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16. Abstract

In a previous study, we reported the efficiency with which various tests of color defective vision predict performance during daylight conditions on a practical test of ability to discriminate aviation signal red, white, and green. In the current study, subgroups of the subjects used in the previous investigation were tested with the signal light gun at night.

Comparisons of the efficiency of each of seven tests of color defective vision in predicting performance under day and night conditions are reported. In general, the commercial tests were less efficient in predicting performance at night than in the daytime. This reduction in efficiency may be attributed to an increase in the false alarm rate of each test.

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COLOR DEFECTIVE VISION AND DAY AND NIGHT RECOGNITION
OF AVIATION COLOR SIGNAL LIGHT FLASHES

I. Introduction.

Candidates for Federal Aviation Administration medical certificates (Class II and III) must be able to discriminate aviation signal red, green, and white.[1] Currently, a number of clinical tests are being used by Aviation Medical Examiners to satisfy this color vision requirement. In a previous study,[2] subjects were given several of these clinical tests together with a practical test of their color vision abilities. This practical test, using the signal light gun, is the same one given airman applicants desiring a Statement of Demonstrated Ability for the color vision requirement. The signal light gun test is administered during daylight hours, but if an airman applicant fails this test, his certificate is marked invalid for "night flight or by color signal control." The question arises as to how well these same people would perform on the signal light gun test if they were given the test again, this time at night. Some of the subjects from the previous study were retested on the practical test at night, and the results were compared with their performances on the clinical tests and the signal light gun test given during daylight.

II. Method.

A. *Subjects.* Men and women previously recruited from a test booth at the 1968 Oklahoma State Fair were part of the retest group. Additional subjects were taken from a study employing active duty personnel at Tinker Air Force Base, Oklahoma City. A total of 55 subjects was used. They had all previously been tested on seven clinical color vision tests and the signal light gun test given during the day.

B. *Tests and Procedures.* Following is a description of the complete test battery given the subjects in the previous studies.

1. The American Optical H-R-R Pseudo-isochromatic plates[3][4] consist of demonstration, screening, and diagnostic plates. The subject was instructed that there would be one, two, or no figures on each plate. Failure on this test was any error in plates 12 to 14. These are the plates diagnosing a medium red-green color deficiency.

2. The Dvorine Pseudo-Isochromatic plates consist of 15 numerical plates, including one demonstration plate. A failure for this test was any error on 12 or more of the plates.

3. The Farnsworth Panel D-15 was designed to differentiate the severe color defective from the moderate color defective and the color normal.[5] The test has 15 color plastic test caps and one reference cap. The subject was instructed to place each cap next to the one most like it in color and to begin with the reference cap. A failure was scored if there were at least two cross-overs in approximately the same direction on the score sheet circle.

4. The Farnsworth-Munsell 100-hue test was designed to measure color discrimination among normals and areas of confusion in people with color defective vision.[5] The test consists of four hinged boxes. The lid of each box contains one-fourth of the 85 color test caps randomly arranged. The bottom has two fixed reference caps, one at either end. The subject was told to take the test caps from the lid and place them in the bottom half of the box in order according to color. The failure criterion was a calculated error score of 100 or more.

Each of the four previous tests was given in a darkened room under a Macbeth easel lamp equipped with a daylight filter. This lighting approximates the C. I. E. source C.

5. The Color Threshold Test, developed by the Air Force,[6] consists of two vertically arranged discs, each containing eight filters, placed in front of a test light. The upper disc contains neutral density filters to vary lumi-

nance of the test light and the lower has color filters to vary color. The test, given in a darkened room, consisted of showing and naming the eight colors at the highest luminance and then having the subject name them at the lowest luminance first, then at each succeedingly higher luminance. The order of presentation was reversed from each previous showing. Failure was considered to be a score of 49 or less.

6. The Farnsworth Lantern, developed by the Navy,[7] has a pair of vertically arrayed lights. They can be red, green, or white in any combination, and all nine possible pairs were shown to the subject in a random order. The test was given in a lighted room. The subject pased if he completed the first run of the nine color pairs with no errors. If an error was made, two more runs were shown and scored and a failure was an average of more than one error per run for the last two runs.

7. The Nagel-type anomaloscope displays a monocular illuminated view of a bipartite circle. The top half is a variable red-green mixture, and the bottom is a yellow whose luminance can be varied. The subject was first told to stare at the Trendelenburg adaptation light for two minutes. Then he was asked to look into the anomaloscope at the circle and to vary both halves until they matched exactly in color and in brightness. He was then asked to match a color set by the examiner in the top half of the circle by varying the luminance of the bottom portion. Between each match, he was told to stare at the adaptation light for 30 seconds. The procedure continued until the outside limits for each subject's matches were reached. After the series under "neutral" adaptation, a chromatic adaptation series was run. The subject was asked to continue staring into the anomaloscope at the circle between his matches and to adjust the luminance as the examiner adjusted the red-green mixture. Ranges for both series were noted and those outside a range from 38 to 44 on a scale for the red-green mixture of 0 to 73 were considered defective. This pass-fail criterion and also the classifications for mild, moderate, and severe deficiencies were arbitrarily selected for purposes of comparison with other tests. A range of 10 or less was classified as a mild

defect, 11 to 25 as a moderate one, and 26 or more as a severe defect. An anomaly was diagnosed when the range under chromatic adaptation was greater than the range under "neutral" adaptation.

8. The signal light gun test was given to each subject during the day. The gun was stationed indoors at an elevation of 38 feet. The subject was tested outdoors at distances of 1000 and 1500 feet from the window and asked to identify a five-second flash of aviation signal red, green, or white. Three flashes were presented two minutes apart at each distance. The order of presentation was selected randomly but each color was presented at least once in each six-flash series. The subject was asked to identify the color before the termination of the flash. The failure criterion was any error.

The eight preceding tests were given to the subjects in the previous studies. In this investigation, the subjects were each tested with the color signal light gun at night using a procedure identical to that used in the daylight testing.

III. Results and Discussion.

The color vision deficiencies of the subject population, as diagnosed by the anomaloscope test, are seen in Figure 1. The ranges obtained under chromatic adaptation from subjects labeled extreme anomalies are indicated by broken lines, while solid lines indicate the matches obtained under "neutral" adaptation. The degree of severity of the defects can be seen as well as the distribution of the types of color deficiencies.

These subjects were given the signal light gun test under both day and night conditions. Of the 55 subjects, 20 of those that passed the day test also passed the night test. In terms of the number of flashes missed on the signal light gun test, of the 35 that failed the practical test under day or night or both conditions, 28 subjects made fewer mistakes at night, six made more mistakes, and one subject remained the same. When the subjects were broken down into the two main types of color deficiency, protan and deutan, there was no significant difference in the rates of improvement; i.e., 17% more protans and 23% more deutans passed the signal light gun test when given at night. However, any improve-
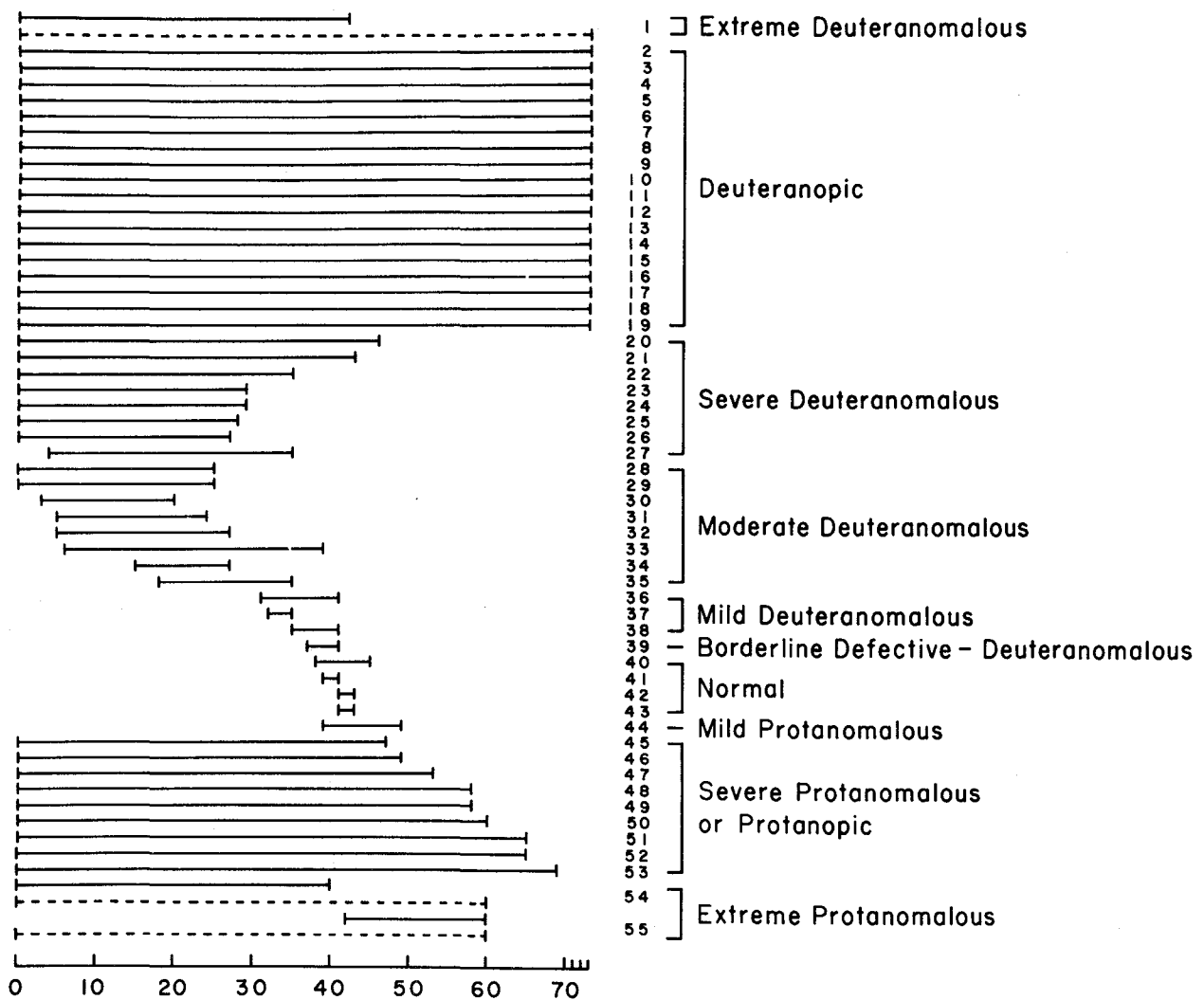
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FIGURE 1. Range of anomaloscope matches made by subjects under conditions of "neutral" adaptation (solid lines) and, where different, chromatic adaptation (broken lines).

ment in test results of performance in day and night testing should be considered as conditional. The day testing was completed first in all cases, and the effect of the previous practice on the results of the night testing is unknown. With a larger test population and an alternative test procedure, the results might have been very different.

Contingency tables showing the efficiency of each clinical test in predicting day and night performance on the signal light gun test are shown in the Appendix. The results are summarized in Table 1. The phi coefficient shows how well each test fared as a predictor of performance on the practical test. As can be seen from a comparison of the phi coefficients, cor-

relations on all tests dropped under the nighttime condition with the exception of the Dvorine plates. In two cases, the correlations fell below an acceptable level of significance. In general, the efficiency of the clinical tests to predict performance on the practical test when given at night was less than satisfactory.

There was also a trend toward lower "miss" rates, that is, the percentage of the subjects that passed the clinical test but failed the practical test. This is important as the "miss" rate represents those applicants who will receive certificates with no color vision restrictions, but who should be issued a certificate with the color vision restriction.

Both the lower "miss" rate and the lower phi

Table 1

Correlation between clinical tests and the color signal light gun test.

| | Day | | Night | |
Test	Phi Coefficient	Per Cent "Misses"	Phi Coefficient	Per Cent "Misses"
A.O. H-R-R	.52*	7.3	.23	7.3
Anomaloscope	.50*	0	.33**	0
Color Threshold Tester	.55*	7.3	.33**	5.5
Dvorine Plates	.45*	5.5	.46*	0
Farnsworth Lantern	.44*	1.8	.36*	0
Farnsworth 100-Hue	.45*	5.5	.21	5.5
Farnsworth Panel D-15	.55*	9.1	.46*	3.6

* Correlations are significant at the .01 level.
** Correlations are significant at the .05 level.

coefficients may be attributed to an increase in the false alarm rate. The false alarm rate is that percentage of subjects that failed the clinical test but passed the practical test. As can be seen in Table 2, the false alarm rate for all tests increased under nighttime conditions. This points out the need for applicants who fail the clinical test to be allowed to take a practical test, given under the conditions in which his license would then be valid.

The lower correlations and the higher false alarm rates of the clinical tests when compared with a practical test given at night indicate the need for an inexpensive, less time-consuming, more efficient test for predicting color vision abilities at night.

Table 2

False alarm rate between clinical tests and the color signal light gun test.

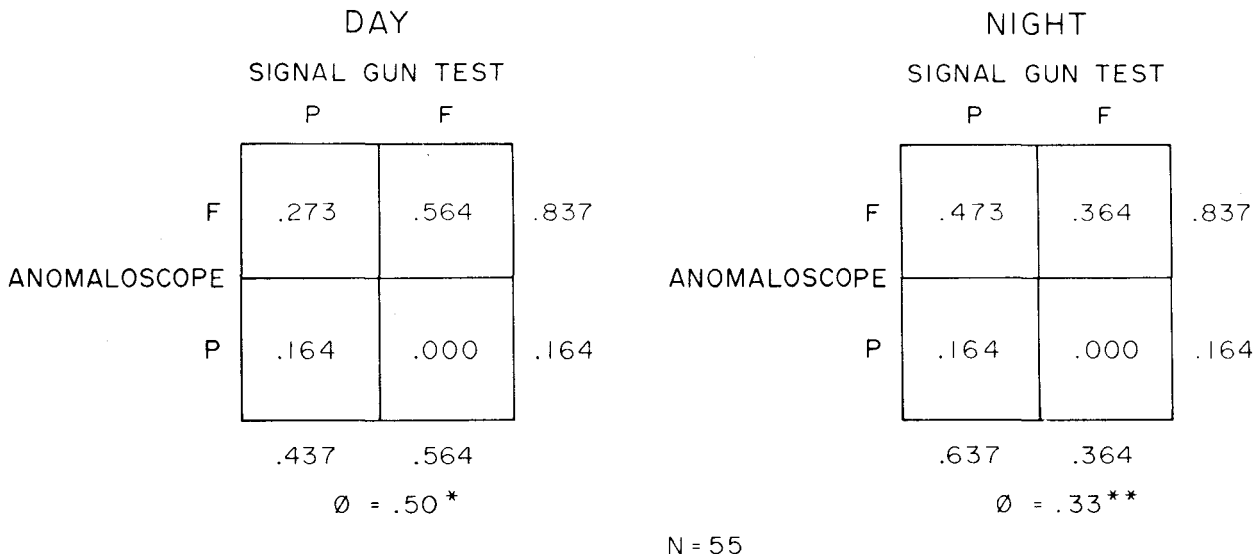| Test	Day	Night
A.O. H-R-R	16.4	36.4
Anomaloscope	27.3	47.3
Color Threshold Tester	14.5	32.7
Dvorine Plates	21.8	36.4
Farnsworth Lantern	27.3	45.5
Farnsworth 100-Hue	21.8	41.8
Farnsworth Panel D-15	12.7	27.3

REFERENCES

1. Federal Aviation Administration: Guide for Aviation Medical Examiners. Department of Transportation, Federal Aviation Administration, Office of Aviation Medicine, June 1970.

2. Lewis, M. F., and J. A. Steen: Colour Defective Vision and the Recognition of Aviation Colour Signal Light Flashes, PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON THE PERCEPTION AND APPLICATION OF FLASHING LIGHTS, London, In Press.

3. Hardy, L. H., G. Rand, and M. C. Rittler: The H-R-R Polychromatic Plates. I. A Test for the Detection, Classification, and Estimation of the Degree of Defective Color Vision, A.M.A. ARCH. OPHTHAL., 51: 216-228, 1954.

4. Hardy, L. H., G. Rand, and M. C. Rittler: The H-R-R Polychromatic Plates. II. Comparison of Qualitative and Quantitative Classifications by H-R-R Plates and Other Tests, A.M.A. ARCH. OPHTHAL., 52: 353-368, 1954.

5. Farnsworth, D.: The Farnsworth-Munsell 100-Hue and Dichotomous Tests for Color Vision, J. OPT. SOC. AMER., 33:568-578, 1943.

6. Rowland, L. S.: Selection and Validation of Tests for Color Vision—Relationship between Degree of Color Deficiency and Ability to Identify Signals from a "Biscuit Gun." School of Aviation Medicine Project Report No. 137-7, November 1953.

7. Farnsworth, D., and P. Foreman: Development and Trial of the New London Navy Lantern as a Selection Test for Serviceable Color Vision, BuMed Project X-457 (AV-241-K), Color Vision Report No. 12, U.S. Submarine Base, New London, Connecticut, 6 May 1946.

DAY

SIGNAL GUN TEST

	P	F	
F	.164	.491	.655
P	.273	.073	.346
	.437	.564	

H-R-R

Ø = .52*

NIGHT

SIGNAL GUN TEST

	P	F	
F	.364	.291	.655
P	.273	.073	.346
	.637	.364	

H-R-R

Ø = .23

N = 55
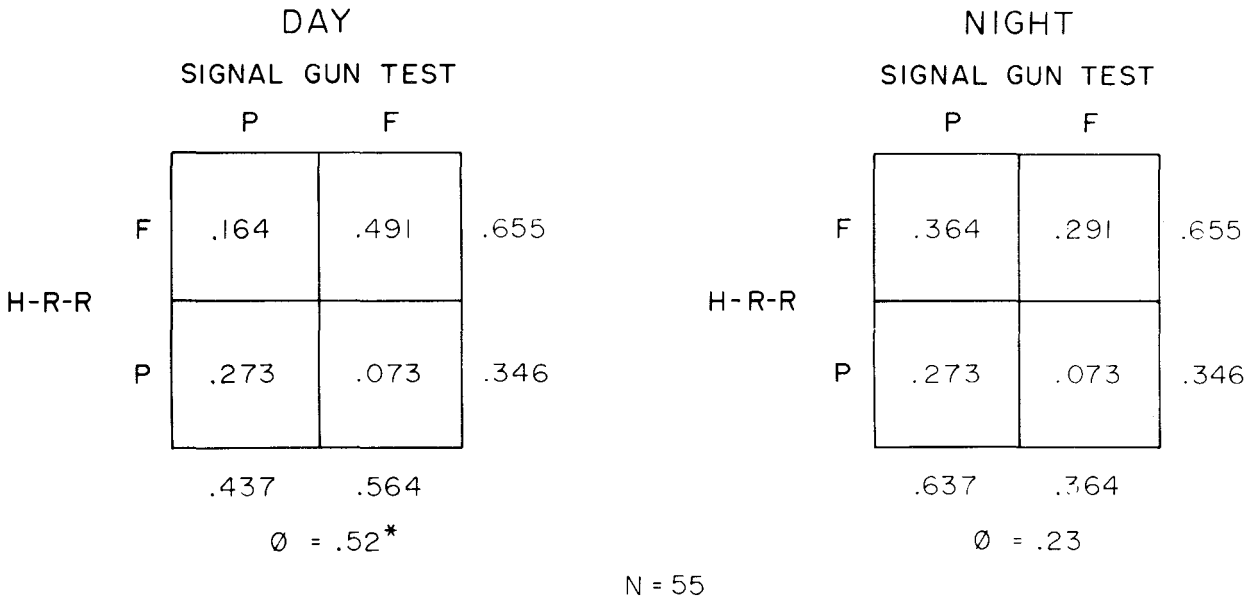
* Correlations are significant at the .01 level.

FIGURE 1. Contingency tables showing the per cent of subjects who passed and failed the signal light gun test under day and night conditions and who passed and failed the A. O. H-R-R plates. Phi coefficients for day and night conditions are also shown.

DAY

SIGNAL GUN TEST

	P	F	
F	.273	.564	.837
P	.164	.000	.164
	.437	.564	

ANOMALOSCOPE

Ø = .50*

NIGHT

SIGNAL GUN TEST

	P	F	
F	.473	.364	.837
P	.164	.000	.164
	.637	.364	

ANOMALOSCOPE

Ø = .33**

N = 55

* Correlations are significant at the .01 level.
** Correlations are significant at the .05 level.

FIGURE 2. Contingency tables showing the per cent of subjects who passed and failed the signal light gun test under day and night conditions and who passed and failed the anomaloscope. Phi coefficients for day and night conditions are also shown.

DAY

SIGNAL GUN TEST

	P	F	
F	.145	.491	.636
P	.291	.073	.364

SAMCTT

.436   .564

∅ = .55 *

NIGHT

SIGNAL GUN TEST

	P	F	
F	.327	.309	.636
P	.309	.055	.364

SAMCTT

.636   .364

∅ = .33 **

N = 55

* Correlations are singnificant at the .01 level.
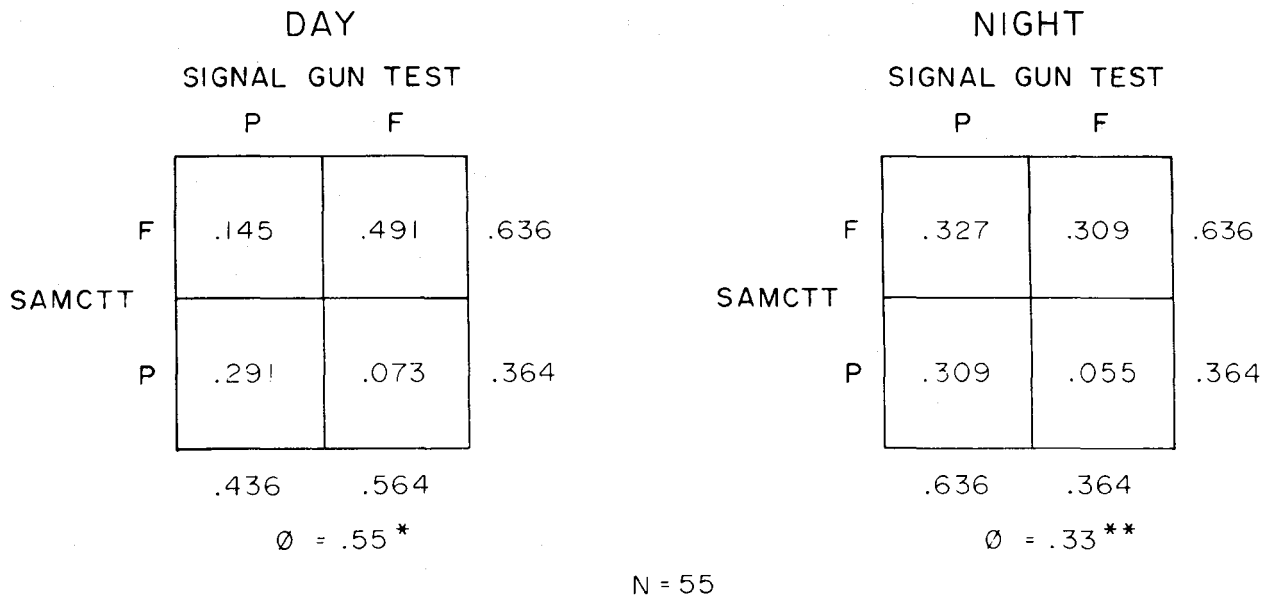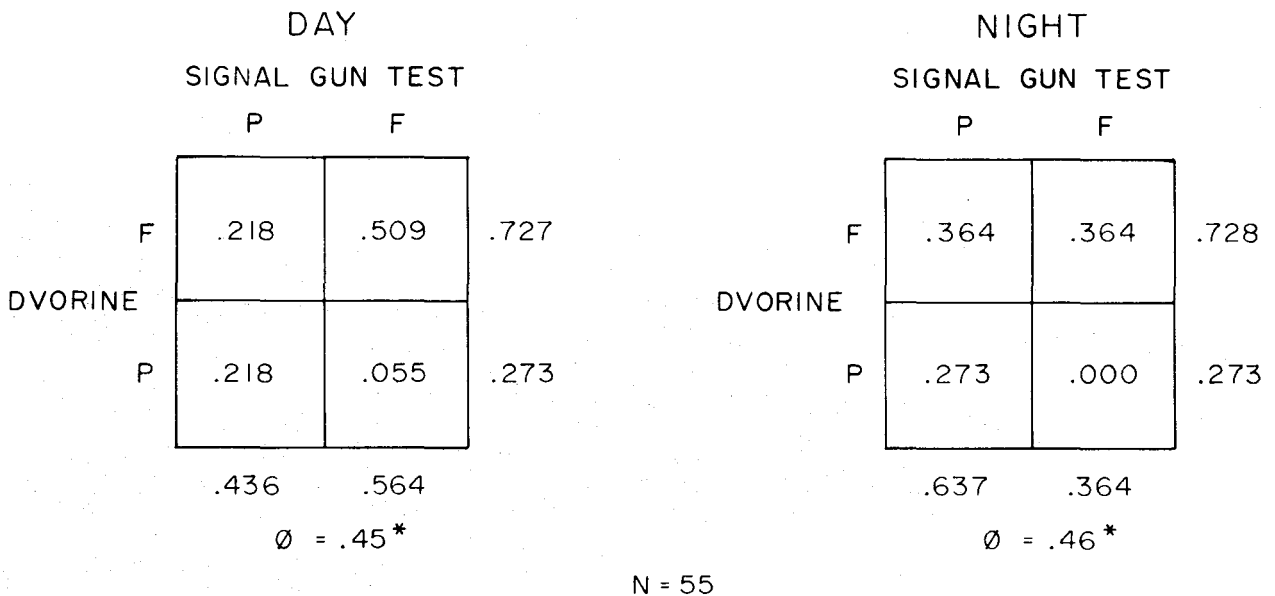** Correlations are singnificant at the .05 level.

FIGURE 3. Contingency tables showing the per cent of subjects who passed and failed the signal light gun test under day and night conditions and who passed and failed the Color Threshold Tester. Phi coefficients for day and night conditions are also shown.

DAY

SIGNAL GUN TEST

	P	F	
F	.218	.509	.727
P	.218	.055	.273

DVORINE

.436   .564

∅ = .45 *

NIGHT

SIGNAL GUN TEST

	P	F	
F	.364	.364	.728
P	.273	.000	.273

DVORINE

.637   .364

∅ = .46 *

N = 55

* Correlations are significant at the .01 level.

FIGURE 4. Contingency tables showing the per cent of subjects who passed and failed the signal light gun test under day and night conditions and who passed and failed the Dvorine plates. Phi coefficients for day and night conditions are also shown.

DAY

SIGNAL GUN TEST

	P	F	
F	273	.545	.818
FARNSWORTH LANTERN			
P	.164	.018	.182
	.437	.563	

$\emptyset = .44^*$

NIGHT

SIGNAL GUN TEST

	P	F	
F	.455	.364	.819
FARNSWORTH LANTERN			
P	.182	.000	.182
	.637	.364	

$\emptyset = .36^*$

N = 55

* Correlations are significant at the .01 level.

FIGURE 5. Contingency tables showing the per cent of subjects who passed and failed the signal light gun test under day and night conditions and who passed and failed the Farnsworth Lantern test. Phi coefficients for day and night conditions are also shown.

DAY

SIGNAL GUN TEST

	P	F	
F	.218	.509	.727
100-HUE			
P	.218	.055	.273
	.436	.564	

$\emptyset = .45^*$

NIGHT

SIGNAL GUN TEST

	P	F	
F	.418	.309	.727
100-HUE			
P	.218	.055	.273
	.636	.364	

$\emptyset = .21$

N = 55

* Correlations are significant to the .01 level.

FIGURE 6. Contingency tables showing the per cent of subjects who passed and failed the signal light gun test under day and night conditions and who passed and failed the Farnsworth 100-hue test. Phi coefficients for day and night conditions are also shown.
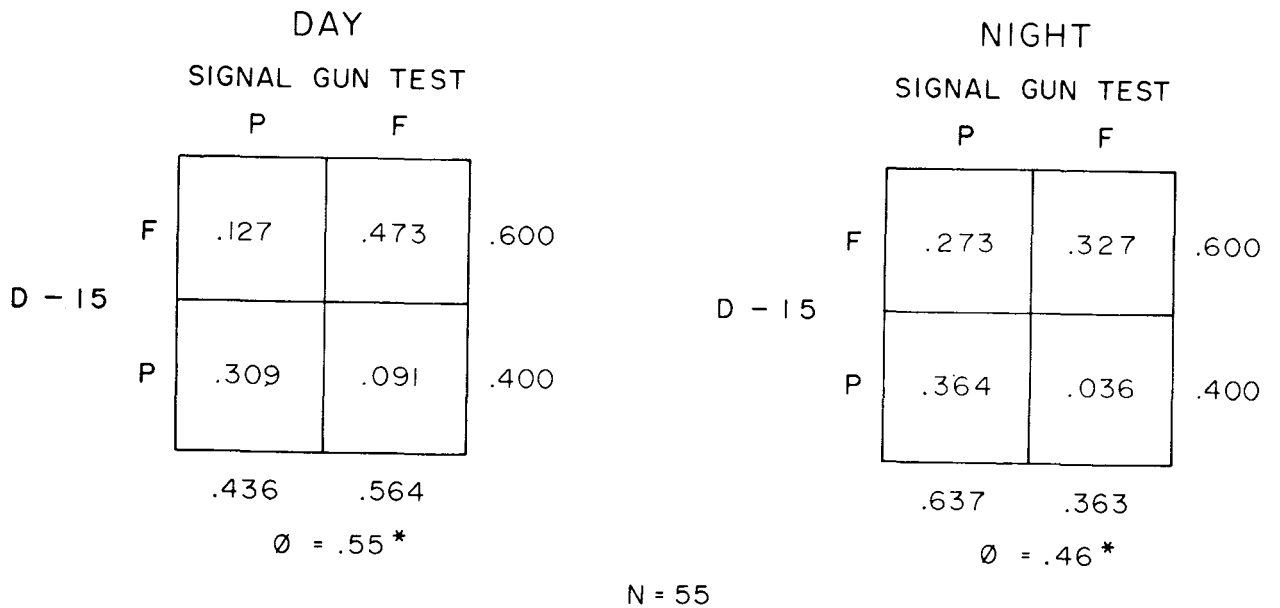
DAY

SIGNAL GUN TEST

	P	F	
F	.127	.473	.600
P	.309	.091	.400
	.436	.564	

D – 15

∅ = .55 *

NIGHT

SIGNAL GUN TEST

	P	F	
F	.273	.327	.600
P	.364	.036	.400
	.637	.363	

D – 15

∅ = .46 *

N = 55

* Correlation are significant at the .0I level.

FIGURE 7. Contingency tables showing the per cent of subjects who passed and failed the signal light gun test under day and night conditions and who passed and failed the Farnsworth Panel D–15 test. Phi coefficients for day and night conditions are also shown.

DAY

SIGNAL GUN TEST

	P	F	
NIGHT **SIGNAL GUN TEST** F	.073	.291	.364
P	.364	.273	.637
	.437	.564	

$$\emptyset = .36^*$$

$$N = 55$$

* Correlations are singnificant at the .0I level.

FIGURE 8. Contingency table showing the per cent of subjects who passed and failed the signal light gun test under day and night conditions. The phi coefficient is also shown.