT)							Second Eye (RIGHT)						
		out		down & out		down	up	up & out	out		down & out		down	up	up & out
		30°	60°	30°	60°	30°	30°	30°	30°	60°	30°	60°	30°	30°	30°
RAW SCORE	1														
EQUIVALENT	2														
	3														
	4														
	5														
	6														
	7														
	8														
Order of Testing		1	2	3	4	5	6	7	8	9	10	11	12	13	14

Remarks: Rapid recognition test (0.2 sec. exposure)

*Test No. 10, Period No. 27, Group II
**Transfer tests given to Group II only with this test

TESTING SHEET

Date: ______

Name: ______ Age: ______ Time: ______

Identification: ______

Code No: ______

Nonperimetric transfer test: binocular; [illegible]° from line of [illegible]

Acuity in mm
- (Horizontal, Left
- (Horizontal, Right
- (Down - [illegible] tries with #[illegible] circle
- (Up - [illegible] tries with #[illegible] circle

		V	%V
First	(L)		
Second	(R)		
Both			

Test No: 11 (Group II)*

Period No: 28 (Group II)

Operator: ______

		First Eye (LEFT)							Second Eye (RIGHT)						
		out		down & out		down	up	up & out	out		down & out		down	up	up & out
		30°	60°	30°	60°	30°	30°	30°	30°	60°	30°	60°	30°	30°	30°
RAW SCORE	1														
EQUIVALENT	2														
	3														
	4														
	5														
	6														
	7														
	8														
Order of Testing		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6	7	8	9	10	11	12	13	14

Remarks:

*Comparable to Test No. 11, Period No. 29, Group I, [illegible]

TESTING SHEET

Date:__________ Code No:__________

Name:__________ Age:______ Time:__________

Identification:__________

TRANSFER TESTS:**

Isolated Points:
(3 squares and a circle)

25 mm.: L
R

10 mm.: L
R

No. 10 Circle:
(10 tries)

L (Out 90°
(Down & Out 90°

R (Out 90°
(Down & Out 90°

		V	%V
First (L)			
Second (R)			
Both			

Test No: 11 (Group I)*
Period No: 29 (Group I)
Operator:__________

		First Eye (LEFT)							Second Eye (RIGHT)						
		out		down & out		down	up	up & out	out		down & out		down	up	up & out
		30°	60°	30°	60°	30°	30°	30°	30°	60°	30°	60°	30°	30°	30°
RAW SCORE	1														
EQUIVALENT	2														
	3														
	4														
	5														
	6														
	7														
	8														
Order of Testing		1	2	3	4	5	6	7	8	9	10	11	12	13	14

Remarks: Normal test, with transfer studies

*See Test No. 11, Period No. 28, Group II
**Given on this period for Group I only

APPENDIX C

THE SUBJECTIVE QUESTIONNAIRE

APPENDIX C

THE SUBJECTIVE QUESTIONNAIRE

In this questionnaire you will answer certain questions about experiences outside the laboratory which may have been the result of your visual training. There are no "right" answers; please give as accurate an account of your experiences as possible.

Date:____________________ Code No:____________

Name:__________________________________

I. In what situations outside the laboratory have you noticed a difference in your visual efficiency, such as:

Check one

	Change	No Change
A. Walking on street		
B. Sports		
C. Reading		
D. Other situations		

II. For those categories in which you have indicated a change describe briefly what your experiences were:

A. Walking on street:

B. Sports:

C. Reading:

D. Other situations:

III. Do the changes you have noticed intrude themselves on your consciousness or are they noticeable only when you think about the eye training? Explain.

IV. Describe any other experiences you may have had which might be of assistance to a person trying to evaluate the results of the eye training.

(use other side if necessary)

APPENDIX D

APPENDIX D

TABLE D-1

ACUITY, MM. VARIABILITY, AND PERCENTILE STEADINESS SCORES OF PROGRESSIVE LANDOLT RING TESTS

Code No.	Classification	Sex		1st Straight Test (N = 43*)	2nd Straight Test (N = 43*)	3rd Straight Test (N = 43*)	4th Straight Test (N = 43*)	5th Straight Test (N = 43*)	6th Straight Test (N = 43*)	7th Straight Test (N = 18)	8th Straight Test (N = 43*)
[illegible]	V-12	M	Acuity	44.5	17.9	33.1	20.5	18.6	29.4	15.9	10.9
			mm. Var	14.1	7.7	8.8	9.9	6.8	9.9	4.9	1.7
			% Steady	68.	57.	72.	52.	65.	66.	69.	84.
[illegible]	USMC	M	Acuity	MILITARY TRANSFER							
			mm. Var.								
			% Steady								
[illegible]	V-12	M	Acuity	32.9	23.6	23.0	23.4	23.9	MILITARY TRANSFER		
			mm. Var.	9.2	3.1	4.0	5.8	4.3			
			% Steady	72.	87.	83.	75.	82.			
[illegible]-4	V-12	M	Acuity	38.7	20.1	16.7	15.7	15.2	13.2	11.0	10.2
			mm. Var.	7.5	4.0	3.7	3.7	4.6	4.1	2.1	3.2
			% Steady	83.	80.	78.	77.	70.	69.	81.	69.
[illegible]-5	V-12	M	Acuity	40.3	24.0	22.9	20.8	17.8	16.1	13.5	13.4
			mm. Var.	9.8	4.7	5.9	3.7	6.0	3.0	2.0	3.4
			% Steady	76.	80.	74.	72.	67.	81.	85.	75.
T-6	USMC	M	Acuity	38.1	23.9	16.8	14.2	11.8	11.3	8.9	8.8
			mm. Var.	6.2	8.2	6.6	3.2	3.2	2.4	2.2	1.3
			% Steady	84.	66.	61.	78.	73.	79.	76.	85.
T-7	V-12	M	Acuity	64.3	34.5	47.8	33.7	35.8	34.6	29.1	31.4
			mm. Var.	18.0	3.	5.9	13.3	10.0	13.3	5.8	9.6
			% Steady	72.	91.	88.	61.	72.	62.	80.	70.

TABLE D-1 (Continued)

Code No.	Classification	Sex		1st Straight Test (N = 43*)	2nd Straight Test (N = 43*)	3rd Straight Test (N = 43*)	4th Straight Test (N = 43*)	5th Straight Test (N = 43*)	6th Straight Test (N = 43*)	7th Straight Test (N = 18)	8th Straight Test (N = 43*)
T-8	USMC	M	Acuity	45.3	28.6	19.6	13.0	10.1	9.6	9.1	6.7
			mm. Var.	12.1	7.3	8.5	2.3	1.9	1.7	1.4	1.5
			% Steady	74.	75.	57.	82.	82.	83.	85.	77.
T-9	USMC	M	Acuity	56.9	35.5	23.9	18.1	17.2	15.5	15.0	14.3
			mm. Var.	15.1	9.3	5.6	4.9	6.7	3.1	1.3	1.2
			% Steady	73.	74.	77.	73.	61.	80.	91.	92.
T-10	V-12	M	Acuity	51.7	34.6	23.2	12.9	10.4	9.0	8.1	8.3
			mm. Var.	12.0	7.9	5.0	4.8	4.0	2.7	.8	.4
			% Steady	77.	77.	79.	63.	62.	70.	90.	97.
T-11	V-12	M	Acuity	72.0	44.8	37.8	30.7	24.6	13.7	[illegible]	[illegible]
			mm. Var.	7.7	7.7	4.9	6.2	7.0	6.0	[illegible]	[illegible]
			% Steady	89.	83.	87.	80.	72.	68.0	74.	[illegible]
T-12	USMC	M	Acuity	34.4	11.1	9.4	8.8	7.2	6.5	6.2	[illegible]
			mm. Var.	8.6	3.5	1.1	3.3	.6	1.3	1.1	1.9
			% Steady	75.	69.	89.	63.	92.	79.	83.	[illegible]
T-13	USMC	M	Acuity	39.6	19.9	11.5	10.4	10.6	[illegible]	[illegible]	[illegible]
			mm. Var.	15.2	5.8	2.2	1.7	.9	1.1	[illegible]	[illegible]
			% Steady	62.	71.	71.	84.	92.	87.	97.	[illegible]
T-14	V-12	M	Acuity	47.4	23.1	23.7	17.9	19.2	17.1	12.8	10.1
			mm. Var.	15.5	5.9	7.1	4.7	5.8	4.4	1.9	1.9
			% Steady	67.	74.	70.	74.	70.	74.	85.	81.
T-15	USMC	M	Acuity	36.0	28.4	22.1	18.2	25.0	20.6	19.0	16.3
			mm. Var.	7.2	8.4	4.6	4.2	5.1	4.8	6.0	4.2
			% Steady	80.	70.	79.	77.	80.	77.	68.	74

TABLE D-1 (Continued)

Code No.	Classification	Sex		1st Straight Test (N = 43*)	2nd Straight Test (N = 43*)	3rd Straight Test (N = 43*)	4th Straight Test (N = 43*)	5th Straight Test (N = 43*)	6th Straight Test (N = 43*)	7th Straight Test (N = 18)	8th Straight Test (N = 43*)
			Acuity	42.9	31.5	22.8	21.5	16.7	15.3	13.6	15.[illegible]
[illegible]	[illegible]	M	mm. Var.	[illegible]	7.1	3.2	3.4	3.5	1.7	1.6	2.[illegible]
			% Steady	79.	78.	76.	84.	79.	89.	88.	84.
			Acuity	36.1	30.[illegible]	24.6	16.1	13.7	12.6	12.5	10.3
[illegible]	[illegible]	[illegible]	mm. Var.	7.5	7.[illegible]	8.3	5.1	2.2	2.6	3.[illegible]	2.5
			% Steady	79.	75.	66.	68	84.	79.	69.	76.
			Acuity	[illegible].7	31.9	20.6	13.3	12.9	10.0	8.3	8.3
[illegible]	[illegible]	[illegible]	mm. Var.	[illegible]	[illegible]	[illegible]	[illegible]	.5	1.[illegible]	[illegible]	[illegible]
			% Steady	[illegible]	35.	78.	79.	96.	34	88.	84.
			Acuity	50.5	21.9	17.5	10.4	11.1	6.0	6.5	5.1
[illegible]	[illegible]	M	mm. Var.	6.6	[illegible].4	4.9	3.0	2.7	1.0	.8	1.6
			% Steady	[illegible]	75.	72.	71.	75.	83.	88.	69.
			Acuity	44.2	29.1	19.7	13.2	15.4	18.7	14.3	10.0
[illegible]	Civ.	[illegible]	mm. Var.	12.0	10.1	4.6	5.5	4.6	6.9	4.9	2.2
			% Steady	73.	65.	77.	59.	70.	63.	66.	78.
			Acuity	27.8	22.7	18.8	13.6	11.0	9.7		6.8
[illegible]	USMC	M	mm. Var.	6.4	7.1	5.7	4.7	5.8	2.9		1.5
			% Steady	77.	69.	70.	66.	47.	70.		77.
			Acuity	66.4	66.2	59.7	45.3	26.2	21.1		16.3
[illegible]-22	USMC	M	mm. Var.	12.3	12.1	17.6	20.2	9.7	6.1		3.8
			% Steady	82.	82.	71.	55.	63.	71.		76.
			Acuity	38.3	28.8	22.9	19.4	18.5	19.0		17.5
T-23	V-12	M	mm. Var.	9.2	9.0	3.8	5.0	6.0	2.1		2.6
			% Steady	76.	69.	83.	74.	68.	89.		85.

TABLE D-1 (Continued)

Code No.	Classification	Sex		1st Straight Test (N = 43*)	2nd Straight Test (N = 43*)	3rd Straight Test (N = 43*)	4th Straight Test (N = 43*)	5th Straight Test (N = 43*)	6th Straight Test (N = 43*)	7th Straight Test (N = 18)	8th Straight Test (N = 43*)
			Acuity	31.5	31.4	27.4	18.4	23.6	20.2		17.1
T-24	Civ.	F	mm. Var.	5.3	5.3	7.1	4.2	7.2	8.0		5.0
			% Steady	83.	83.	74.	77.	70.	60.		[illegible]
			Acuity	47.4	34.4	24.6	23.5	21.3	17.2		10.5
T-25	Civ.	M	mm. Var.	14.9	10.5	9.0	5.8	7.5	2.5		[illegible]
			% Steady	69.	69.	60.	75.	65.	85.		78.
			Acuity	35.5	35.4	36.0	32.1	21.3	15.8		[illegible]
T-26	Civ.	F	mm. Var.	11.4	14.2	9.8	13.3	5.6	4.8		[illegible]
			% Steady	68.	60.	73.	59.	74.	70		[illegible]
			Acuity	32.4	21.1	14.6	14.0	14.0	10.9		[illegible]
T-27	Civ.	M	mm. Var.	8.3	7.6	4.6	4.5	4.5	2.6		[illegible]
			% Steady	74.	64.	69.	68.	68.	76.		[illegible]
			Acuity	54.4	45.0	32.8	39.0	31.9	18.4		[illegible]
T-28	Civ.	F	mm. Var.	12.1	12.7	4.9	7.7	5.5	4.2		[illegible]
			% Steady	88.	72.	85.	80.	73.	77.		[illegible]
			Acuity	51.0	28.4	13.5					
T-29	Civ.	F	mm. Var.	13.5	7.6	6.1			WITHDREW		
			% Steady	74.	73.	55.					
			Acuity	42.3	42.7	35.5	29.3	23.8	21.1		[illegible]
T-30	Civ.	F	mm. Var.	8.0	9.6	9.7	5.8	6.4	5.7		[illegible]
			% Steady	81.	78.	73.	80.	73.	73.		73
			Acuity	32.0	18.1	17.8	18.4	16.8	16.2		15.8
T-31	Civ	F	mm. Var.	4.0	4.7	7.9	2.9	5.0	4.9		5.3
			% Steady	88.	74.	56.	84.	70.	70.		66.

TABLE D-1 (Continued)

Code	Classification	Sex		1st Straight Test (N = 43*)	2nd Straight Test (N = 43*)	3rd Straight Test (N = 43*)	4th Straight Test (N = 43*)	5th Straight Test (N = 43*)	6th Straight Test (N = 43*)	7th Straight Test (N = 18)	8th Straight Test (N = 43*)
			Acuity	55.8?	48.2	40.1	36.6	34.0	28.5		30.3
[illegible]	[illegible]	[illegible]	mm. Var.	15.5?	[illegible]3.2	5.9	5.4	8.4	6.9		6.6
			% Steady	77.	73.	85.	85.	75	76.		78.
			Acuity	40.6	36.9?	27.4	23.8	18.7	16.6		15.5?
[illegible]	[illegible]	[illegible]	mm. Var.	[illegible].7	[illegible]	7.0?	5.4	4.2	2.9		3.9
			% Steady	34.	84.	74.	77.	78.	83.		75.
			Acuity	40.[illegible]	33.0?	25.4	21.6	2[illegible].4	24.3		25.7
[illegible]	[illegible]	[illegible]	mm. Var.	17.6?	9.0	3.7?	4.5?	6.6	6.7		6.[illegible]
			% Steady	[illegible]	73	66	79	71.	72.		74.
			Acuity	48.9?	24.3	7.2	10.5	6.0	4.6		4.0
[illegible]	[illegible]	[illegible]	mm. Var.	12.2?	9.8	3.7	2.7	2.2	1.2		.3
			% Steady	75	30.	49.	75.	63.	75.		94.
			Acuity	52.5?	33.8	27.8	29.3	19.5	15.6		8.0
[illegible]	V-12	M	mm. Var.	20.1	11.3	8.3	5.6	3.7	5.2		1.3
			% Steady	62	65.	70.	81.	81.	67.		85.
			Acuity	68.3	47.0	33.7	39.4	38.6	36.5		23.3
[illegible]	V-12	M	mm. Var.	16.8	10.3	14.2	6.4	9.0	6.0		5.0
			% Steady	75.	78.	62.	84.	77.	84.		79.
			Acuity	46.0	36.3	30.1	26.7	24.4	27.2		23.4
[illegible]-38	V-12	M	mm. Var.	9.1	9.3	14.8	6.2	6.7	2.9		4.4
			% Steady	80.	74.	51.	77.	73.	89.		81.
			Acuity	43.2	30.9	25.4	21.9	18.4	21.1		16.9
[illegible]-39	V-12	M	mm. Var.	8.0	7.2	5.1	4.4	5.9	8.3		5.0
			% Steady	83.	77.	80.	80.	68.	61.		70.

TABLE D-1 (Concluded)

Code No.	Classification	Sex		1st Straight Test (N = 43*)	2nd Straight Test (N = 43*)	3rd Straight Test (N = 43*)	4th Straight Test (N = 43*)	5th Straight Test (N = 43*)	6th Straight Test (N = 43*)	7th Straight Test (N = 18)	8th Straight Test (N = 43*)
			Acuity	37.1	25.1	21.7	19.2	17.7	20.9		15.3
T-40	V-12	M	mm. Var.	4.9	7.5	6.6	5.6	6.4	6.3		4.5
			% Steady	87.	70.	70.	71.	64.	70.		72.
			Acuity	41.1	26.3	26.8	23.4	20.0	16.5		12.9
T-41	NROTC	M	mm. Var.	13.4	3.5	6.3	6.5	6.1	5.2		3.1
			% Steady	67.	87.	77.	72.	70.	69.		76.
			Acuity	53.8	19.7	17.7	16.5	14.4	13.3		12.5
T-42	NROTC	M	mm. Var.	5.7	7.3	4.9	3.5	2.8	3.7		[illegible]
			% Steady	89.	63.	72.	79.	81.	72.		54.
			Acuity	29.4	23.8	17.9	17.0	15.7	13.7		13.7
T-43	NROTC	M	mm. Var.	10.6	4.7	5.4	6.0	5.9	3.0		4.5
			% Steady	64.	80.	70.	65.	57.	78.		[illegible]
			Acuity	26.5	22.3	23.6	16.5	12.5	8.7		[illegible]
T-44	NROTC	M	mm. Var.	8.0	4.7	7.4	6.3	2.6	2.5		[illegible]
			% Steady	70.	79.	69.	62.	74.	72.		[illegible]
			Acuity	37.8	27.7	26.4	23.4	20.2	11.5		[illegible]
T-45	NROTC	M	mm. Var.	6.1	5.3	7.7	4.8	4.4	2.5		2.5
			% Steady	84.	77.	71.	80.	78.	78.		84.
			Acuity	35.1				WITHDREW			
T-46	NROTC	M	mm. Var.	6.6							
			% Steady	81.							
			Acuity	45.4	29.9	23.7	22.1	17.8	14.9		[illegible]
T-47	NROTC	M	mm. Var.	10.2	6.5	5.8	4.2	3.3	4.4		2.9
			% Steady	78.	78.	75.	81.	72.	71.		72.
			Acuity	44.4**	30.1	25.1	21.2	18.7	16.6	12.6	13.5
Average Score			mm. Var.	10.3	7.6	6.7	5.5	5.1	4.3	2.5	3.1
			% Steady	77.	74.	72.	74.	72.	75.	81.	77.

*Includes only those subjects who completed training regime.

**In 100 untrained subjects these scores were: acuity, 47.9; mm. variability, 10.6; and percentile steadiness, 77. See: Low, F. N. Op. cit. (Footnote 11 of this report.)

TABLE D-2

ACUITY, MM. VARIABILITY, AND PERCENTILE STEADINESS SCORES OF SPECIAL TESTS
(MONOCULAR AND BINOCULAR TRANSFER TESTS)

Code No.	Class	Sex		Rapid recognition 0.2 sec. BEFORE TRAINING (N = 25*)	Rapid recognition 0.2 sec. AFTER TRAINING (N = 25*)	Night Visual Acuity .00005 ft. candles AFTER TRAINING (N = 42)	Rotated Meridians AFTER TRAINING (N = 42)	No. 10 Circle at 90° BEFORE TRAINING (N = 42*)	No. 10 Circle at 90° AFTER TRAINING (N = 42*)	Binocular Transfer Out 15° to left (N = 25)	Binocular Transfer Out 15° to right (N = 25)	Binocular Transfer Up 15° and Down 15° (N = 25)
			Acuity		24.1	15.8	21.0	12	33			
T-1	V-12	M	mm. Var.		5.9	2.5	4.5					
			% Steady		60.	84.	79.					
			Acuity									
T-2	USMC	M	mm. Var.				MILITARY TRANSFER					
			% Steady									
			Acuity									
T-3	V-12	M	mm. Var.			MILITARY TRANSFER		21				
			% Steady									
			Acuity		42.1	22.6	10.4	18	35			
T-4	V-12	M	mm. Var.		9.3	6.8	1.9					
			% Steady		78.	70.	82.					
			Acuity		32.3	21.6	14.1	15	15			
T-5	V-12	M	mm. Var.		5.6	4.3	4.3					
			% Steady		83.	80.	70.					
			Acuity		28.0	36.9	12.5	26	37			
T-6	USMC	M	mm. Var.		4.8	4.3	2.9					
			% Steady		83.	88.	77.					

TABLE D-2 (Continued)

Code No.	Class	Sex		Rapid recognition 0.2 sec. BEFORE TRAINING (N = 25*)	Rapid recognition 0.2 sec. AFTER TRAINING (N = 25*)	Night Visual Acuity .00005 ft. candles AFTER TRAINING (N = 42)	Rotated Meridians AFTER TRAINING (N = 42)	No. 10 Circle at 90° BEFORE TRAINING (N = 42*)	No. 10 Circle at 90° AFTER TRAINING (N = 42*)	Binocular Transfer Out 15° to left (N = 25)	Binocular Transfer Out 15° to right (N = 25)	Binocular Transfer Up 15° and Down 15° (N = 25)
			Acuity		79.8	45.8	34.5	12	19			
T-7	V-12	M	mm. Var.		12.9	13.2	10.6					
			% Steady		84.	71.	69.					
			Acuity		24.3	41.4	11.3	25	39			
T-8	USMC	M	mm. Var.		3.9	5.5	1.8					
			% Steady		84.	87.	84.					
			Acuity		38.2	37.7	16.1	17	24			
T-9	USMC	M	mm. Var.		13.2	4.9	3.1					
			% Steady		65.	87.	81.					
			Acuity		20.8	34.3	8.9	15	27			
T-10	V-12	M	mm. Var.		8.7	4.9	2.1					
			% Steady		58.	86.	76.					
			Acuity		20.4	30.7	19.2	9	34			
T-11	V-12	M	mm. Var.		2.9	3.9	3.9					
			% Steady		86.	87.	80.					
			Acuity		27.5	24.4	11.2	17	38			
T-12	USMC	M	mm. Var.		2.5	4.8	3.7					
			% Steady		91.	80.	67.					

TABLE D-2 (Continued)

Subj. No.	Class	Sex		Rapid recognition 0.2 sec. BEFORE TRAINING (N = 25*)	Rapid recognition 0.2 sec. AFTER TRAINING (N = 25*)	Night Visual Acuity .00005 ft. candles AFTER TRAINING (N = 42)	Rotated Meridians AFTER TRAINING (N = 42)	No. 10 Circle at 90° BEFORE TRAINING (N = 42*)	No. 10 Circle at 90° AFTER TRAINING (N = 42*)	Binocular Transfer Out 15° to left (N = 25)	Binocular Transfer Out 15° to right (N = 25)	Binocular Transfer Up 15° and Down 15° (N = 25)
T-13	USMC	M	Acuity		26.3	26.6	10.8	14	40			
			mm. Var.		2.7	6.6	2.9					
			% Steady		90.	75.	74.					
T-14	V-12	M	Acuity		22.9	16.8	15.4	14	33			
			mm. Var.		3.8	4.0	3.5					
			% Steady		83.	76.	84.					
T-15	USMC	M	Acuity		31.1	34.0	15.9	11	23			
			mm. Var.		4.2	3.2	2.6					
			% Steady		87.	91.	84.					
T-16	USMC	M	Acuity		27.0	40.3	11.7	20	35			
			mm. Var.		5.0	4.0	1.6					
			% Steady		82.	91.	86.					
T-17	USMC	M	Acuity		34.9	39.7	10.6	20	32			
			mm. Var.		7.1	3.7	2.1					
			% Steady		80.	90.7	80.					
T-18	V-12	M	Acuity		22.7	32.5	9.4	11	29			
			mm. Var.		7.6	4.7	1.9					
			% Steady		67.	86.	80.					

TABLE D-2 (Continued)

Code No.	Class	Sex		Rapid recognition 0.2 sec. BEFORE TRAINING (N = 25*)	Rapid recognition 0.2 sec. AFTER TRAINING (N = 25*)	Night Visual Acuity .00005 ft. candles AFTER TRAINING (N = 42)	Rotated Meridians AFTER TRAINING (N = 42)	No. 10 Circle at 90° BEFORE TRAINING (N = 42*)	No. 10 Circle at 90° AFTER TRAINING (N = 42*)	Binocular Transfer Out 15° to left (N = 25)	Binocular Transfer Out 15° to right (N = 25)	Binocular Transfer Up 15° and Down 15° (N = 25)
T-19	V-12	M	Acuity		12.5	25.4	9.8	17	39			
			mm. Var.		3.2	2.4	4.0					
			% Steady		74.	91.	60.					
T-20	Civ.	F	Acuity			TEST NOT TAKEN		22				
			mm. Var.									
			% Steady									
T-21	USMC	M	Acuity	60.4	9.5	30.7	11.2	31	36	2.6	[illegible].7	[illegible]
			mm. Var.	13.7	2.3	7.3	5.6					
			% Steady	77.	76.	76.	50.					
T-22	USMC	M	Acuity	81.9	57.4	33.5	22.7	15	27	3.5	3.5	17
			mm. Var.	12.1	11.2	3.7	6.3					
			% Steady	85.	81.	89.	72.					
T-23	V-12	M	Acuity	63.5	38.1	34.1	20.1	20	26	2.2	2.2	18
			mm. Var.	11.0	3.6	2.8	4.6					
			% Steady	83.	91.	92.	77.					
T-24	Civ.	F	Acuity	74.1	44.3	37.9	14.9	16	32	5.3	3.5	13
			mm. Var.	18.1	6.7	7.3	5.0					
			% Steady	76.	85.	81.	66.					

TABLE D-2 (Continued)

[illegible]	Class	Sex		Rapid recognition 0.2 sec BEFORE TRAINING (N = 25*)	Rapid recognition 0.2 sec. AFTER TRAINING (N = 25*)	Night Visual Acuity .00005 ft. candles AFTER TRAINING (N = 42)	Rotated Meridians AFTER TRAINING (N = 42)	No 10 Circle at 90° BEFORE TRAINING (N = 42*)	No. 10 Circle at 90° AFTER TRAINING (N = 42*)	Binocular Transfer Out 15° to left (N = 25)	Binocular Transfer Out 15° to right (N = 25)	Binocular Transfer Up 15° and Down 15° (N = 25)
			Acuity	[illegible] 2	42.0	54.8	20.2	21	24	3.5	[illegible]	[illegible]
[illegible]-25	Civ.	M	mm. Var.	12.1	4.8	6.2	6.5					
			% Steady	[illegible]	53.	39.	63.					
			Acuity	91.2	22.7	37.8	24.1	13	37	1.7	1.7	18
[illegible]	Civ.	F	mm. Var	9.[illegible]	9.7	6.1	5.0					
			% Steady	89.	57.	84.	79.					
			Acuity	61.6	27.2	27.1	10.8	23	36	1.7	1.2	20
[illegible]-27	Civ	M	mm. Var.	12.0	6.2	6.2	2.3					
			% Steady	81	77.	77.	79.					
			Acuity	78.8	53.9	32.1	23.9		8	1.7	1.7	16
T-28	Civ.	F	mm. Var	18.0	5.3	6.4	3.6					
			% Steady	77.	90.	80.	85.					
			Acuity	81.6				13				
T-29	Civ.	F	mm. Var	23.6		WITHDREW						
			% Steady	71.								
			Acuity	100.0	53.9	62.0	23.3	15	17	5.3	4.5	14
T-30	Civ.	F	mm. Var.	25.2	[illegible]	10.7	7.2					
			% Steady	75.	79.	83.	69.					

TABLE D-2 (Continued)

Code No.	Class	Sex		Rapid recognition 0.2 sec. BEFORE TRAINING (N = 25*)	Rapid recognition 0.2 sec. AFTER TRAINING (N = 25*)	Night Visual Acuity .00005 ft. candles AFTER TRAINING (N = 42)	Rotated Meridians AFTER TRAINING (N = 42)	No. 10 Circle at 90° BEFORE TRAINING (N = 42*)	No. 10 Circle at 90° AFTER TRAINING (N = 42*)	Binocular Transfer Out 15° to left (N = 25)	Binocular Transfer Out 15° to right (N = 25)	Binocular Transfer Up 15° and Down 15° (N = 25)
			Acuity	64.1	36.2	47.3	23.9	28	31	1.7	1.7	18
T-31	Civ.	F	mm. Var.	5.7	8.0	6.6	6.4					
			% Steady	91.	88.	86.	73.					
			Acuity	75.7	55.7	52.5	25.2	18	27	3.5	2.2	18
T-32	Civ.	F	mm. Var.	17.7	13.7	8.4	5.3					
			% Steady	77.	75.	84.	79.					
			Acuity	64.9	50.1	39.4	21.4	26	34	1.7	1.2	18
T-33	Civ.	F	mm. Var.	12.3	11.3	3.5	7.1					
			% Steady	81.	77.	91.	67.					
			Acuity	80.1	59.5	61.4	24.8	16	25	3.5	3.5	25
T-34	Civ.	F	mm. Var.	22.3	7.7	12.3	7.7					
			% Steady	73.	87.	80.	69.					
			Acuity	56.5	17.3	28.6	3.7	23	40	.7	.7	20
T-35	NROTC	M	mm. Var.	13.6	10.3	6.4	1.4					
			% Steady	76.	41.	78.	62.					
			Acuity	80.2	11.4	31.1	16.8	20	31	2.6	2.6	20
T-36	V-12	M	mm. Var.	14.6	3.1	18.5	4.1					
			% Steady	82.	73.	73.	76					

TABLE D-2 (Continued)

Subj. No.	Class	Sex		Rapid recognition 0.2 sec BEFORE TRAINING (N = 25*)	Rapid recognition 0.2 sec. AFTER TRAINING (N = 25*)	Night Visual Acuity .00005 ft. candles AFTER TRAINING (N = 42)	Rotated Meridians AFTER TRAINING (N = 42)	No. 10 Circle at 90° BEFORE TRAINING (N = 42*)	No. 10 Circle at 90° AFTER TRAINING (N = 42*)	Binocular Transfer Out 15° to left (N = 25)	Binocular Transfer Out 15° to right (N = 25)	Binocular Transfer Up 15° and Down 15° (N = 25)
			Acuity	105.0	75.7	57.8	35.3	11	12	3.5	2.6	14
T-37	V-12	M	mm. Var.	15.4	12.0	6.6	7.8					
			% Steady	85.	84.	89.	78.					
			Acuity	82.8	51.1	75.4	30.0	15	12	2.6	5.3	18
T-38	V-12	M	mm. Var.	15.0	12.1	12.6	8.1					
			% Steady	82.	76.	83.	73.					
			Acuity	74.2	49.6	32.5	30.1	11	27	2.6	2.2	13
T-39	V-12	M	mm. Var.	21.4	11.8	3.7	6.8					
			% Steady	72.	76.	87.	77.					
			Acuity	68.8	48.6	31.6	19.6	15	16	2.2	1.7	20
T-40	V-12	M	mm. Var.	17.5	10.2	6.3	4.9					
			% Steady	75.	79.	80.	75.					
			Acuity	82.8	42.4	33.1	15.5	26	30	3.5	2.6	18
T-41	NROTC	M	mm. Var.	9.6	8.7	2.8	3.1					
			% Steady	88.	80.	92.	80.					
			Acuity	86.9	32.5	33.0	11.6	17	33	3.5	2.6	19
T-42	NROTC	M	mm. Var.	13.4	6.2	6.7	2.1					
			% Steady	85.	82.	80.	82.					

TABLE D-2 (Concluded)

Code No.	Class	Sex		Rapid recognition 0.2 sec. BEFORE TRAINING (N = 25*)	Rapid recognition 0.2 sec. AFTER TRAINING (N = 25*)	Night Visual Acuity .00005 ft. candles AFTER TRAINING (N = 42)	Rotated Meridians AFTER TRAINING (N = 42)	No. 10 Circle at 90° BEFORE TRAINING (N = 42*)	No. 10 Circle at 90° AFTER TRAINING (N = 42*)	Binocular Transfer Out 15° to left (N = 25)	Binocular Transfer Out 15° to right (N = 25)	Binocular Transfer Up 15° and Down 15° (N = 25)
T-43	NROTC	M	Acuity	54.7	28.7	38.5	12.2	25	31	4.5	2.2	20
			mm. Var.	13.3	4.3	3.3	1.1					
			% Steady	76.	85.	91.	91.					
T-44	NROTC	M	Acuity	82.1	38.8	43.8	12.8	25	34	1.7	2.2	20
			mm. Var.	18.5	8.5	4.9	3.9					
			% Steady	78.	78.	89.	70.					
T-45	NROTC	M	Acuity	75.8	46.0	45.5	13.5	20	16	2.2	2.2	[illegible]
			mm. Var.	16.4	8.6	7.9	3.3					
			% Steady	79.	81.	83.	76.					
T-46	NROTC	M	Acuity	63.2								
			mm. Var.	17.6				WITHDREW				
			% Steady	72.								
T-47	NROTC	M	Acuity	84.9	41.3	43.5	15.1	15	22	2.2	2.2	19
			mm. Var.	16.7	8.6	4.6	1.2					
			% Steady	80.	79.	89.	92.					
Average Score			Acuity	76.7	41.3	37.4**	17.3	17	28	2.8	2.5	18
			mm. Var.	15.2	8.3	6.1	4.2					
			% Steady	80.	79.	84.	76.			7.2#	4.5#	13#

*Includes only those subjects whose scores on these tests are complete

**In 100 untrained subjects these scores were: acuity, 70.1; mm. variability, 11.2; and percentile steadiness, 83.8. See: Low, F. N. Op. cit. (Footnote 11 of this report.)

#These are corresponding average scores in 22 untrained subjects.

TABLE D-3

ISOLATED FORMS ON HORIZONTAL MERIDIAN
(MONOCULAR TRANSFER TEST)

Code No.	Classification	Sex		BEFORE TRAINING Angular Deviation in Degrees from Line of Vision (N = 42*)	AFTER TRAINING (N = 42*)	GAIN OR LOSS Difference in Degrees
T-1	V-12	M	25 mm. left eye	25	75	50
			25 mm. right eye	30	70	40
			10 mm. left eye	15	40	25
			10 mm. right eye	15	40	25
T-2	USMC	M	25 mm. left eye			
			25 mm. right eye			
			10 mm. left eye			
			10 mm. right eye			
T-3	V-12	M	25 mm. left eye	15		
			25 mm. right eye	30		
			10 mm. left eye	15		
			10 mm. right eye	15		
T-4	V-12	M	25 mm. left eye	25	45	20
			25 mm. right eye	25	45	20
			10 mm. left eye	15	20	5
			10 mm. right eye	15	20	5
T-5	V-12	M	25 mm. left eye	25	45	20
			25 mm. right eye	30	45	15
			10 mm. left eye	15	30	15
			10 mm. right eye	15	30	15
T-6	USMC	M	25 mm. left eye	40	50	10
			25 mm. right eye	40	45	5
			10 mm. left eye	15	35	20
			10 mm. right eye	15	35	20
T-7	V-12	M	25 mm. left eye	20	35	15
			25 mm. right eye	25	40	15
			10 mm. left eye	15	15	0
			10 mm. right eye	15	15	0
T-8	USMC	M	25 mm. left eye	35	55	20
			25 mm. right eye	40	55	15
			10 mm. left eye	15	35	20
			10 mm. right eye	15	40	25

TABLE D-3 (Continued)

Code No.	Classification	Sex		Angular Deviation in Degrees from Line of Vision — BEFORE TRAINING (N = 42*)	AFTER TRAINING (N = 42*)	GAIN OR LOSS — Difference in Degrees
T-9	USMC	M	25 mm. left eye	30	45	15
			25 mm. right eye	30	45	15
			10 mm. left eye	15	20	5
			10 mm. right eye	15	20	5
T-10	V-12	M	25 mm. left eye	30	50	20
			25 mm. right eye	20	50	30
			10 mm. left eye	15	40	25
			10 mm. right eye	15	35	20
T-11	V-12	M	25 mm. left eye	30	50	20
			25 mm. right eye	25	55	30
			10 mm. left eye	15	35	20
			10 mm. right eye	15	45	30
T-12	USMC	M	25 mm. left eye	60	60	0
			25 mm. right eye	55	55	0
			10 mm. left eye	15	50	35
			10 mm. right eye	25	50	25
T-13	USMC	M	25 mm. left eye	45	50	5
			25 mm. right eye	35	55	20
			10 mm. left eye	25	40	15
			10 mm. right eye	15	40	15
T-14	V-12	M	25 mm. left eye	30	60	30
			25 mm. right eye	25	65	40
			10 mm. left eye	15	35	20
			10 mm. right eye	15	40	25
T-15	USMC	M	25 mm. left eye	35	45	10
			25 mm. right eye	40	40	0
			10 mm. left eye	15	20	5
			10 mm. right eye	15	20	5
T-16	USMC	M	25 mm. left eye	25	55	30
			25 mm. right eye	15	55	40
			10 mm. left eye	15	20	5
			10 mm. right eye	15	25	10
T-17	USMC	M	25 mm. left eye	40	60	20
			25 mm. right eye	35	55	20
			10 mm. left eye	15	25	10
			10 mm. right eye	15	20	5

TABLE D-3 (Continued)

Code No.	Classification	Sex		BEFORE TRAINING Angular Deviation in Degrees from Line of Vision (N = 42*)	AFTER TRAINING (N = 42*)	GAIN OR LOSS Difference in Degrees
T-18	USMC	M	25 mm. left eye	25	55	30
			25 mm. right eye	25	55	30
			10 mm. left eye	15	35	20
			10 mm. right eye	15	40	25
T-19	V-12	M	25 mm. left eye	30	65	35
			25 mm. right eye	15	70	55
			10 mm. left eye	15	45	30
			10 mm. right eye	15	50	35
T-20	Civ.	F	25 mm. left eye	30		
			25 mm. right eye	30		
			10 mm. left eye	15		
			10 mm. right eye	15		
T-21	USMC	M	25 mm. left eye	35	55	20
			25 mm. right eye	25	65	40
			10 mm. left eye	20	35	15
			10 mm. right eye	20	35	15
T-22	USMC	M	25 mm. left eye	25	35	10
			25 mm. right eye	20	50	30
			10 mm. left eye	20	30	10
			10 mm. right eye	20	30	10
T-23	V-12	M	25 mm. left eye	25	45	20
			25 mm. right eye	20	45	25
			10 mm. left eye	20	20	0
			10 mm. right eye	20	20	0
T-24	Civ.	F	25 mm. left eye	30	40	10
			25 mm. right eye	40	45	5
			10 mm. left eye	20	20	0
			10 mm. right eye	20	20	0
T-25	Civ.	M	25 mm. left eye	35	35	0
			25 mm. right eye	40	55	15
			10 mm. left eye	20	25	5
			10 mm. right eye	20	25	5
T-26	Civ.	F	25 mm. left eye	20	60	40
			25 mm. right eye	30	50	20
			10 mm. left eye	20	30	10
			10 mm. right eye	20	25	5

TABLE D-3 (Continued)

Code No.	Classification	Sex		BEFORE TRAINING	AFTER TRAINING	GAIN OR LOSS
				Angular Deviation in Degrees from Line of Vision (N = 42*)	Angular Deviation in Degrees from Line of Vision (N = 42*)	Difference in Degrees
T-27	Civ.	M	25 mm. left eye	35	65	30
			25 mm. right eye	50	75	25
			10 mm. left eye	20	55	35
			10 mm. right eye	20	60	40
T-28	Civ.	F	25 mm. left eye	20	45	25
			25 mm. right eye	25	45	20
			10 mm. left eye	20	20	0
			10 mm. right eye	20	20	0
T-29	Civ.	F	25 mm. left eye	20		
			25 mm. right eye	20		
			10 mm. left eye	20		
			10 mm. right eye	20		
T-30	Civ.	F	25 mm. left eye	25	30	5
			25 mm. right eye	35	35	0
			10 mm. left eye	20	20	0
			10 mm. right eye	20	20	0
T-31	Civ.	F	25 mm. left eye	35	40	5
			25 mm. right eye	35	45	10
			10 mm. left eye	20	20	0
			10 mm. right eye	20	20	0
T-32	Civ.	F	25 mm. left eye	35	30	-5
			25 mm. right eye	40	35	-5
			10 mm. left eye	20	20	0
			10 mm. right eye	20	20	0
T-33	Civ.	F	25 mm. left eye	35	50	15
			25 mm. right eye	30	45	15
			10 mm. left eye	20	25	5
			10 mm. right eye	25	25	0
T-34	Civ.	F	25 mm. left eye	35	35	0
			25 mm. right eye	40	25	-15
			10 mm. left eye	20	20	0
			10 mm. right eye	20	20	0
T-35	NROTC	M	25 mm. left eye	35	75	40
			25 mm. right eye	40	65	25
			10 mm. left eye	30	50	20
			10 mm. right eye	20	40	20

TABLE D-3 (Continued)

Code No.	Classification	Sex		BEFORE TRAINING Angular Deviation in Degrees from Line of Vision (N = 42*)	AFTER TRAINING (N = 42*)	GAIN OR LOSS Difference in Degrees
T-36	V-12	M	25 mm. left eye	20	50	30
			25 mm. right eye	35	65	30
			10 mm. left eye	20	30	10
			10 mm. right eye	20	25	5
T-37	V-12	M	25 mm. left eye	20	35	15
			25 mm. right eye	20	30	10
			10 mm. left eye	20	20	0
			10 mm. right eye	20	20	0
T-38	V-12	M	25 mm. left eye	20	30	10
			25 mm. right eye	25	30	5
			10 mm. left eye	20	20	0
			10 mm. right eye	20	20	0
T-39	V-12	M	25 mm. left eye	25	45	20
			25 mm. right eye	35	50	15
			10 mm. left eye	20	20	0
			10 mm. right eye	20	20	0
T-40	V-12	M	25 mm. left eye	25	25	0
			25 mm. right eye	30	25	-5
			10 mm. left eye	20	20	0
			10 mm. right eye	[illegible]	20	0
T-41	NROTC	M	25 mm left eye	[illegible]	40	10
			25 mm right eye	[illegible]	40	10
			10 mm left eye	[illegible]	20	0
			10 mm right eye	[illegible]	20	0
T-42.	NROTC	M	25 mm [illegible]	[illegible]	50	30
			25 mm [illegible]	[illegible]	50	20
			10 mm [illegible]	[illegible]	25	5
			10 mm [illegible]	[illegible]	40	20
T-43	NROTC	M	25 mm. [illegible]	[illegible]	50	10
			[illegible]	[illegible]	50	25
			[illegible]	[illegible]	25	5
			[illegible]	[illegible]	20	0
T-44	NROTC	M	25 mm [illegible]	[illegible]	50	10
			[illegible]	[illegible]	55	15
			[illegible]	[illegible]	25	5
			[illegible]	[illegible]	20	0

TABLE I-[illegible] (Concluded)

Code No.	Classification	Sex		INITIAL TRAINING	AFTER TRAINING	GAIN OR LOSS
				Angular Deviation in Degrees from Line of Vision (N = 42*)	(N = 42*)	Difference in Degrees
T-45	NROTC	M	25 mm. left eye	30	35	5
			25 mm. right eye	30	35	5
			10 mm. left eye	20	20	0
			10 mm. right eye	20	20	0
T-46	NROTC	M	25 mm. left eye			
			25 mm. right eye			
			10 mm. left eye			
			10 mm. right eye			
T-47	NROTC	M	25 mm. left eye	30	35	5
			25 mm. right eye	30	40	10
			10 mm. left eye	20	20	0
			10 mm. right eye	20	20	0
Average Score			25 mm. left eye	31	48	17
			25 mm. right eye	31	49	18
			10 mm. left eye	19	28	9
			10 mm. right eye	18	28	10

*Includes only those subjects whose scores for this test are complete.

SOME CHARACTERISTICS OF PERIPHERAL VISUAL PERFORMANCE

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From the Department of Anatomy, School of Medicine, University of North Carolina, Chapel Hill

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SOME CHARACTERISTICS OF PERIPHERAL VISUAL PERFORMANCE[1]

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Numerous fundamentals of peripheral visual function were discovered by workers of the German schools in the latter half of the nineteenth century. Duke-Elder, in his reference Textbook of Ophthalmology (1), has frequent occasion to refer to the phenomena observed by these early workers. However, the material presented by them is largely qualitative and was derived, usually, from a very small number of subjects. Very little quantitative data have been offered which are useful to the present day worker who wishes to predict performance in a sizeable group of individuals. The special problems of modern aviation, particularly those encountered in the landing and takeoff of airplanes and in spotting the approach of aircraft, have lent new importance to peripheral vision, the interest in the normal functioning of which has heretofore been academic rather than practical. The need for more quantitative data led to the present investigations of peripheral visual function. These studies aimed at (a) the development of a standardized measure of peripheral visual acuity, and (b) an investigation of the practicality of training the peripheral function to insure better performance.

Visual acuity scores. The simple form acuity of the retinal periphery has been measured by a newly developed technique and reported (2, 3) in two groups of 100 subjects each. The first group (2) was tested with bright (photopic) illumination. The technique and apparatus were modified in the second group (3) for testing in dim (scotopic) illumination. The test consisted of a measure of simple form acuity on seven points of the retinal periphery of each eye. The technique required the identification of the position of progressively decreasing sizes of Landolt circles. The "total scores" of the subjects consist of the summation of corrected values of the 14 individual point scores and represent the over-all ability of the subjects (3, fig. 2).

The possibility that some points on the retina might be better indices of the subject's ability than others led to an examination of the relationship of the 14

[1] The work described in this paper was done (in part) under a contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and the University of North Carolina. The systematic training of peripheral vision was undertaken for the Committee on Selection and Training of Aircraft Pilots as one of a series of researches conducted under the provisions of a contract between the Civil Aeronautics Authority and the National Research Council.

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individual point scores (and groups of them) to the total scores by the Pearson product-moment method of correlation.

An initial set of correlations was made on the scores of the original group whose photopic acuity had been measured. Each individual point score was correlated with the total score, the coefficients ranging from 0.60 to 0.77. Calculation of the non-significant range of variation revealed an overlap between even the farthest removed coefficients. Thus, it was evident that no benefit would accrue from the removal of any one of the points as a shortening measure; the reliability of the total score would suffer. Similar results were obtained when each individual point was correlated with the score for that particular eye (sum of 7 individual point scores). Here the coefficients ranged from 0.64 to 0.75 with similar overlap of non-significant range of variation. Certain groups of points were correlated with both the total score and the score for the same eye. These included all 30° points, all 60° points, etc. No point or group of points was found which correlated sufficiently well with the total score to justify the omission of other points. In general, the larger the group of points the better the correlation. All evidence pointed to an ever present source of error in the progressive measurement of the 14 points. In individual subjects some points were better than the total score indicated they should be and others were worse. Such periods of efficiency and inefficiency were apparent regardless of the retinal area measured or the normal acuity of that area. They tended to cancel each other out progressively through the test. This progressive cancellation was sufficiently complete to give the test an over-all reliability of 0.91 (2).

A similar but less extensive set of correlations was made on the scores of the 100 night visual acuity subjects. Individual point scores, when correlated with the total score, yielded coefficients of from 0.44 to 0.78. There was overlap of the non-significant range of the coefficients in all cases. However, the coefficient of the first point tested (0.44) was far removed from the remainder, the next lowest being 0.54 and the majority above 0.60. The standard deviation of the scores on this point did not differ from that of similar points and the mean was not displaced (3, fig. 1). It was concluded that the poor correlation coefficient indicated a starting difficulty. This was not observed in the day visual acuity group. Other features of the night visual acuity scores demonstrated by correlations similar to those of the day visual acuity group revealed the essential similarity of the two. The same ever present source of error in the form of fluctuating efficiency was noticed.

The total scores of both groups were correlated with age, time of day, test operator, etc. All of these yielded non-significant coefficients. It was concluded that the scores were independent of such values.

Extraction of a measure of spontaneous fluctuation. The fluctuating efficiency revealed by the above series of correlations had been previously noticed during the testing. Here it was quantitatively large enough to intrude itself upon the operator's attention. It was irregular in its appearance and more evident in some subjects than in others. It was present apparently regardless of the subject's over-all ability. The presence of this phenomenon, its persistence and its apparent independence of other functions led to an effort to extract a quantitative measure of it from acuity scores. The total score was known to be the most reliable measure of the subject's ability. The individual point scores were known to be less reliable and subject to the fluctuation mentioned above. It was assumed that the "true" acuity of any point bore a constant relationship to the total score and that the fluctuations observed during the testing, and confirmed by the correlations, operated above and below this mean. The numerical value of this "true" acuity for any subject is unknown during the testing but can be obtained from the total score. The percentile relationship of the mean acuity scores for any one point to the mean total score in a group of 100 was adopted as the true relationship of the acuity of that point to the subject's total score. This was found to be constant within one or two per cent at most in widely different groups and ranges of scores. To discover the "true" acuity of any subject for any point it is only necessary to multiply the subject's total score by the percentile value for that point and divide by 100. This gives a figure (hypothetical score) which the subject should have gotten when that point was tested and which he would have gotten had it not been for the presence of the spontaneous fluctuation in his ability which characterized his performance. The difference between this calculated "true" score and the measure of his actual performance (recorded score for that point) is the measure of how much he deviated from his own mean during the testing of that point. The deviation for each of the 14 points tested can be similarly calculated. A summation of these deviations for all points was adopted as the measure of the subject's spontaneous fluctuation. This measure, as are the data from which it is derived, is in millimeters and has been called the "millimeter variability" of the subject.

The millimeter variability (fig. 1) was found to average 10.6 in the 100 day visual acuity subjects with the dispersion of scores ranging from 2.5 to 20. The 100 night visual acuity subjects had an average millimeter variability of 11.2 with a dispersion somewhat more contracted. The eye-to-eye correlation of the millimeter variability for each eye (photopic) was 0.44. Correction by the Spearman-Brown formula brings this to 0.61, the over-all reliability of the measure. Since there was no correlation of scores with external circumstances these low coefficients were interpreted to be due to intrinsic changeability of the fluctuation. Later observations bore out this interpretation.

Formulation of the subject's percentile steadiness. In the performance of our tests the average day visual acuity subject fluctuated or wavered 10.6 millimeters and got an acuity of 47.9 millimeters. In other words, he varied 22 per cent of his total score or, conversely, was 78 per cent steady (fig. 2). The average night visual acuity subject fluctuated 11.6 millimeters with an acuity of 70.1 millimeters and thus varied 16 per cent of his total score and was 84 per cent steady. The dispersion of these percentile steadiness scores in the day visual acuity group was from 60 to 95 per cent and in the night visual acuity group from 70 to 98 per cent. This index of steadiness has proved useful in the interpretation of subsequent studies.

Interpretation of spontaneous fluctuation. The possibility that the observed fluctuation might be an expression of inherent strength or weakness of the retinal areas measured has not been neglected. Numerous series of repeated tests on the same subjects have revealed the patterns of fluctuation to be unique for each test. Any retinal area in any subject may measure either better or worse than the score indicated by the subject's over-all ability. Also, on special oc-

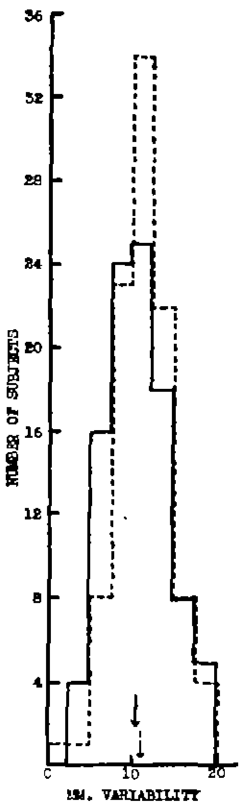

Fig. 1

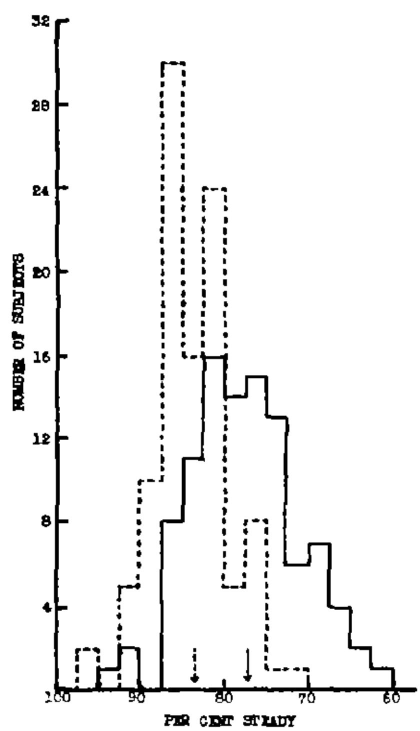

Fig. 2

Fig. 1. Frequency distribution of millimeter variability scores in peripheral vision in two groups of 100 subjects each. Solid line represents scores in bright illumination and dotted line those in dim illumination. Arrows indicate means.

Fig. 2. Frequency distribution of percentile steadiness scores in peripheral vision in two groups of 100 subjects each. Solid line represents scores in bright illumination and dotted line those in dim illumination. Arrows indicate means.

casions when a subject did very poorly on the testing of a certain point, the technique was immediately repeated. The subject usually recovered from the spell of inefficiency well enough to make a better score, more in keeping with expectations. This procedure was never permitted, however, during routine testing where the accepted success criterion was rigidly maintained.

Standard accounts of perimetry (4, 5) describe the visual fields and peripheral visual perception as steady and fixed, no mention being made of fluctuating efficiency. However, most of the experimentation from which current concepts have been formulated has been done with simple test objects such as white circles or squares on a black background. A rigid success criterion was not used. The subject could either see the stimulus object or not; if he didn't he could try again, and momentary failure did not alter the recorded result. The experiments here reported differ in two ways from such previous experimentation. First, the stimulus object was a Landolt circle. The position of the break in this circle might be in any one of four positions which had to be identified as such. This required the subject not only to see the test object but to distinguish a part of it from the background and from the rest of the object itself. Thus the measure was one of simple form acuity as distinguished from simple acuity. Second, and more important, an unvarying success criterion was rigidly applied throughout all of the tests. To be successful with a certain size test object the subject had to tell the position of the break in the circle correctly for four consecutive presentations before he missed the second time. The second miss always disqualified, no matter how large the circle or how poor and illogical the performance seemed to be. This method served to preserve in the score sheet irregularities of performance which would otherwise have been lost. Despite the fact that the standard conceptions of the peripheral visual process imply constant, somewhat static performance, the evidence here reported makes it necessary to regard peripheral perception as essentially intermittent and subject to extensive fluctuation in efficiency.

Subjective experiences of the writer with this technique and numerous discussions with subjects have helped in the interpretation of the intermittency which has been observed. During periods of difficulty the Landolt circle appears as a solid ring without any break at all. Frequently misinterpretation of circle position occurs because all positions look alike. When the testing has progressed to small circles they often are temporarily completely invisible, the card appearing blank. With patient attention, the circle later appears. In the presence of concentration the entire circle sometimes disappears completely only to reappear later. When near to threshold sizes are presented they appear vague and then resolve themselves momentarily with relatively great clarity and then become vague again. Much of the time taken by the test is due to waiting for such clear resolutions to appear. They are usually not evoked by intense concentration, but are more likely to appear on mild attention while waiting. Some few subjects can retain these clear images but most lose them again in 2 or 3 seconds. These phenomena suggest that peripheral perception is characterized by intermittent scotomata which may be either partial or complete, their chief characteristic being their appearance and disappearance in oscillatory fashion anywhere on the peripheral retina. A concept of multiple short lived scotomata as an ever present characteristic of the peripheral retina is a difficult one to accept unless it is realized that such scotomata can become very large without the subject becoming aware of their presence. The normal blind spot serves to illustrate this. It causes a scotoma the size of a person's head 6 or 7 feet away (1, p. 907). In spite of its size it is not evident even when the opposite eye is closed and the scotoma is absolute. Special precautions are always necessary to demonstrate its presence. It is interesting to note that the size of the blind spot is many times the size of the break in a Landolt circle which represents the threshold of acuity in the areas immediately surrounding the blind spot. Thus it appears that a scotoma can exceed the threshold of acuity without becoming visible. It would seem that the scotomata here postulated so blend with the visual surrounds (rather than appear black) that they are invisible except when demonstrated by perimetry. Scotomata on the periphery as normal phenomena have been recognized as long ago as 1857 by Aubert and Förster (6) who classified them as (a) permanent, due to retinal vessels, and (b) temporary, due to local fatigue and glare. During the progress of the investigations here reported, which represent well over 1000 hours of perimetry, no permanent scotomata were observed. All appeared to be temporary, existing for very short periods of time. It is unlikely that these could be attributed to glare since they appeared under scotopic conditions as well as in the photopic testing. Fatigue seems to be a more reasonable explanation for these scotomata although the fatigue must be understood to be essentially regional, restricted to small retinal areas, since the scotomata have appeared in all conditions of freshness and fatigue of the subjects as well as being temporary.

Training by controlled practice. An impressive feature of performance which became evident early in the experimentation was the tendency of the subjects to improve their acuity through practice. This was evident even in the course of a single test, where the second eye tested always scored better on the average than the first, regardless of whether it was the left or the right eye. Test-retest scores showed improvement in groups even when a shortened version of the technique taking less than 15 minutes (compare with 45 min. for the usual test) was used (7). This feature of improvement through practice, previously reported by Dobrowolsky and Gaine (8), was made the subject of an exhaustive investigation designed to determine the extent of the improvement possible and to test the practicality of a systematic effort to train large groups of individuals by a course of controlled practice. The training was done by subjects working in pairs under the supervision of an instructor, alternately operating the technique and being trained by their partners, in a laboratory equipped with specially constructed perimeters. Peripheral acuity was successfully trained in 43 subjects to a measure that was 334 per cent of the starting score (9). The measure was based on the linear measurement of the break in the smallest circle which could be correctly identified (fig. 3). However, in calculating the minimum retinal area which is stimulated for successful response both length and breadth must be taken into account, and it will be seen that the average trained subject responded successfully to the stimulation of an area only one-eleventh the size required for such a response before the training. Thus the average trained subject can be regarded as eleven times as efficient in responding to peripheral stimuli of minimum size as the average untrained subject. Extremes of performance varied greatly. The best subject reached 1200 per cent of his starting score, or 144 times as efficient according to the above method of calculation. The worst subject barely halved the starting score (accomplishment of 200 per cent) and was 4 times as efficient.

This large quantitative increase in simple form acuity through practice necessitates the interpretation of the peripheral retina as an unpracticed sensory area. The demands of everyday life do not tax the capacity of the peripheral retina sufficiently to bring its performance to peak efficiency. Some 25 hours of practice, the approximate amount of training per subject, are necessary to develop this function to, or near to, its ultimate capacity. The unpracticed nature of the retinal periphery is probably due to the great specialization for good acuity in the foveal area. In everyday life very little effort is made to detect detail peripherally perceived because foveal performance is so much better. Instead, an object is perceived, usually because it is in motion relative to its

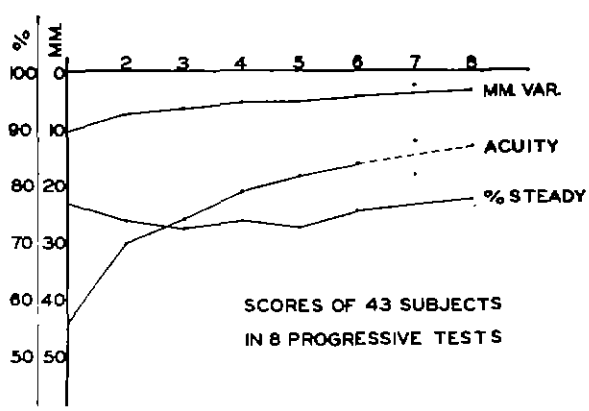

Fig. 3. Progressive scores in peripheral visual acuity, millimeter variability, and percentile steadiness in a group whose acuity was being trained by a course of systematic practice. Test No. 7 was taken by only eighteen subjects (the first group of two) and is not represented in the curve or in the reported calculations.

surrounds, and the eye is fixated on it so that the image which is the object of the attention falls on the fovea. It follows, then, that the natural way to improve peripheral acuity is to force peripheral evaluation of visual stimuli under conditions which prevent fixation of the eye on the stimulus object. This primary requirement was met by the training method used in these experiments, utilizing perimetric technique. It was noticed that a subject whose fixation was poor during training showed poor improvement. This was in contradiction to a previous supposition that some of the improvement was due to poor fixation. In general, experiences encountered during this course strongly indicate that controlled fixation achieved by perimetric or similar apparatus is necessary for the success of such a training program.

Various "transfer" tests were included in the training program to check the extent to which the improved acuity operated in other situations involving peripheral stimuli. Successful transfer was observed to (a) unfamiliar test objects, (b) one-fifth second exposure necessitating rapid recognition, (c) areas of the retina not practiced by the technique, (d) non-perimetric laboratory situations, (e) night visual acuity and (f) situations outside the laboratory in everyday life.

The improvement of night visual acuity was observed in the form of better acuity scores than normal in the 42 subjects who took the night visual acuity test at the end of their training. Their average score was 37.4 as compared to 70.1 in 100 normal untrained subjects (9, 3). This improved score is 187 per cent of the untrained subjects' score. It was impractical to secure night visual acuity scores from the trainees at the beginning of the course because of technical difficulties arising from the necessity of working in the dark with an unfamiliar technique. However, after many hours of practice in the testing technique the subjects were able to operate a night visual acuity test without difficulty. A separate series of night visual acuity tests on two subjects resulted in improvement of scores which indicated the amenability of the retina to train under scotopic conditions. But the improvement was quantitatively less than similar improvement observed in a like series of repeated tests under photopic illumination. The above reported scores among subjects who had been trained only under photopic conditions may represent the extent to which training can improve night visual acuity although it seems probable that further improvement could be achieved with practice under scotopic conditions. If the observed improvement in night visual acuity represents a nearly maximal value then this suggests a means of increasing the efficiency of night visual performance by a training method which does not depend upon the awkward conditions imposed by literally working in the dark.

The most arresting feature of the training results was the changes experienced by the subjects in their awareness of peripheral stimuli outside of the laboratory. It was not supposed that the improved acuity would be sufficient to produce subjective awareness elsewhere, but student discussions of new experiences in peripheral perception in everyday life became so persistent toward the middle of the course that a questionnaire on these experiences was submitted to them. Data were gathered on typical everyday experiences such as walking, driving, sports, reading, etc. Forty-one out of 42 subjects had noticed differences. Thirty were certain that these differences were intrusive, reaching the consciousness without the subject's having been thinking about the training course when they occurred. One hundred and three situations involving change were reported and all but 2 of these were interpreted to be helpful rather than detrimental to the behavior of the subject.

During the course of the training a series of acuity tests, identical with those used to establish the original norms, were obtained to check the progress of the work. The behavior of the millimeter variability and the percentile steadiness during the improvement was calculated (fig. 3). The millimeter variability decreased in direct proportion to the acuity measures to such an extent that the percentile steadiness varied within a range of less than 5 per cent of the original value. This occurred in the presence of a change of 334 per cent in the acuity. This established the intermittent nature of the peripheral response as a fundamental of the peripheral visual process rather than a phenomenon incidental to the unpracticed condition of the peripheral retina. If the latter had been so then the intermittency would would have disappeared entirely upon training.

Correlations of the acuity scores of the progressive tests of the training course afford a check on the previously calculated reliability of the measure. The series of 7 acuity tests taken by the 43 subjects during the course were separated by three or more practice periods. However, correlations of consecutive tests were used to check the test-retest reliability of the technique. The coefficient of correlation of the acuity scores of the first test with those of the second test was 0.62 and that between the last two tests was 0.88 with a rising coefficient in between. The original calculation of the reliability of the test was 0.91 and was based on an eye-to-eye correlation of scores on the assumption that the two eyes ought to score equally. The relatively poor test-retest correlation early in the training technique indicates a fluctuation in efficiency in the untrained individual functioning over a longer period of time than was required to take a single test. This fluctuation operates from day to day and was noticeable in the form of good days and bad days in the performance of the training subjects. The curve representing the average accomplishment of the group is regular and is a typical learning curve, but the curves of the individual subjects were characterized by occasional losses between tests in some cases. The fluctuations must be regarded as unique to the individual since no tendency to fluctuation has been observed in the mean scores of the group in training or in the relationship of individual point scores to the total scores in any group. The failure of scores to correlate with external circumstances such as time of day, test operator, etc., suggest that the fluctuations are independent of such influences.

Correlations of the millimeter variability scores of the training group in the same series of 7 tests revealed significant coefficients in only half of the consecutive tests. This indicates a lesser reliability of this measure of wavering; it is subject to greater change than the acuity. This is in keeping with the poor eye-to-eye correlation of this measure observed in single tests. Here again, the flux is unique to the individual rather than an expression of a periodic function of the entire group and is apparently independent of external circumstances.

The relationship of the percentile steadiness scores to each other in correlations of consecutive tests showed no significant coefficients whatever. There was indiscriminate improvement or decline in the steadiness of individual subjects during the training, although the mean of the scores of the 43 subjects remained nearly constant.

Late in the training course a rapid recognition test limiting the time of exposure of the stimulus object to one-fifth second showed a scoring similar to that observed in the night visual acuity tests. The mean night visual acuity score was 37.4: the mean rapid recognition score (with photopic illumination) was 41.3. A correlation of these two scores yielded a coefficient of 0.62. This contrasted with the correlation between the night visual acuity scores and the final acuity scores (in the last normal acuity test) which did not show a significant coefficient. It was concluded that restriction of the time of exposure under photopic conditions somehow duplicated the difficulty experienced under scotopic conditions. It suggested a means of substituting the easier photopic technique for the more difficult scotopic one.

DISCUSSION. The intermittent nature of the response to peripheral visual stimuli and its spontaneous fluctuation, coupled with the unpracticed condition of the retina, has been demonstrated to exert a marked effect on the performance of the individual. The ultimate ability of the individual to interpret such stimuli is but a poor index of what his reaction actually will be. Differences in performance of the same individual at different times is conditioned by two major variables, (a) a spontaneous fluctuation of efficiency which may operate around a range of 100 per cent or more (estimate), and (b) the amount of practice in peripheral interpretation previously experienced by the individual, which can cause performance to differ over a range of 350 per cent or more. The former variable can operate on responses to stimuli rapidly following each other. The latter variable operates through its range only over somewhat longer periods of time under the special circumstances resulting from previous training. These variables exclude the practicality of collating peripheral perceptual performance with rod and cone populations in the retina. The number of rods and cones in any area of the retina undoubtedly impose an ultimate ceiling of performance on the perception of peripheral detail, but the amenability of the peripheral retina to training indicates that that ceiling is not reached except by long practice. Even if such a ceiling of ability were attained by practice, the persistence of wavering in the original percentile relationship to the acuity strongly contraindicates the possibility of useful correlation of performance with the number of rods and cones.

The close similarity of day visual acuity in the periphery and night visual acuity in the same retinal areas has been appreciated in measures of simple acuity (1, p. 937). This was confirmed for simple form acuity in these investigations (3) where the relationship was found to be as 5 is to 7 in the presence of brightness differences of more than 2,000,000 to 1. The interchangeability of certain features of performance such as the improvement of night visual acuity by practice under photopic conditions and the significant correlation between night visual acuity and rapid recognition tests of day visual acuity tend to bring the photopic and scotopic performances of the peripheral retina still closer together. Additional points of similarity are to be found in the millimeter variability and percentile steadiness scores of different groups tested under these two conditions of brightness. There is a tendency to regard night vision problems as quite separate from the problems of day vision. It is believed that much benefit would accrue to the design of problems in night vision if peripheral perception under both scotopic and photopic conditions were regarded as the expression of a common perceptual phenomenon rather than as the functioning of separate entities bearing no relationship to each other.

The slight differences in acuity observed here and elsewhere in the presence of very great differences in illumination further discourage the attempt to correlate function and population of light sensitive elements but, at the same time, afford some evidence concerning the functions of the two types of receptor. It is known that rods are roughly 17 times as numerous as cones in the human retina (1). The function of the cones in photopic illumination and color vision is well established. That the cones are not stimulated under scotopic conditions is generally accepted, convincing evidence here being the foveal scotoma and absence of color perception in the photochromatic level of brightness. However, evidence that the rods are inactive in photopic illumination is lacking, although commonly inferred. Evidence supporting rod activity in bright light is found in the cone-free rat retina which is not blind in daylight and in the cone-free far periphery of the human retina which reacts to bright light. This evidence suggests that photopic perception in the periphery is the result of co-operative rod and cone activity, a thing manifestly possible by the complex synaptology of the retina. Further evidence supporting this concept is the increase in peripheral acuity of about 40 per cent in the change from scotopic to photopic conditions. If the rods were inactive in bright light this would mean that the increased acuity occurred in the presence of the stimulation of only about one-seventeenth as many receptors.

The extensive transfer of the laboratory training to conditions of everyday life as well as to other laboratory situations seems to justify the assumption of persistence of the effects of training in practical visual situations. On the basis of improved acuity measures after training, the expected performance of the trained individual under such practical conditions contrasts markedly with that of the untrained individual. Under photopic illumination the trained subject is able to become aware of a peripheral stimulus only one-eleventh the size of the minimum perceptible stimulus falling on the same area of the retina of the untrained individual. Under scotopic conditions the trained individual's ability enables him to respond to a stimulus less than one-third the size required to stimulate the same area of the untrained retina, or, conversely, for any stimulus of given size the trained individual can detect more than three times as much detail as the untrained person. Although the quantitative change in night visual acuity is much less than in photopic acuity the practical benefit of such improvement may be greater because of the absence of a central point of great acuity which, in photopic vision, is called upon for verification of peripheral stimuli.

The peripheral retina has long been recognized to possess inherently poor acuity but, to this basic understanding of its function, it is necessary to add two important features; (a) an habitually sub-maximal performance due to its unpracticed condition, and (b) a fundamental intermittency and fluctuation of efficiency in its response to constant stimulation. Both of these factors have been shown to alter its performance to a great extent. It is also well to include in a concept of its function a recognition of its essential sameness of performance in all levels of illumination.

SUMMARY

1. In a 14 point perimetric test for peripheral visual acuity correlations of individual point scores and groups of scores with the total score did not reveal any point or group of points significantly more reliable than others. This was true of the test scores of both day visual acuity and night visual acuity subjects.

2. A measure of spontaneous fluctuation or wavering in the response to peripheral visual stimuli was extracted.

3. Day visual acuity performance was found to be 78 per cent steady and night visual acuity performance 84 per cent steady.

4. Training by controlled practice in 43 subjects yielded a final score which was 334 per cent of the starting score.

5. There was successful transfer of the effects of the training to both other laboratory situations and conditions of outside life.

6. There was successful transfer of training under photopic conditions to night visual acuity to the extent of 187 per cent of a normal untrained score.

7. A day visual acuity test with time of exposure of the stimulus limited to $\frac{1}{5}$ second correlated with night visual acuity scores in the same 42 subjects with a coefficient of 0.62.

8. The intermittent nature of peripheral visual function is interpreted to be due to temporary multiple scotomata.

9. The peripheral retina is interpreted to be an unpracticed sensory area.

10. The nature of the peripheral visual process is discussed.

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