A STUDY OF THE RELATIONSHIP BETWEEN PHOTOPIC AND SCOTOPIC VISUAL ACUITY

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(The opinions presented in this paper are those of the authors and do not necessarily reflect the views of the Department of the Army.)

Modern warfare requires that the individual soldier perform many of his duties at night. The degree of success of many military operations depends upon the ability of the soldier to see at night as well as during the day. The Army has long been using a measure of photopic visual acuity, employing a variation of the Snellen chart. In 1942, recognition of the need for training in seeing at night stimulated the development of the Army night vision tester. However, the relationship between day vision and night vision had not been determined. This project was designed to investigate the existence and extent of any such relationship. If the two types of visual acuity measures are highly correlated, there is no need to measure them separately. On the other hand, if the correlation between the two is low, separate measures of each function are needed.

Background of the Research Problem

No record has been found of a controlled experiment to ascertain the relationship between a measure of photopic visual acuity and a measure of scotopic visual acuity. Although the duplicity theory of retinal function (1) is frequently considered a law, nevertheless there are many cells of the retina which, it is thought, act together. Polyak (2) points out that the bipolar cells often collect impulses from several rods and cones, and rods and cones frequently deliver impulses to a number of bipolar cells; thus, neural effects arising in the rods and cones both diverge and converge in their transmission from receptor cells to ganglion cells. In other words, though rods and cones constitute two distinct types of receptor cells, their connection with bipolar cells indicates that they do not necessarily form two distinct functional systems as has been frequently assumed. In reviewing the evidence, then, there is some support for a theory of no relationship between scotopic and photopic visual acuity in the differences in function of the two types of end organ. However, there is also indication of a possible relationship between the two functions on the basis of interconnection of the neural structure and of the central and cortical function and in the complexity of the transmission of neural impulse. In addition, of course, one must consider behavior of the total human organism, including central and cortical functions, which could account for indications of relationship between photopic and scotopic visual acuity.

The hypothesis to be tested in this study, then, was that there is no relationship between photopic and scotopic visual acuity. In this study the limits of brightness for photopic vision were 9.5 and 10.5 log micromicro-lamberts. The limits for scotopic vision were set as 3 and 6 log micromicro-lamberts.

General Design of the Research

Selected photopic visual-acuity charts were administered to 202 subjects. These subjects were also tested with the Army Night-Vision Tester-R2X. Intercorrelations of all measures were computed using Pearson product moment correlation techniques. Correlations were also computed between the photopic and scotopic tests, correcting for attenuation in the photopic variables by utilizing reliability data from previous studies. Adequate controls with respect to test administration and other factors were maintained.

Population

Data were collected on 202 soldiers stationed at Ft. Myer, Virginia. Testing took place between May 6 and June 15, 1949. The mean age was 20.1 years with a standard deviation of 3.17 years. The age range was from 17 to 43, with only 9 cases above 25 years. Of this group 15 percent (or 31 subjects) had need of and wore glasses. For this population the mean Army General Classification Test score was 101.4 with a standard deviation of 14.86 and a range of from 56 to 140, which is fairly representative of the current Army population.

In order to enable further analysis of control factors, if desired, the following descriptive data were gathered on each subject:

1. Name
2. Army serial number
3. Age
4. Whether wore glasses
5. Army General Classification Test score
6. Seat position in ANVT-R2X testing
7. Date of tests
8. Hour of tests
9. General subjective feeling of health or well-being
10. Amount of sleep previous night

In studying the relationship between photopic and scotopic visual capacity, the problem arises of the effects of refractive correction for each of these functions. It is obvious that in the case of photopic visual acuity, sizable correction can result from refraction. In regard to scotopic visual acuity, little is known about the amount of correction effected through the use of lenses. This experiment was designed to provide a frame of reference which would render the results applicable to the military situation and more specifically to the Army situation. Consideration was given to conditions under which military subjects are likely to be tested and classified for specific duty assignments and under which those subjects would actually use their eyes in functioning in a military situation. For example, it may be assumed that very few soldiers are at present provided with special corrections for night myopia. Furthermore, it is unlikely that soldiers, even under daylight conditions, will be wearing corrections for the minor amounts of hyperopia, myopia, or astigmatism which are compatible with 20/20 uncorrected vision. Also, it is reasonable to assume that for the present the corrections that they normally "wear" will be used under conditions of night operations. Hence, research in this project was restricted to conditions which approximated the operational situation. It was decided that subjects who usually wear glasses should wear them while being tested. The findings, therefore, are limited. They do not attempt to explain the effect of refractive error on the relationship between scotopic and photopic vision. They do indicate whether the ANVT-R2X, a measure of scotopic visual acuity, is related to measures of photopic visual acuity. However, it is recognized that any relationship found may not be the same as that between uncorrected photopic visual acuity and uncorrected scotopic visual acuity.

Test Variables

The Army night vision tester, ANVT-R2X, was the measure of scotopic visual acuity used in this study. This instrument is an improved form of the ANVT-15, utilizing a radium plaque rather than a lamp as a source of illumination. The ANVT-15 has been shown to have a test-retest reliability in the mid-eighties and its validity has been determined in a previous study (3) to be about .50.

The Army Night Vision Tester-R2X is a large, metal, box-type tester utilizing eight levels of illumination. (See Fig. 1). It presents a black, two-degree Landolt Ring at 20 feet on a 4 degree background of transilluminated tracing cloth. The illumination is supplied by a self-luminous radium plaque in a diffusion box. The intensity of illumination

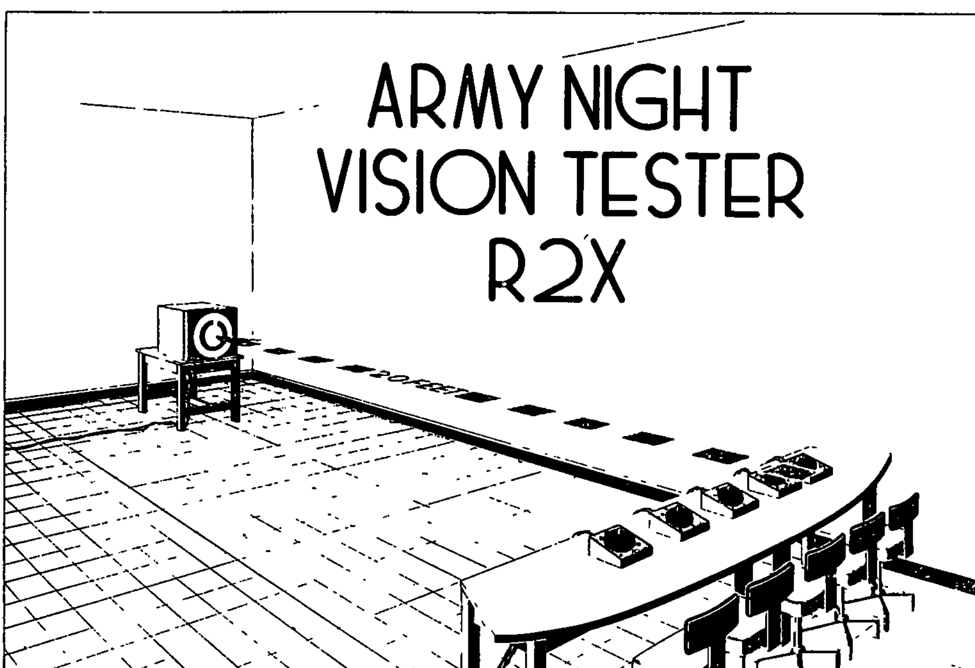

Figure 1. Scotopic Booth of the PRS Vision Laboratory

is varied by placing masking shields over the plaque; there are eight shields, each containing a circular aperture of a different size. In this way eight different levels of brightness are produced. The tracing cloth used was standard Air Force supply cloth (specification cc-c-531c). Dark-adapter subjects were seated behind their respective units at 20 ft. from the tester. An examiner presented the predetermined random settings of the Landolt Ring by turning the opening to any one of eight positions. Brightness was decreased in steps by placing the graded shields before the radium plaque.

The Taylor Low-brightness Illuminometer was used to check the brightness of the target of the Army night-vision tester. In Table 1 are given the levels of illumination in foot-lamberts and in log micromicro-lamberts of apparent brightness as used in the present investigation. (See Fig. 2).

Table 1

LEVELS OF ILLUMINATION OF THE ANVT-R2X (TEST FOR SCOTOPIC VISION)

Level	Foot-lambert	Log micromicro-lamberts
1	.00017	5.26
2	.000085	4.96
3	.000047	4.70
4	.000040	4.63
5	.000017	4.26
6	.000014	4.17
7	.000008	3.93
8	.000003	3.51

The score on the night vision test was the number of correct responses to 64 test positions as scored by the recorder.

Some investigators may question the use of the term scotopic visual acuity for the measure secured with ANVT-R2X, and may prefer the terms scotopic vision or night vision. The latter terms may be favored by investigators who feel that the variation in angular size at a specific brightness level is a more acceptable measure of acuity than the variation in brightness level holding target-size constant. It has been shown that "the relationship between visual acuity and the logarithm of illumination is sigmoid"(4). Taking this fact into account, Alphonse Chapanis increased the size of the test character from 37.5 min. to 2 deg. when accompanied by decrease in the

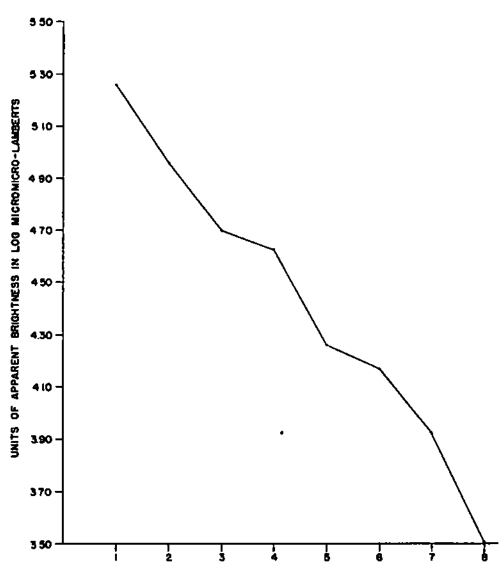

Figure 2. Illumination Levels of ANVT-R2X

general level of illumination (from 3.6 to 0.7 log micromicro-lamberts) in order to make proper threshold measures (5), and concluded that "for practical night vision testing, the size appears to make but little difference," since the relative position of subjects remains relatively stable. In addition, the RCAF Biophysics Laboratory felt that "in any test one may keep illumination constant and vary the size of the tests, or vice versa"(6).

Six variables were used to measure photopic visual acuity:

1. The Army Snellen chart was selected as a traditional measure of visual acuity, irrespective of factor-loading content.

2. The checkerboard variable grid, a wall-chart test of "retinal resolution" had been developed for a previous PRS study. It was included in the present study in order to examine possible differences in relationship that may result from differences in visual-factor content. In the factor analysis reported (7), "retinal resolution" was identified as the factor which accounted for the greatest portion of the variance on a number of tests. Of these tests, the variable grid was the one with the greatest "purity" on the retinal resolution factor.

3. Included was a measure of photopic brightness discrimination. Some investigators (8) believe that the type of scotopic measure used in this project involves a fairly heavy loading on a "brightness discrimination" factor. Hence, a measure of photopic brightness discrimination was included to determine its relationship with the scotopic measure used. Since there is no reasonably pure test of photopic brightness discrimination available, the technique of measuring this factor reported in PRS Report 763 was used (9). This technique involves use of the line resolution test and the checkerboard variable grid test. The latter is used for partialling out the resolution factor from the line resolution test which measures both resolution and brightness. The derived brightness discrimination score in the present investigation is a weighted composite of the line resolution test score and checkerboard variable grid test score. This score was obtained for the present population using the procedure developed in the earlier study (10).

The following formula for combination was adopted:

$$Z_B = \left(\frac{1}{\sqrt{1 - r^2_{RC}}}\right) Z_C - \left(\frac{r_{RC}}{\sqrt{1 - r^2_{RC}}}\right) Z_R$$

R represents a "resolution" test
C represents a test measuring "brightness" and "resolution"
B represents the derived brightness discrimination measure

In this case R represents the Checkerboard Variable Grid and C represents the Line Resolution Test. In the present study the correlation between these tests (r_{RC}) is .65. Substituting this value for r_{RC} yields the following equation: $Z_B = 1.32\ Z_C - .86\ Z_R$ which equals in terms of raw scores $X_B = .21\ X_C - .16\ X_R$. These scores were used to prepare a scatter plot of derived brightness scores against ANVT scores to check by inspection for linearity of the correlation.

4. The measure of brightness discrimination obtained with the line resolution test was compared to that obtained with two other measures which have been shown to have heavy loadings on the brightness discrimination factor. These measures were the quadrant variable-contrast and the dot variable-contrast wall-chart tests.

5. Since the Landolt ring is used as the target in ANVT-R2X, a photopic visual acuity measure with a comparable target was employed. The modified Landolt ring wall-chart was used for this purpose.

6. The Bausch and Lomb orthorater acuity tests, utilizing standard checkerboard targets, were also administered.

The Macbeth illuminometer was used to check the apparent brightness of illumination on the test charts and floor and walls of the photopic booth. The chart had the highest illumination (10.5 foot-candles), and the surroundings had no less than 6 nor more than 10.5 foot-candles. Table 2 gives the results of the illumination survey for the photopic vision booth.

Test Procedures

All tests were administered in the vision laboratory of the Personnel Research Section, AGO, in the Pentagon, Room 1C 912. This laboratory has been standardized in conformity with the specifications set by the Armed Forces National Research Council Vision Committee. (Fig. 3 and 4).

Table 2

TABLE OF ILLUMINATION OF PHOTOPIC WALL-CHARTS

Location	Illumination Ft. Candles
Front Wall	
Chart (center)	10.5
Top	10.5
Bottom	9.5
Center 1 1/2 ft. above	10.5
Center 1 1/2 ft. below	9.5
Center 1 1/2 ft. left	9.0
Center 1 1/2 ft. right	9.0
Center 3 ft. left	8.5
Center 3 ft. right	8.5
Left Wall	
3 1/2 ft. from front wall	8.2
12 1/2 ft. from front wall	7.0
20 ft. from front wall	6.3
Right Wall	
3 1/2 ft. from front wall	7.2
12 1/2 ft. from front wall	6.5
20 ft. from front wall	6.3
Floor Center	
3 1/2 ft. from front wall	8.0
12 1/2 ft. from front wall	8.0
20 ft. from front wall	6.7

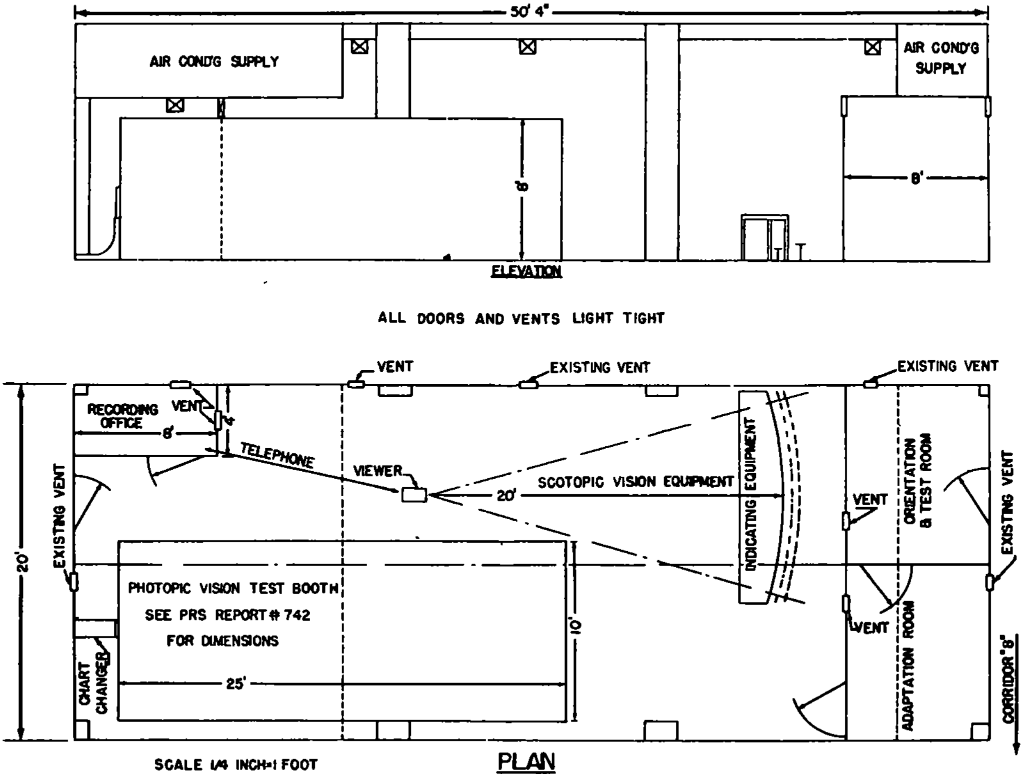

Figure 3. Layout for Vision Laboratory, Personnel Research Section, AGO

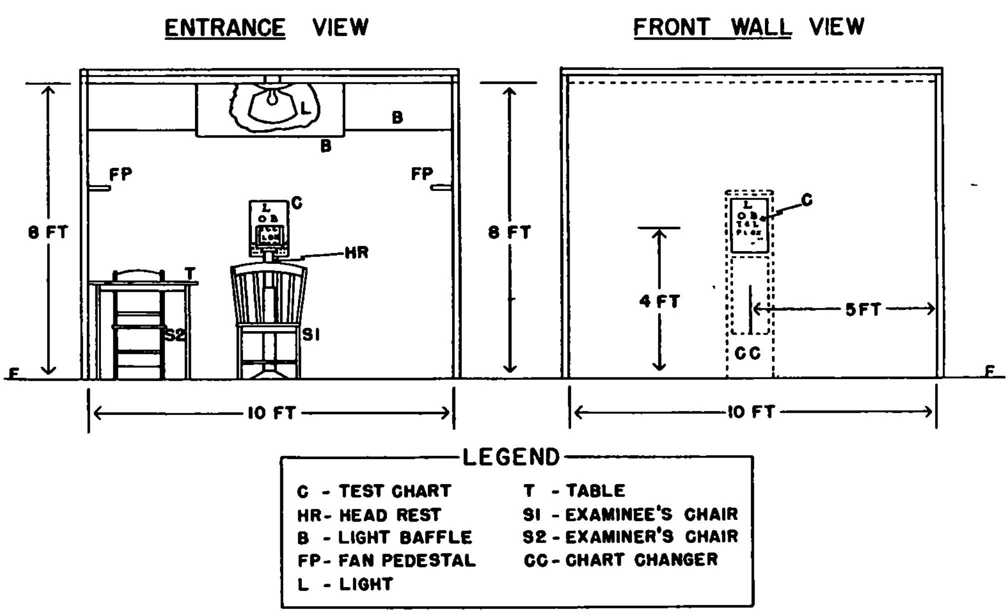

Figure 4. Construction Plan for Photopic Vision Booth of the PRS Vision Laboratory

The ANVT-R2X was administered before the photopic vision tests. Testing was scheduled for two sessions each working day, one at 8:45 a.m. and one at 1:15 p.m. Five subjects were tested at each session. The scotopic tests were administered in the light-proofed rooms of the PRS vision laboratory. The photopic tests were administered in the laboratory's photopic-vision booth.

All tests were administered for binocular vision with the refractive correction customarily used by the subject. Specific directions for administration of the tests are presented in the standard operating procedures on file in the Personnel Research Section, AGO. Subjects spent 30 min. becoming dark adapted. In groups of five, they first spent 20 min. in the adaptation room, illuminated by a low intensity (25 watts; 120 volts) frosted red lamp. This was followed by 10 min. in the light-proofed testing room. During the adaptation time, the subjects were oriented in the principles of night seeing: off-center viewing, scanning, and avoidance of fixation. They were also instructed in the test procedure and informed of the method of recording responses and scoring.

Subjects were tested for eight positions of the break in the Landolt ring at each of eight intensities of illumination, making 64 trials in all. The eight trials at the first and highest level of illumination were practice items. Duration of each trial was 10 seconds. The recording and timing were accomplished in a recording room adjacent to the scotopic vision room; communication between experimenter and recorder was effected by a small handset field telephone.

The order of presentation of individual wall-chart tests and instrument tests (refer to Figure 5 for sample items) was (1) modified Landolt ring, (2) Army Snellen, (3) quadrant variable contrast, (4) dot variable contrast, (5) line resolution, (6) checkerboard variable grid, (7) Bausch and Lomb orthorater (far), and (8) Bausch and Lomb orthorater (near). The subject was seated 20 ft. from the wall-chart in the photopic booth. A headrest was used. He was shown a sample hand-chart and given standard directions. The standard procedure provided in the Bausch and Lomb orthorater test manual was used for the Bausch and Lomb orthorater tests.

The method of scoring the wall-chart tests was that shown to be the most reliable method in the studies reported in PRS Report No. 742 (10). For the modified Landolt ring, the Army Snellen, and the line resolution and checkerboard variable grid tests, the score was the number of correct responses given by the subject up to the point where he had made three consecutive errors. For the dot variable contrast and quadrant variable contrast tests, the

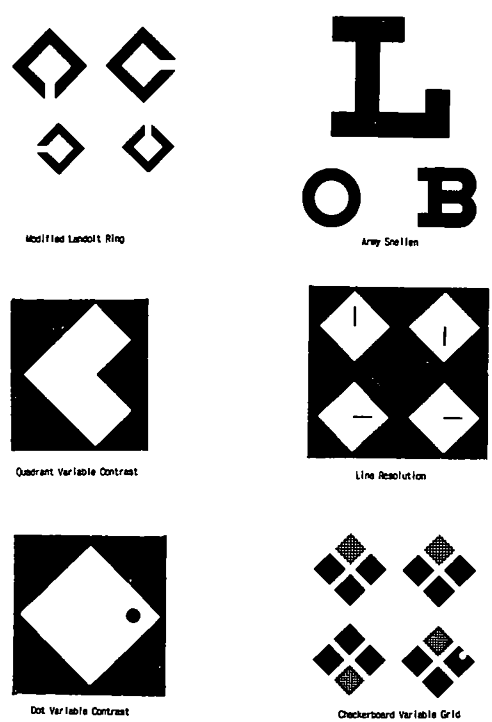

Figure 5. Photopic Visual Acuity Test

score was the number of correct responses up to the first miss. The scoring directions given in the Bausch and Lomb orthorater test manual were followed in the case of the orthorater tests.

Reliability of the ANVT-R2X

Based on the 202 subjects used in this study, the Army Night Vision Tester-R2X was found to have an odd-even reliability coefficient of .94 after correction with the Spearman-Brown formula. This measure of reliability is fairly consistent with findings on the ANVT-15, previously mentioned in this report, and it is reasonable to expect that the test-retest reliability of ANVT-R2X is as high as, or higher than, that of the ANVT-15. Hence the ANVT-R2X can be considered a reliable instrument.

Based on research by the School of Aviation Medicine (11) and also on our own analysis of the data gathered for this study, a "hot spot"/1 has been suspected on the screen of the ANVT. Using the information gathered in this study, the question as to whether a hot spot affects the reliability of the scotopic visual acuity measures obtained with the ANVT has been examined.

Table 3 indicates that seat variation for the total test is not significant and hence the hot spot does not influence total scores when the frequency of the target positions used is balanced, as they were in this study. The F test has not been computed because the variance within groups exceeds that between groups.

Table 3

MEANS, STANDARD DEVIATION, AND ANALYSIS OF VARIANCE DUE TO GROUP (SEATS) AND DUE TO WITHIN GROUP (SEATS) VARIATION

Seat	1	2	3	4	5	Total
M	49.2	49.7	50.9	48.8	48.7	49.5
σ	9.9	8.8	8.1	10.3	10.7	9.6
N	41	40	41	41	39	202

Source of Variation	Sum of Squares	d.f.	Variance
Between groups (seats)	134	4	33.50
Within groups (seats)	18538	197	94.10
Total	18672	201	

/1 The "hot spot" of ANVT-R2X may be created by the fact that there is a small area of illumination behind the larger target screen. This condition possibly results in greater illumination along the visual line of regard on certain portions of the target screen when these areas coincide with the opening in the Landolt ring and may result in an easier or in a more difficult item, depending on the line of regard from the seat position to the target position.

Reliability of the Photopic Test

Reliabilities of the photopic visual-acuity measures were not computed on the populations used in this study but secured from a previous study (12). The test-retest reliabilities of the six wall-chart photopic visual-acuity tests are given in Table 4. Reliability estimates for the two photopic visual-acuity tests from the Bausch and Lomb orthorater instrument were also secured from the previous study, PRS Report 742, and are also given in Table 4. The reliability estimate on the derived measure for brightness discrimination is .55.

Table 4

CORRELATIONS OF THE SCOTOPIC VARIABLE WITH THE PHOTOPIC VARIABLES, CORRECTED FOR ATTENUATION OF THE PHOTOPIC VARIABLES

Photopic Variables	Correlation with ANVT-R2X	Correlation with ANVT-R2X, Corrected for Attenuation	Coefficient of Reliability, Test-Retest
Modified Landolt ring	.35	.39	.80
Army Snellen chart	.38	.40	.88
Line resolution	.39	.42	.85
Quadrant variable contrast	.21	.28	.57
Dot variable contrast	.19	.29	.43
Checkerboard variable grid	.29	.32	.81
B and L Orthorater (far)	.27	.29	.87
B and L Orthorater (near)	.25	.27	.82

Relationship between Scotopic and Photopic Measures of Visual Acuity

In Table 5 are presented the intercorrelation of the scotopic measure, the nine photopic-acuity tests, the derived brightness-discrimination measure, and the Army General Classification Test score. The relationship between the scotopic visual-acuity measure, ANVT-R2X, and the nine photopic-acuity measures ranges from .19 to .39. Since the population consisted of 202 cases, and the standard error of a correlation coefficient of zero for a sample this size is .07, it may then be concluded that these correlations are significantly different from zero at the 1 percent level of significance. Furthermore, it may be seen that the correlation between the ANVT-R2X and the line resolution test, and the correlation between the ANVT-R2X and the Army Snellen test, are the two highest correlations, .39 and .38 respectively, among the comparisons between photopic and scotopic acuity measures. It is to be noted that these two photopic measures have the highest test-retest reliability, .85 and .88, respectively (Table 4). The correlations between ANVT-R2X and the checkerboard variable grid and between ANVT-R2X and the modified Landolt ring are relatively high, .29 and .35, respectively, and their reliabilities are .81 and .80, respectively. The correlations between ANVT-R2X and quadrant variable contrast and between ANVT-R2X and dot variable contrast are lower, .21 and .19, respectively, the reliabilities being .57 and .43, respectively. Thus we see the order of magnitude of the correlation between

TABLE 5

INTERCORRELATIONS OF PHOTOPIC AND SCOTOPIC VISUAL ACUITY VARIABLES

N=202 Enlisted Men at Ft. Myer, Va.

Mean	Standard Deviation	Description of Variables		1	2	3	4	5	6	7	8	9	10
49.42	9.60	Army Night Vision Tester	1										
27.77	3.71	Modified Landolt	2	.35									
34.89	5.59	Army Snellen	3	.38	.69								
5.18	1.10	Quadrant Contrast	4	.21	.30	.25							
42.51	6.18	Line Resolution	5	.39	.68	.68	.34						
3.51	.99	Dot Variable Contrast	6	.19	.42	.43	.30	.45					
19.74	5.52	Checkerboard Variable Grid	7	.29	.57	.56	.13	.65	.38				
11.24	1.68	Bausch and Lomb Orthorater (far)	8	.27	.50	.60	.17	.59	.33	.58			
10.64	1.57	Bausch and Lomb Orthorater (near)	9	.25	.53	.62	.10	.49	.27	.53	.58		
5.79*	1.03*	Derived Brightness Discrimination Score	10	.25	.38	.38	.31	.72	.25	-.01	.25	.18	
101.35	14.86	Army General Classification Test Score	11	.12	.08	.06	.04	.08	-.10	.07	.02	.04	.05

* Brightness Discrimination = .21 Line Resolution - .16 Checkerboard Variable Grid

the ANVT-R2X and the several photopic-acuity tests is related to some extent to the rank order of the reliability of the photopic-acuity variables.

Further inspection of the intercorrelations shows that the derived photopic brightness-discrimination measure/2 correlates about as well with the ANVT-R2X measure as does the checkerboard variable grid (.25 and .29, respectively). Thus, one may conclude that approximately an equal amount of photopic brightness discrimination variance and photopic "pure" retinal resolution variance is contained in the scotopic-acuity measure used in this study. In Table 6 are presented the upper and lower limits of the correlations shown in Table 5 at the 1/2 percent level of significance. The coefficients shown in the upper-right triangle of Table 6 are the minimum values, and the coefficients shown in the lower-left triangle of Table 6 are the maximum values which can be expected as often as 1 case in 200 respectively. The probability for both limits together represents a 1 percent test of significance. As further interpretation of the values presented in this table, an example is offered: In this study the correlation found between the scotopic visual-acuity measure ANVT-R2X and the Army Snellen test was .38. However, this is a fallible measure. That is, if the "true" correlation coefficient is .22, only one correlation coefficient in 200 for similar samples under similar conditions would be as high as .38. Similarly, if the true correlation happens to be .53, only 1 of 200 correlation coefficients computed on similar samples would be as low as .38.

/2 One may assume that this derived brightness measure is a pure measure of brightness discrimination. It should be noted that the correlation between this derived brightness-discrimination measure and the checkerboard variable grid scores is -.01, indicating that, on a computational basis, there is some evidence for the plausibility of this assumption.

TABLE 6

THE LIMITS OF THE VALUES OF THE CORRELATION COEFFICIENTS OF TABLE II
AT THE 1% LEVEL OF SIGNIFICANCE

		1	2	3	4	5	6	7	8	9	10	11
Army Night Vision Tester (ANVT)	1		.18	.22	.03	.23	.01	.12	.09	.07	.07	-.06
Modified Landolt Ring	2	.50		.58	.12	.57	.26	.43	.35	.38	.21	-.11
Army Snellen	3	.53	.77		.07	.57	.27	.43	.46	.50	.22	-.13
Quadrant Contrast	4	.37	.45	.41		.17	.13	-.05	-.01	.08	.13	-.15
Line Resolution	5	.53	.77	.77	.49		.30	.53	.46	.34	.61	-.10
Dot Variable Contrast	6	.36	.56	.56	.46	.59		.22	.15	.09	.07	-.28
Checkerboard Variable Grid	7	.45	.68	.68	.30	.74	.53		.45	.39	-.19	-.11
Bausch and Lomb Orthorater (far)	8	.43	.63	.70	.34	.70	.48	.69		.44	.08	-.16
Bausch and Lomb Orthorater (near)	9	.41	.65	.72	.28	.61	.43	.65	.69		.01	-.14
Derived Brightness Discrimination Score	10	.41	.52	.53	.46	.79	.41	.17	.42	.35		-.13
Army General Classification Test	11	.30	.25	.23	.21	.26	.08	.25	.20	.22	.23	

Table 4 presents for comparison purposes the correlations between the above-mentioned eight photopic measures and the scotopic measure, together with the corresponding correlations corrected for attenuation of the photopic variables. The reader is cautioned to remember that these reliabilities are based on a different population sample from that of the present study, having been taken from PRS Report 742. The examination of the corrected coefficients reveals that the increase in relationship when the photopic-acuity measures are corrected for attenuation is negligible.

An additional point of interest is the relationship between AGCT and the acuity measures, which ranges from -.10 to .12. Considering the standard error of a zero coefficient of correlation for a sample of the size used here, it becomes apparent that correlation of the Army General Classification Test score with the measures of visual acuity is not significantly different from zero at the 5-percent level of significance. Thus, "general learning ability" does not account for the relationship between scotopic and photopic visual acuity.

In summary, it may be said that there is a positive correlation, exceeding expectation in the light of general accepted theory, between the measures of photopic and scotopic acuity, under the conditions used in this study. However, this relationship is still not high enough for predicting one variable from the other for the range of value in this study.

With regard to the practical significance of the above conclusion, if selection procedures must provide instruments appropriate to measuring photopic, scotopic, or both types of vision, at least one instrument of each type would need to be used for the present. There should be a scotopic visual-acuity test as well as a photopic visual-acuity test, since correlation between the two variables is not sufficiently high to permit scores from the measure of one of these abilities to represent the other.

A further interesting interpretation is possible when one examines the table of intercorrelations and the appropriate scatter plots among the vision variables. Selecting one of the best predictors, one finds the correlation between the Army Snellen and the ANVT-R2X to be .38. An examination of that scatter plot (Table 7) shows that if the top 28 cases

TABLE 7

4074-07-02 SCATTER PLOT OF ARMY NIGHT VISION TESTER vs ARMY SNELLEN

ARMY SNELLEN	ANVT-R2X SCORES													
Scores	14-17	18-21	22-25	26-29	30-33	34-37	38-41	42-45	46-49	50-53	54-57	58-61	62-65	fy
44-45										1	1	2		4
42-43								2	5	3	7	5	2	24
40-41						1		2	3	1	4	6		17
38-39				1	1		1		2	3	2	1		11
36-37	1		1	1			1	7	2	11	6	6	3	39
34-35				2	1	2	3	4	4	7	12	9	3	47
32-33					1	1	1	2	4	7	6	1		23
30-31							1	3	1	3	3	1		12
28-29							1		1		1			3
26-27				2	1		2	2		1				8
24-25		1									1			2
22-23								1	2		1			4
20-21				1			1		1			1		4
18-19				1										1
16-17	1	1							1					3
fx	2	2	1	8	4	4	11	23	26	37	44	32	8	202

are selected on the photopic variable, the mean of those 28 cases on the scotopic variable is 54.1 as compared with the mean of 49.4 for the total group. No case among the 28 would fall more than .66 below the mean for the total group. Hence, the interesting possibility presents itself that if prediction were necessary only in the extremes for a population, particularly on the upper extreme, it may be possible to predict scotopic vision in terms of the photopic-vision variables. Furthermore, the population used in this study has been quite restricted in range on the photopic variables. More specifically, this population, which was tested with corrected refraction and which had better photopic visual acuity than the population used in PRS Study 742, obtained a sigma on the Army Snellen Test 59 percent as large as the population utilized in the study reported in PRS Report 742. Hence, the relationships reported are underestimates as compared to the relationships likely in a population similar to that used in the previous study. Furthermore, it is also recognized that one would want to examine the relationship between photopic predictors and night-vision validity criteria before accepting the predictability of scotopic vision from photopic measures.

Since a positive correlation was found between photopic visual acuity at the usual level of illumination (approximately 10 f.c.) and scotopic visual acuity at very low levels illumination (3.5 to 5.5 log micromicrolamberts) further research is indicated to explore relationships at various intermediate levels of illumination. This research project would test the hypothesis that there are higher degrees of relationships between photopic visual acuity at intermediate levels of illumination and scotopic visual acuity.

Summary

The problem was to determine the relationship between photopic (day) and scotopic (night) visual acuity. A further objective was to ascertain whether the two types of visual acuity can both be measured by the same instrument or whether two types of visual-acuity tests are required. The information is applicable in selection procedures.

Two hundred and two soldiers between the ages of 17 to 43 were tested with the Army night-vision tester, ANVT-R2X, the modified Landolt ring, the Army Snellen, the quadrant variable contrast chart, the dot variable contrast chart, the checkerboard variable grid chart, the line resolution chart, and the Bausch and Lomb Orthorater. A derived brightness-discrimination score was also computed. All subjects used both eyes in taking the tests and were permitted to wear glasses if correction was necessary to their everyday vision. Thirty-one subjects or 15 percent wore glasses. All of the tests were administered in the vision laboratory of the Personnel Research Section, AGO. This laboratory has been standardized in conformity with the specifications set by the Armed Forces National Research Council Vision Committee. The light under scotopic conditions varied between 3.51 and 5.26 log micromicro-lamberts in 8 approximately equal steps. The light under photopic conditions was 10.5 foot-candles on the charts and no more than 10.5 nor less than 6 foot-candles in the booth.

All subjects were dark adapted for 30 min. and instructed in night-seeing principles: off-center viewing, scanning the target, and avoidance of fixation. With regard to the photopic tests, all subjects viewed the wall-charts from a distance of 20 ft. with binocular vision. The photopic measures correlated with the scotopic measure in a range from .19 to .39. There was no appreciable correlation between these tests and intelligence as measured by the Army General Classification Test. The report concludes that there is a positive correlation between the measures of photopic and scotopic visual acuity under conditions of this study and for the population used, and that this correlation somewhat exceeds expectations in the light of generally accepted theory.

The above findings are of practical significance in considering possible use of selection measures of photopic or scotopic visual acuity, or both, in the case of a population similar to that in the study. For the present, it is felt that at least one instrument of each type should be employed, inasmuch as the correlation between the two measures is not sufficiently high for the scores on one measure to be used as representative of the other. Nevertheless, data secured in this study indicate that further research may provide a means of identifying, by use of photopic wall-charts, a portion of a given population (probably 10 to 15 percent) whose night-vision score would tend to be considerably above the mean of the total population.

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