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THE PERFORMANCE OF THE FARNSWORTH LANTERN AT THE SUBMARINE MEDICAL RESEARCH LABORATORY AND IN THE FIELD FROM 1955 TO 1965

by

Helen M. Paulson

Bureau of Medicine and Surgery, Navy Department
Research Work Unit MF022.03.03-9017.01

Released by:

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SUMMARY PAGE

PROBLEM

To investigate the performance of the Farnsworth Lantern, an official U. S. Navy color vision test, at the Submarine Medical Research Laboratory and in field activities over the past ten years.

FINDINGS

The performance of the Farnsworth Lantern at the Submarine Medical Research Laboratory has been found practically faultless. Its performance in the field has not been as exemplary. Reasons for this are given.

APPLICATION

Six recommendations are made for improving the performance of the Farnsworth Lantern in field activities. If these recommendations are adopted, seven benefits should accrue to the U. S. Navy.

ADMINISTRATIVE INFORMATION

This investigation was conducted as a part of Bureau of Medicine and Surgery Work Unit MF022.03.03-9017—Development of Color Vision Devices and Procedures. The present report was approved for publication on 19 January 1966 and has been designated as Submarine Medical Research Laboratory Report No. 466. It is Report No. 1 on the Work Unit shown above.

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ABSTRACT

The Farnsworth Lantern is a color vision test which was developed for Naval use by the late CDR Dean Farnsworth, MSC, USNR, when he was attached to this Laboratory. Whereas a set of pseudo-isochromatic plates, the other color vision test commonly used by the Navy, was designed to pass normals and fail all color defectives, the Farnsworth Lantern was designed to pass normals and the mild color defectives and to fail the moderate, severe, and dichromatic color defectives.

Good color vision is required for acceptance at many Naval training schools because, upon completion of the training, the man will be called upon to make critical color judgments as part of his Naval duties. When plates were used as the qualifying color vision test for these schools, all color defectives — ten percent of the applicants — were rejected (when the plates were correctly administered). With the introduction of the FaLant as a qualifying test, thirty percent of the color defective population is being salvaged (i.e., the FaLant passes three of the ten men in a hundred who are color defective) by rating them as safe for making accurate color judgments.

The Farnsworth Lantern has been in use at SMRL and at various Naval activities, such as hospitals, training schools, air stations, etc., for some ten years. The present paper analyzes its performance at the Submarine Medical Research Laboratory and in the field during this period.

At SMRL the FaLant has rendered excellent service. Data are presented which show its test validity, its high test-retest reliability, the significant increase in error score with increase in degree of color defect, the correctness of its pass-fail cut-off point, etc. At SMRL this FaLant test has proven to be nearly faultless. In the field, however, its performance has not been as exemplary. Reasons for this are discussed and six recommendations are made for improving its performance in the field.

THE PERFORMANCE OF THE FARNSWORTH LANTERN AT SMRL AND IN THE FIELD FROM 1955—1965

The Farnsworth Lantern[1] (hereafter called FaLant) is a color vision test which presents specially selected pairs of red, green, and white lights. It was developed for Naval use by the late CDR Dean Farnsworth, MSC, USNR (1946) to minimize the number of color defectives disqualified for rates in which color judgments are critical. The sets of pseudo-isochromatic plates in use at that time, as now, were designed to pass normals and to fail all color defectives, approximately ten per cent of the male population. The FaLant was designed to pass normals and that proportion of the color defective population which can make color discriminations adequate to certain Naval task requirements. Some 250 FaLants have been produced and are now functioning at various Naval activities, such as hospitals, training schools, air stations, recruiting stations, etc.

During Farnsworth's tour of duty at SMRL, a color vision referral facility was established to examine men who fail color vision screening tests. This facility has continued to function since its inception—with several hundred men per year being examined. Applicants for Submarine School and other Naval training schools and programs are referred to this facility as are applicants for the Service Academies, Civil Service, and F.A.A. pilot licenses. Additional personnel are referred for color perception examination as part of their annual, promotion, re-enlistment, or discharge physicals.

A test battery for determining degree of defect (Farnsworth, Sperling, and Kimble, 1949) was developed for classification of these referrals. The version of the color vision test battery currently in use at SMRL is shown in Table I. It contains two tests not included in the original battery — the D-15 (Farnsworth, 1947) and the H-16. Both tests consist of a series of colored buttons which lie in the confusion zones for color defectives: the subject is asked to arrange these buttons in a continuous line according to color. The H-16 is easier for color defectives to pass, because the chromaticities of the pigments lie farther out from Illuminant "C" on the C.I.E. diagram.

Table I

SMRL Test Battery for Determining Degree of Color Vision Defect.

	Pseudo-Isochromatic Plates	FaLant	D-15 Test	H-16 Test
Class I				
Normal Trichromat	Pass	Pass	Pass	Pass
Class II				
Mild Anomalous Trichromat	Fail	Pass	Pass	Pass
Class III				
Moderate Anomalous Trichromat	Fail	Fail	Pass	Pass
Class IV				
Severe Anomalous Trichromat	Fail	Fail	Fail	Pass
Class V				
Dichromat	Fail	Fail	Fail	Fail

Notes: (1) To determine type of defect (protan or deutan), an anomaloscope is used for Classes II and III and the D-15 Test is used for Classes IV and V.

(2) Throughout the paper, the following terms are used synonomously when referring to color defectives: Class II, mild, safe, acceptable; Class III—V, moderate-dichromatic, unsafe, unacceptable.

1. The Farnsworth Lantern reported on in this paper—the one at SMRL and the ones in field activities—should not be confused with

(a) The original SMRL prototype of the Farnsworth Lantern, called "Navy Lantern" and reported on in SMRL Rpt. No. 105.

(b) The 25 experimental models of the "Navy Lantern" produced in 1946 under contract with U.S. Naval Special Devices and issued to U.S. Air Force Laboratories, U.S. Naval Laboratories, U.S. Naval Hospitals, and various Universities for evaluation. Since the filters in these experimental models did not meet SMRL's specifications, these experimental models were recalled by SMRL and destroyed.

(c) Various pre-production models produced for SMRL evaluation during the period 1950—1953.

(d) The first 50 Farnsworth Lanterns produced in 1954-55 under auspices of the Armed Services Medical Procurement Agency; the neutral aperture plate filter in these first 50 FaLants was not etched on both sides, resulting in the stimuli being too bright and hence making the test too easy. Nov 1955—Jan 1956, SMRL recalled these incorrect aperture plate filters from the first 50 Naval activities issued FaLants and supplied them with the correct aperture plate filter.

Through all these years the FaLant has occupied a critical position in the test battery. Since many referrals are examined here each year, a large amount of data on, and experience with, the FaLant has been accumulated.

In 1962 the Bureau of Medicine and Surgery requested of the author a synopsis of SMRL experience with the FaLant. These unpublished data gave considerable assurance to BuMed that the FaLant was valid and reliable and that there was a significant increase in error score with increase in degree of color defect. They also showed that the mild color defectives accepted by the FaLant represented a relatively large percentage of the total number of color defective Submarine School applicants and that to increase the number of errors allowed in a Pass FaLant Score would result in accepting too few of the moderates relative to the number of severes and dichromats also accepted. As a result of these brief analyses, it was decided that the status quo relative to the FaLant be maintained.

Recently, prompted by continuing inquiries from the Forces and the Bureau of Medicine and Surgery, the present paper was prepared to augment and publish the 1962 data and to evaluate and discuss the performance and effect of the FaLant in the field and at SMRL over the past ten years. Six recommendations are made for improving the performance of the FaLant in the field.

VALIDITY OF THE FALANT AT SMRL

Table II presents the FaLant validity data collated in 1962; these findings were confirmed in a more recent survey of SMRL data (Laxar, 1967). The borderline designation in Table II refers to a subject whose FaLant performance vacillated around the pass-fail cut-off score and who required additional testing in order to resolve the question as to whether he belonged in the Pass FaLant or the Fail FaLant category. His total FaLant performance in the test session led to his designation as borderline

Table II
FaLant Results and SMRL Test Battery Classification.

FaLant Results	Battery Classification					
	Normal	Mild	Moderate	Severe	Dichromatic	Total
Pass	160	320	0	0	0	480
Borderline	0	17	3	2	0	22
Fail	0	0	112	68	87	267
Total	160	337	115	70	87	769
Deuts		306	78	41	68	493
Prots		31	37	29	19	116

in compilation of the 1962 data. This borderline category will be discussed later in the paper. Laxar has no borderline category because he made use of only one FaLant test per subject, that test upon which final classification was made.

The performance of the milds and moderates depicted in Table II cannot be used directly as a criterion of FaLant validity, since the distinction between these classes is based on FaLant score. However, the fact that most of the borderline cases were eventually found to fall into either of these two classes is consistent with the assumption that the FaLant is valid. The important aspect of Table II is that, for persons clearly passing or failing the FaLant, discrimination between normals and the more extreme types of color defectiveness is errorless.

FALANT ERROR SCORE AS RELATED TO TYPE AND DEGREE OF COLOR VISION DEFECT

Table III presents the 1962 data on FaLant error score as related to type and degree of defect. A detailed report on this topic, based on a larger sample, has been prepared by Laxar (1967). However, the attention of the reader is directed toward two striking features of the FaLant indicated by the 1962 data and confirmed by Laxar's more extensive data:

(1) The median error score systematically increases as the degree of color vision defect increases.

(2) The median error score for protans

Table III

Frequency Distribution of Scores of 391 Color Defectives Failing the FaLant as Related to Type and Degree of Color Vision Defect.

Color Vision Defect	N	FALANT SCORE															Median
Deutan Type		1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	
Class III	96	11	12	11	14	13	12	7	6	8	2	0	0	0	0	0	3
Class IV	47	3	0	5	4	6	10	6	8	2	2	1	0	0	0	0	4
Class IV-V	41	2	0	0	4	4	5	7	4	3	5	3	1	2	1	0	4½
Class V	76	1	1	0	1	6	2	5	17	16	7	10	5	3	3	1	5½
Protan Type																	
Class III	45	5	8	6	3	8	4	3	4	2	1	0	1	0	0	0	3½
Class IV	35	0	2	1	2	4	5	4	7	0	4	4	1	0	1	0	4½
Class IV-V	30	0	1	0	6	0	3	0	3	4	2	4	3	4	0	0	5½
Class V	21	0	0	0	0	1	1	0	2	0	3	5	2	4	2	1	6½
	ΣN = 391																

Notes: 1. No subject obtained a FaLant score of 9.
2. All medians were computed to the nearest real score.
3. Class IV-V consists of men who were not administered tests to determine whether they were Class IV or Class V.

for each degree of defect is always a little higher than that for deutans of the same degree of defect.

Table II showed that the FaLant is a valid test for distinguishing between normals and the more severe color defectives. This table shows that the FaLant, in addition, has excellent internal validity.

RELIABILITY OF THE FALANT AT SMRL

FaLant reliability data for 130 color defectives are presented in Table IV. The subjects in the Pass Test column are all Class II, and the subjects in the Fail Test column are all Class III-V. No reliability data for normals are presented, because this color vision referral facility rarely has occasion to see the same normal twice. Table IV shows that the FaLant as used in this facility has almost perfect test-retest reliability. The one reversal record (a borderline who was classified as moderate on test and mild on retest) will be discussed later when the topic of borderlines receives attention. The interval between test and retest ranged from one day to ten years, the median being fifteen months.

Table IV

Reliability of the FaLant for 130 Color Defectives.

		RETEST	
		Pass	Fail
TEST	Pass	63	0
	Fail	1	66

A discussion of reliability, and subsequent sections of this paper, require an understanding of the following terms with respect to the FaLant: run, test, retest, error, average error score (or FaLant score), pass, and fail. Appendix A is a copy of the set of instructions for administration, scoring, and operation of the FaLant printed on a metal plate and permanently affixed to the back of every instrument. Referring to Appendix A, it is seen that a **run** is a random presentation (starting with a RG or GR combination) of each of the nine combinations of red, green, and white lights. If an examinee makes no errors on this first run, this particular single

run is his FaLant Test, his **average error score** (or **FaLant Score**) is zero, and the examinee rates a **Pass FaLant**. If an examinee makes errors on this first run, his **test** consists of that run plus two additional complete runs (presented without any break and also presented randomly). His **average error score** (or **FaLant score**) is the number of errors on the last two runs divided by two: if his average error score is one or less, the examinee rates a **Pass FaLant**; if his average error score is more than one, the examinee rates a **Fail FaLant**. An **error** is the miscalling of one or both of a pair of lights.

At SMRL each administration of the FaLant during one session, with appropriate breaks or diversion by other tests, is considered a FaLant **test**. When a referral returns to our facility at some future date for another color vision examination (as part of his promotion, discharge, re-enlistment, etc. physical), all the FaLants administered on this later date are considered **retests**.

In examining the actual FaLant test and retest scores obtained by the subjects of Table IV, it became evident to us that our practice of re-examining borderline subjects prior to classification is contributing to the high test-retest reliability. These "just pass" or "just fail" borderlines may perform as follows on re-examination: (1) continue to pass or fail the FaLant, (2) improve, or do poorer, and maintain that performance, or (3) vacillate back and forth between pass and fail. The last type of performance results in a final classification of Fail FaLant because the policy here has been to lean toward the side of safety in these rarely-occurring cases.[2] Once we have determined whether the borderline rates a Pass FaLant or a Fail FaLant, we have considerable confidence that he will reproduce that classification should he return for a retest.

2. The sole reversal in the SMRL FaLant reliability data was one of these borderlines who vacillated back and forth between fail and pass on his test day. He was classified as moderate in accord with our policy here to lean toward the side of safety in these rarely-occurring cases. When he returned here at a future date, he barely passed the FaLant and was classified as mild.

DISCUSSION OF FALANT RE-EXAMINATION

Before we recommend to FaLant testers in the field that they adopt our practice of re-examining a limited number of color defectives, let us investigate (1) the net gain in correct classifications as related to the increase in workload and (2) the rationale for such a re-examination procedure.

Net Gain in Correct Classification as Related to Increase in Workload:

In order to ascertain how great an additional workload this procedure would impose on FaLant testers in the field and to determine if such a procedure is warranted, sample size was increased from the 130 men for whom test-retest data were available to 500. Data were drawn from the SMRL files so that the number of color defectives in each class would be representative of the number found in an unselected population.

Table V contains the initial FaLant test scores obtained by our 500 color defectives. Seventeen of the 500 would have been misclassified by their initial FaLant score if we had not re-examined them. Fifteen of these seventeen initially had a failing score but their additional test scores were consistently pass, and so these fifteen subjects were rated as Pass FaLant (Class II). Two of the seventeen had an initial Pass FaLant score, but their additional test scores vacillated between pass and fail, and so they were rated as Fail FaLant (Class III) in accord with standing policy.

There are two impressive points about initial FaLant scores shown by the Table V data:

(1) The great majority of color defective subjects (83% of them) received initial scores that are clearly pass (0 or ½) or clearly fail (3½ or more).

(2) Subjects who receive an initial score of 1½ (Fail FaLant) should be re-examined because 83% of them rated a final Pass FaLant.

Table VI was derived from the data for the 500 color defectives to show the net gain

Table V

Initial FaLant Test Scores Obtained by 500 Color Defectives.

Initial FaLant Test Score		Number of Color Defectives Obtaining this Score II Dent	II Prot	III Dent	III Prot	IV & V Dent	IV & V Prot	Total Ns
	0	98	6	0	0	0	0	104
PASS	½	10	5	0	0	0	0	15
	1	9	5	2	0	0	0	16
	1½	8	2	0	1	1	0	12
FAIL	2	1	0	8	1	3	4	17
	2½	1	0	6	4	3	0	14
	3	1	1	12	3	4	5	26
	3½	0	0	8	3	12	2	25
	4 or more	1	0	31	22	144	73	271
Total N's		129	19	67	34	167	84	500

Note: Underline indicate subjects who would have been misclassified by their initial score.

in correct classifications as related to various re-examination procedures. Referring to Procedure A, the ratio of correct to incorrect classification of color defectives would be 483 to 17; to Procedure B, 493 to 7; to Procedure C, 499 to 1. In determining the increase in workload, it must be remembered that for every 500 color defectives tested in the field there would be 4,500 normals. In view of the fact that none of the hundreds of normals tested here in this facility with the set of instructions found in Appendix A has ever initially failed the FaLant, this would mean that the number of men in the field requiring re-examination would be 0 of 5000 examinees for Procedure A; 12 of 5000 examinees for Procedure B; and 85 of 5000 examinees for Procedure C. Again it would appear that the appropriate trade off would be to re-examine those who receive an initial score of 1½ (Procedure B). That is to say the increase in workload is minimal in relation to reduction in incorrect classifications.

Table VI

Net Gain in Correct Classifications as Related to Various Re-Examination Procedures.

Procedure A. Re-examine no one	Class II	Classes III - V
Pass FaLant	193	2
Fail FaLant	15	350
Procedure B. Re-examine on score of 1½	**Class II**	**Classes III - V**
Pass FaLant	143	2
Fail FaLant	5	350
Procedure C. Re-examine on score of 1 - 3	**Class II**	**Classes III - V**
Pass FaLant	147	0
Fail FaLant	1	352

Rationale for Such a Procedure:

Following Farnsworth's initial report on the FaLant (1946), a few prototype models were produced. Further evaluation and standardization of the FaLant by this color vision referral facility ensued. Different sets of verbal instructions, rules for administration, and scoring methods were analyzed. This work led to improvements over those found in the original FaLant report. These improved instructions, etc., found in Appendix A, have been issued with all FaLants since its mass production.

During this standardization period, it became apparent that the stimuli in the Fa-

Lant were extremely effective in failing those color defectives whose degree of defect was such (Class III—V) that it was mandatory they be disqualified. The dichromatic defective was failing the test because the chromaticity coordinates of the specially selected red, green, and white filters were located in the confusion zones for protans and deutans, and hence the colors were frequently indistinguishable to him. As a result, he would make many non-reproducible "guess" responses, or would consistently use two instead of three color names, or would be so frustrated by the task that he would give up with "I just can't tell them apart." The moderate defective was failing the test for different reasons and in a different manner. He would make two types of reproducible error responses:

(1) He tended to call white light the complement of the color with which it was presented (i.e., Red-White called Red-Green, Green-White called Green-Red, etc.).

(2) When a pair of lights of the same color, but differing in brightness by 50% as is true in the FaLant, was presented to him, he tended to call it different colors (i.e., Green-Green called Green-White — the brighter Green called White, etc.). This would occur because his hue perception was reduced sufficiently for him to resort to brightness cues to help him judge colors.

Our efforts, therefore, were directed primarily toward standardizing the FaLant test so that normals and mild color defectives would not inadvertently fail it. We attempted to avoid the need for any re-examination by careful design of the set of verbal instructions, rules for administration, and scoring method. Despite these efforts, occasionally there would be a normal or a mild who would make some initial improvement. Hence, the final selection of rules for administration direct FaLant testers to discard the results of the first run if errors are made thereon. It now appears evident that in occasional cases the first test results should also be discarded.

The reason why occasionally a first test needs to be discarded is the same as that for discarding a first run. The subject fails to heed during his first run, or his first test, four particular phrases found necessary during standardization of the FaLant test which were added to the original set of verbal instructions. If the subject does not heed them by the second and third run, he requires a break, a repitition of the entire set of instructions, and a re-examination.

These four important phrases are: (1) "Remember, only three colors—red, green, and white . . .," (2) "They look like signal lights at a distance," (3) "Call out the colors as soon as you see them," (4) "in any combination."

(1) The names of the three colors are repeated at the end of the set of instructions because during FaLant standardization occasionally normals and milds would respond with only two color names. Presumably the bias is supported by, if not generated by, presentation of the lights in pairs. Failure to use all three color names would, of course, result in a false Fail FaLant record for normals and milds. Incidentally, if an examinee responds with more than three color names, it should not result in a false Fail FaLant because the tester is instructed to remind such examinees during the test that there are only three colors—red, green, and white.

(2) Some normals and milds resist calling a white light white unless it is a snow-white white. Therefore, the phrase "They look like signal lights at a distance" was added so that the examinee would think of them as lights in a field situation (where white lights are not snow-white). Also, FaLant testers are directed to begin the test with a Red-Green or Green-Red combination so that the examinee would see how extremely red the red is and extremely green the green is before called upon to judge a white.

(3) Our standardization efforts showed that better results were obtained with the FaLant if we could get the subject to give us an immediate response (his first impression) instead of a studied, reasoned response. Hence the statement to all examinees "Call out the colors as soon as you see them" and the reminder to those who respond too slowly were incorporated in the final instructions. Occasionally, we have found it extremely difficult to hasten some of these subjects with such a reminder during the test session and have had to resort to giving such a subject a break and a re-examination. Before re-examination we tell the subject that the first time through he responded too slowly, thereby invalidating the test results, and that this time he is to respond immediately.

(4) The phrase "in any combination" was incorporated into the final set of instructions because occasionally a subject would say "Oh, I didn't know that there could be two lights the **same** color at a time." Again, a break and a re-examination, preceded by emphasis on "in any combination" may be necessary for an occasional borderline.

The important point about these four phrases is: re-examinations, with emphasis placed upon the set of verbal instructions, are **only** for those examinees who are initially borderline Fail FaLants—not for examinees whose initial FaLant score is higher. As we have stated in the beginning of this section, we **expect** Class III—V color defectives to make the above-mentioned types of errors. The only parts of the above discussion that apply to them are the two reminders to be given during the test session—the reminder for the examinee who responds with yellow, pink, etc., and the reminder for the examinee who responds too slowly (Nos. 9 and 10 in Appendix A).

EFFECT OF FALANTS IN THE FIELD ON THE COLOR DEFECTIVE POPULATION REPORTING FOR SUBMARINE SCHOOL

BuMed Instruction 6730.2 of 16 June 1954 announced the adoption of the FaLant as the final validating test for color vision of all Naval personnel and as the test standard for admission to certain specialized programs. Initially, fifty specific Naval activities were directed to requisition the FaLant. Examining activities not having FaLants were directed to continue using the American Optical Company plates. However, the Instruction required that candidates who **failed** the plate test must pass the FaLant as part of their preliminary screening prior to transfer to schools requiring normal color vision. Such candidates were to be sent to the nearest activity possessing a FaLant. The purpose of this procedure was to prevent the unnecessary travel and expense of sending unqualified candidates to the approximately forty Naval training schools with color vision requirements.

How has this BuMed Instruction relative to the use of the FaLants in the field affected the color defective population arriving here in New London for Submarine School—one of the schools with a color vision requirement? The 1962 data on this topic have been updated and expanded and are found in Table VII. These data concern U. S. Navy Submarine School applicants. Data with similar results are found for the U.S. Naval Reserve Submarine School applicants in Appendix B.

There are three time spans in Table VII. The first time span (January 1949 — June 1954) represents the era before FaLants were issued to field activities. The second time span was selected to begin July 1956 in order to provide an appropriate waiting period for field activities to begin using the FaLant routinely for preliminary screening; it ended in June 1959 because the FaLant (instead of plates) began to be used at SMRL for screening purposes, and hence records relative to the number of mild color defectives reporting here are not available. In

Table VII
Effect of FaLants on Color Defective Population Reporting for Submarine School—USN

A. Before FaLants in the Field

Time	Total Applicants	Total C.D.'s	Color Defectives: Degree Mild	Mod	Sev&Dic	Type Deut	Prot
1/49-6/49*	1659	36	17	5	14	28	8
1/50-6/50*	643	22	15	2	5	19	3
7/50-6/51	1889	54	31	11	12	47	7
7/51-6/52	2190	58	30	17	11	50	8
7/52-6/53	3178	86	31	27	28	67	19
7/53-6/54	2258	67	29	15	23	55	12
TOTAL N:	11817	323	153	77	93	266	57
PERCENT:		2.7	47.4	23.8	28.8	82.4	17.6

* No records available of total number of applicants for period 7/49-12/49—hence no tally for this period.

B. After FaLants in Use in the Field

Time	Total Applicants	Total C.D.'s	Color Defectives: Degree Mild	Mod	Sev&Dic	Type Deut	Prot
7/56-6/57	3403	62	45	8	9	48	14
7/57-6/58	5167	128	88	19	21	111	17
7/58-6/59	3350	86	60	14	12	74	12
TOTAL N:	11920	276	193	41	42	233	43
PERCENT:		2.3	69.9	14.9	15.2	84.4	15.6

C. Current Tally

Time	Total Applicants	Total C.D.'s	Color Defectives: Degree Mild	Mod	Sev&Dic	Type Deut	Prot
7/65-6/66	2279	103	74	12	17	95	8
PERCENT:		4.5	71.8	11.7	16.5	92.2	7.8

July of 1965, plates were once again used at SMRL for screening, making another fiscal year tally possible.

In order to facilitate interpretation of Table VII, data for an unselected population of color defectives are required. During the past ten years, school nurses have been trained by SMRL staff to do color vision screening of the local high school boys. The schools send the color defectives so detected to SMRL for classification. The results represent an unselected color defective population and are found in Table VIII.

The data in Table VII show that the FaLant is fulfilling the main purpose for which it was created—namely, utilizing men who, though they fail plates, have a color vision defect mild enough to be safe for all Naval tasks. Introduction of the FaLant into the field has resulted in increasing the percentage of such mild color defectives reporting for Submarine School from 47% of USN color-defective applicants before the FaLants were in the field, to 70% shortly after FaLants were in use in the field, to a high of 72% today.

From the data presented in Table VII, the percentage of milds in the total applicant population reporting to New London can be derived. Before FaLants were in the field, 1.3% of the total USN applicants reporting to New London were mild; shortly after FaLants were in use in the field, 1.6% were mild; today, 3.2% are mild. Recalling that approximately 10% of the male population is color defective and referring to Table VIII, it can be derived that 3% of an unselected population would be mild. The percentage of mild color defectives reporting to New London (3.2) approximates that of the unselected population. Once again it would appear that the FaLants are doing an excellent job in qualifying for transfer those who should be qualified and transferred.

Table VIII

Unselected Population of 321 Color Defective High School Boys According to Type and Degree of Defect.

		Degree			
		Mild	Mod	Sev&Dic	TOTAL	%
Type	Deut	83	43	107	233	72.6
	Prot	12	22	54	88	27.4
	TOTAL	95	65	161	321	
	PERCENT	29.6	20.2	50.2		100.0

Another purpose of FaLant adoption was to prevent unnecessary travel and expense caused by the transfer of unsafe color defectives to schools which require applicants who are normal or only mildly color defective. The data in Table VII show that the introduction of FaLants into the field has resulted in a drop in the percentage of color defective Submarine School applicants reporting to New London who are unsafe—from 53% of USN color defective applicants before FaLants were in the field, to 30% shortly after FaLants were in the field, to 25% today.

The percentage of unsafes in the total applicant population reporting to New London can be derived from the data presented in Table VII. Before FaLants were in the field, 1.4% of the total USN applicants reporting to New London were unsafe; shortly after FaLants were in use in the field, 0.7% were unsafe; today, 1.3% are unsafe. Again recalling that approximately 10% of the male population is color defective and referring to Table VIII, it can be derived that 7% of an unselected total population would be unsafe. Comparing this 7% figure with the 1.3% figure, it is seen that the FaLant is disqualifying for transfer many—but not all of those who should be disqualified and should not be transferred. Reasons for transfer to New London of some unsafes will be given later in this paper when the performance of the FaLants in the field is discussed.[3]

Probably it is true that the FaLants in the field are doing a better job in disqualification of unsafe color defectives than is revealed by the chronological percentages presented in this paper. In 1951 color vision defects ceased to be a cause for rejection from enlistment and re-enlistment in the Navy; hence, the pool from which Submarine School applicants are drawn contains many more unsafe color defectives today than in pre-FaLant days. It is reasonable to assume, therefore, that the FaLants, as used in the field for preliminary physicals prior to transfer, must be even more effective than is evident in the data available here.

One additional fact about the effect of FaLants in the field can be gleaned from the data which have been tallied for this paper. This concerns men reporting to New London as applicants for Submarine School whose rate requires that they have normal color vision. Before FaLants were in the field 66% of the men whose rate required normal color vision were unsafe color defecaives; today 36% of such men are unsafe color defectives. The decrease is significant but there is still improvement needed in this

3. Every few years a number of unsafe color defectives arrive here for some unique reason. For example, a particular Naval activity sent to New London, over a period of several months, all Submarine School volunteers who failed the FaLant on the assumption that color vision defects were no longer a cause for rejection. Similarly, men in critically-needed rates are occasionally transferred to New London under the mistaken belief that the defect will be waived.

area. This topic will receive attention later in this paper when specific recommendations are made for improving the performance of the FaLant in the field.

EFFECT OF CHANGE IN FALANT PASS SCORE ON SUBMARINE SCHOOL APPLICANT POPULATION

In 1962, BuMed also requested that, in the interest of providing more men for Submarine training, an investigation be made of the effect of increasing the number of errors allowed in a FaLant pass score on the total number of additional men, and the number of moderates compared with severes and dichromats, thereby made available. Figure 1 is based on the data of Table III and shows the percentage of total moderates comapared with the percentage of total severes and dichromats passed by each systematic increase in the number of errors allowed in a FaLant pass score. Here it is seen that any increase in the number of errors allowed would pass some severes and dichromats as well as some moderates. Not until seven errors are allowed in a pass score would 100% of the total moderates be passed and, at this seven-error pass score, 91% of the total severes and dichromats would also be passed.

If a change in the FaLant pass score should be recommended, it would be effective in the field (where FaLants are used for preliminary Submarine School physicals, for entrance to certain Naval training schools, etc.) as well as here at SMRL. Hence, if we want to estimate the actual number of additional men (moderates, severes, and dichromats) made available for Submarine training, it is necessary to examine the effect of a change in the FaLant pass score on a population which has not had men eliminated from it because of color deficiency,—bearing in mind that, today, color vision defect is no cause for rejection from enlistment. Hence the percentage of

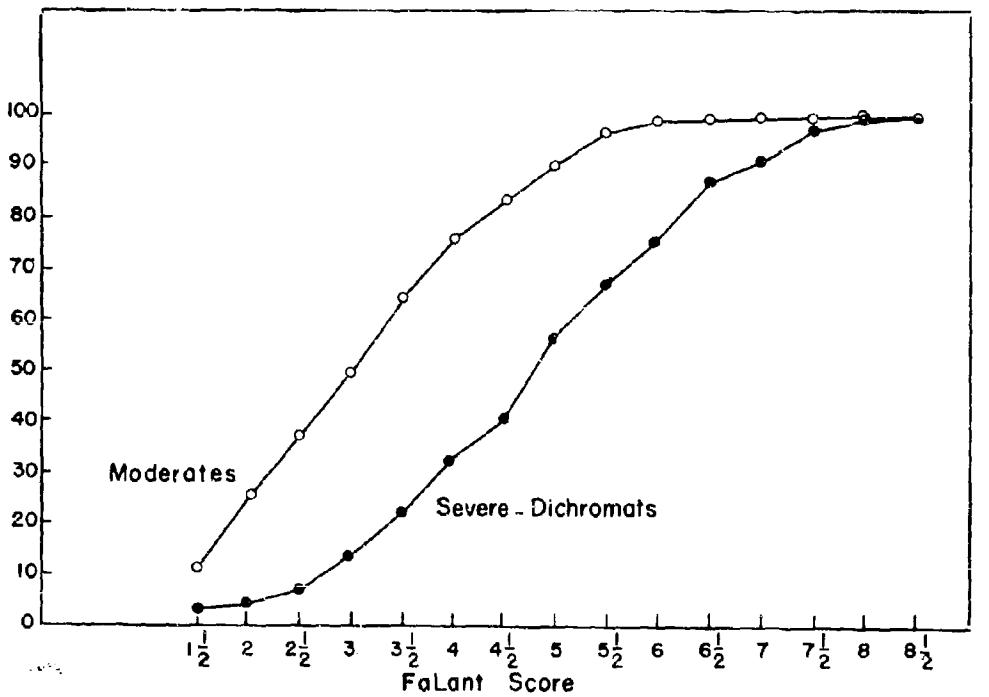

Figure 1.—Accumulated percentages of total moderates and of total severes and dichromats obtaining a particular FaLant score.

total moderates and the percentage of total severes and dichromats in Figure 1 must be related to the data of our unselected color defective population (Table VIII), where it is seen that there are five severes and dichromats to two moderates. This would mean that for every 1000 men volunteering for Submarine School, where 930 are accepted by the current FaLant pass score of one error (900 normals and 30 milds), this 930 would be increased by three men (2 moderates and 1 severe or dichromat) if the FaLant pass score is raised to one and a half errors and by seven men (5 moderates and 2 severes and dichromats) if it is raised to two errors. An increase to three errors would yield 17 more men (10 moderates and 7 severes and dichromats) and at a FaLant pass score of four errors almost an equal number of moderates and of severes and dichromats would be accepted—15 moderates and 16 severes and dichromats. All the moderates in a 1000-man population would be accepted (20 men) at a FaLant pass score of seven errors, but 46 of the 50 severes and dichromats would also be accepted.

These data show that the present cut-off score cannot be increased at all without accepting some severes and dichromats and, furthermore, no new FaLant pass score can be selected which would pass a large number of the moderates relative to a small number of the severes and dichromats. It is generally agreed that the acceptance of any severe or dichromatic color defective for Submarine training would be potentially hazardous, and so it would be inadvisable to change the current FaLant pass score of one error. This was stated in 1962 and is restated today.

It should be pointed out that conducting the manpower analysis does not imply that moderates are safe for Submarine duty. Data collected and reported by Farnsworth (1950) and other data collected more recently at SMRL indicate the wisdom of rejecting moderates (as well as severes and dichromats) and in accepting only mild color defectives.

FALANT PERFORMANCE IN THE FIELD

In an attempt to analyze the performance of the FaLants in the field, our color vision test records were surveyed for information about the color vision testing of our referrals before they reported to New London. It has been a rather general practice for the SMRL testers to obtain this information from either the referrals, health records or verbal reports, or both. An effort is made to insure the honesty of these verbal responses by testing the referrals and recording the qualifying or disqualifying results prior to history taking. Data for this survey are for the continuous time period from July 1956 (when use of the FaLant in the field began to be routine) to the present time.

Before we analyze the performance of the FaLants in the field, let us investigate its frequency of usage in the field. The data show that in 1956, 56% of USN Submarine School applicants, 13% of USNR Submarine School applicants, and 36% of all other Naval referrals had the FaLant test sometime previous to their reporting at New London, whereas currently the percentages are 92, 46, and 63, respectively.

How did the FaLants in the field perform for these referrals? Did the results agree with our results? The FaLant test results from the field were correct for 71% of the 480 referrals on whom previous FaLant testing information had been obtained. Separating the data into two categories, that for the Class II's and that for Class III—V's, the FaLant results were correct for 92% of the Class II's (N = 262) but for only 45% of the Class III—V's (N = 218). Obviously, there is a decided tendency for FaLant results in the field to err on the side of passing the unsafe color defective rather than failing the safe. Before giving reasons for this, reliability data of FaLants in the field will be presented.

Our files contain records on 149 color defectives who had had more than one FaLant test in the field before reporting here. Some of the referrals had had the FaLant at half a dozen different times and places. The test-

retest data of FaLants in the field are found in Table IX, where it is again evident that the FaLant results in the field are better for Class II's than for Class III—V's.

Sources of Error in the Testing of Class II Defectives:

In general, the performance of the FaLants in the field for Class II's is good, but not as good as the performance of the FaLant at SMRL. The survey of our test records for information about the previous FaLant testing of our referrals revealed that when Class II's failed the FaLant in the field it was due to **incorrect administration** and that primarily there were four rules for FaLant administration (Appendix A, Section 1, Rules 1, 8, and 9, and Section 2, Rule 3) that were not being followed and hence, causing the difficulty: (1) Frequently the tester did not give the examinees the complete set of verbal instructions, with the result that the examinees failed because they used only two color names instead of three, used more than three color names, or used the wrong color names; (2) When the examinee used more than three color names or used the wrong color names, he was not reminded that there were only three colors—red, green, and white; (3) Frequently, the tester stationed the examinees too far away from the lantern—at a 15-foot and even 20-foot distance; experience here at SMRL has shown that Class II's and even some Normals may very well fail the FaLant at this great distance; (4) Occasionally myopic examinees needing corrective lenses were administered the test without the use of such lenses; experience here at SMRL has shown that myopic Class II's and even some myopic Normals may very well fail the FaLant without use of their corrective lenses.

Table IX
Reliability of FaLant in the Field.

	TEST-RETEST IN THE FIELD		
SMRL Classification	Pass-Pass	Fail-Fail	Pass & Fail
Class II	67	0	12
Class III—V	15	23	32

Sources of Error in the Testing of Class III—V's:

In general, the performance of the FaLants in the field for Class III—V's is poor. Our survey revealed that when Class III—V's passed the FaLant in the field it was due to **incorrect administration, improper entries in the health records, and other improper produres.** A great number of the rules for FaLant administration (Appendix A) were not being followed, resulting in a great number of incorrect "Pass FaLants." Examples of incorrect administration are listed here: (1) Frequently the tester stationed the examinees too close to the lantern,—at a 4-foot, 2-foot, and even 0-foot (with examinee's face at aperture!) distance; the chromaticities of the lights selected were based on the visual angle subtended by the 1/10-inch aperture viewed at an eight-foot distance and moving the examinee closer to the lantern nullifies the test results. (2) Frequently not all nine pairs of lights were exposed—three, two, and even only one pair of lights were shown to examinees; the test consisted of all nine pairs of lights and, obviously, it would be easy to pass some moderates and severes by showing them just a RG, GR, and RR. (3) Frequently the examinees were allowed to watch other examinees taking the test and were able to memorize correct responses; one examinee even reported that he passed the test by having a tall normal who was in line behind him whisper the correct responses. (4) Frequently the tester did not use a random order in the presentation of the pairs of lights and examinees were readily able to memorize the order of presentation. (5) Frequently examinees were given as long a time as they wanted for responding to each light. (6) Occasionally, even rules for scoring were not followed—e.g., an error score of 1½ and even 4 was considered by the tester to be good enough to rate a "Pass FaLant" and one tester only counted the reds and greens miscalled (the whites miscalled were ignored).

Ranking with incorrect administration as a cause for Class III—V's passing the FaLant in the field is failure on the part of the test-

ers to make proper entries in the examinees' health records. With embarrassing frequency, examinees reported that they really had failed the FaLant but that a "Pass FaLant" was recorded; this occurred most often when it was important that the examinee pass the FaLant (e.g., preliminary Submarine School physicals in the field). Not only were "Pass Falant" entries made when the examinees, in truth, failed the FaLant, but also "Pass FaLant" entries were made when the examinees in reality had not taken the FaLant test (e.g., took no color vision test at all, had the plate test instead of the FaLant, were asked if they were color defective and answered negatively, were asked to name the color of a red and green ribbon lying on a table, were asked if they could tell the color of running lights and answered affirmatively, etc.).

Finally, our survey revealed that, as is inevitably true when large masses of men are tested, there were various other improper procedures causing "Pass FaLant" results to be found in Class III—V's health records (e.g., testers helped examinees pass the FaLant test, examinee outranked the tester and coerced the tester into writing "Pass FaLant," examinees falsified their records, etc.).

Obviously, the performance of the FaLants in the field can be greatly improved by insistence that the testers in the field make proper entries in the health records and by insistence that the testers follow exactly and to the letter each and every rule for administration of the FaLant (Appendix A).

Corroborative Evidence from Records of Plate Testing in the Field:

During the survey, information about the plate testing of our referrals before they reported to New London was also obtained and the performance of the plates in the field shows the same picture as the performance of the FaLants. The plates worked correctly for only 59% of the color defectives appearing here with records of previous plate testing (N=557). As for reliability of the plates in the field, the same type of data emerges as was found for FaLant reliability in the field—namely, of the 120 color defective referrals who had had more than one plate test before reporting here, 18 had pass-pass records, 51 had fail-fail, and 51 had pass-and-fail. When the plates did not fail the color defectives, it was due again to the testers' failure to adhere to the rules of administration, the testers' failure to make proper entries in the health records, and general improper procedures. Although this paper is concerned with the FaLant, the performance of plates in the field is brought up not only because it shows the same picture as the FaLant performance in the field but also because incorrect plate results have a detrimental effect on FaLant results. FaLant testers in the field are somewhat hesitant to fail an examinee who has a previous record of being normal (because he passed a plate test) and 41% of those color defectives with plate records were incorrectly diagnosed in the field as normal. Furthermore, plates are still in very common use in the U. S. Navy—either as a supplementary or sole color vision test; currently 77% of USN Submarine School applicants, 92% of USNR Submarine School applicants, and 83% of all other Naval referrals had the plate test sometime previous to their reporting to the Submarine Medical Research Laboratory.

Reports of Corpsmen on Field Test Procedures:

Additional data which corroborate that obtained from the examinees' histories follow. It has been our practice over the past three years to request the hospital corpsmen attending our School of Submarine Medicine to complete a questionnaire on the color vision testing practices which they employed prior to their coming to this Submarine Base. Of the 122 corpsmen responding to the questionnaire, 89 had administered color vision tests in the U.S. Navy—83 had administered the plate test, and 35 the FaLant test. Only 13% of the corpsmen who had administered plates stated that they had given the test in accordance with all the rules of administration. This percentage is so extremely low

because the testing facilities at which 50% of the corpsmen served did not have the required daylight lamp. Only 37% of the corpsmen who had administered the FaLant stated that they had given the test in accordance with all the rules as stated on the back of each FaLant (Appendix A). Not only did these corpsmen admit to incorrect administration, but some of them also admitted to making improper entries in the health records.

The inadequacy of test administration practices in the field appears to reflect the unsatisfactory state of training in color vision testing. About one-third of the corpsmen spontaneously reported that training was inadequate, or non-existent.

A detailed case history of the color vision testing of one particular Navy man over a four-year period is presented in Appendix C. This case history, while not particularly representative, is not particularly rare either. It is presented here because it seems to sum up so well this section on the performance of the FaLant in the field.

RECOMMENDATIONS FOR IMPROVING THE PERFORMANCE OF THE FALANTS IN THE FIELD

It is certainly possible for the FaLant in the field to perform as well as it does at SMRL. Six recommendations for improving its performance in the field are presented here. Some of these were initially suggested in a letter of 25 April 1962 to the Chief of the Bureau of Medicine and Surgery and later in memorandum form in response to a letter of 9 June 1965 from BuMed. The results of the survey of color vision test records undertaken for this paper give additional support to these former recommendations. The other recommendations are based on the findings reported in this paper. The six recommendations are as follows:

1. Any examinee receiving a score of exactly 1½ on a properly administered FaLant test should be re-examined, after a five-minute break for that examinee (away from the test area) and repetition of the complete set of instructions.

2. Official Navy documents citing color vision requirements should be revised for purposes of clarity.

   a. All parts of the BuMed Manual and BuPers Recruit Selection Criteria Instructions dealing with color perception should be revised as follows: Instead of the words "normal color perception," substitute the following: "acceptable color perception, as defined by a Pass Score on a properly administered FaLant Test."

   b. BuMed Manual references to Plate Tests should be modified as follows: "The Plate Test may be used only if a FaLant is not available. A Pass Score on a properly administered Plate Test qualifies an examinee. However, color perception disqualification may be determined only by a FaLant Test."

   c. BuMed Manual should be amended to clarify whether or not the color vision criteria for appointment and training (Chapter 15-13A (5)) also apply to eligibility for the corresponding ranks and rates.

3. Each activity using the FaLant should perform a maintenance check at the beginning of each work week to guarantee that

   a. All pairs of lights are fully exposed and centered in the test field.

   b. The lamp is operating and a spare lamp is available in the base of the lantern.

4. An appropriately selected sample of lanterns should be checked for stability of the colored filters.

5. Two aids to administration of the FaLant, Appendices D and E, should be provided to all Naval activities using the FaLant.

6. The Naval Training Film MN-8246 "Color Vision Deficiencies—Definition and Evaluation" should be included in the course of study at the two Naval Hospital Corps Class "A" Schools at San Diego and Great Lakes. The film should also be used in indoctrination of Medical Corps officers.

RATIONALE FOR THE SIX RECOMMENDATIONS

1. The recommendation for re-examination of examinees who receive a score of exactly 1½ (not higher) on a properly administered FaLant test is made as a result of our investigation of the reliability of the FaLant as used at SMRL. This practice should result in an improvement in the performance of the FaLant in the field for an occasional Class II color defective and an occasional Normal. Incidentally, the survey of color vision test records and the questionnaire administered to corpsmen revealed that oftentimes **any** examinee who failed the test was retested and oftentimes retested repeatedly; such unnecessary retesting and such repetitive retesting should be avoided.

It is suggested that this recommendation be added to the scoring template (Appendix E) under "Notes."

2. The recommendation for BuMed Manual and BuPers Instruction revisions is made because the survey of color vision test records showed that there is considerable confusion about color perception requirements. One confusion arises from official statements that various schools, programs, designations, and ratings require men whose color perception is normal and that the Farnsworth Lantern is one of the two tests approved for use. This is conflicting because, if the FaLant is approved for use and its results considered final, then in truth Normals **and mild color defectives** are acceptable for all the categories requiring "normal color perception." A considerable number of our referrals stated that, upon failing the Plate Test, on their own initiative or on the advice of the examining personnel, they gave up trying for programs requiring "normal color perception" (e.g., NROTC, NESEP, Naval Aviation, etc.). These men and the examining personnel in the field were unaware that three men in ten who fail the Plate Test pass the FaLant Test, which is the qualifying test for these programs. The other confusion arises from unsafe color defectives holding ranks and rates in which accurate color vision is necessary. They obtained these ranks and rates either by on-the-job training or by erroneous acceptance at the respective schools.

3. The survey of color vision test records and the questionnaire administered to corpsmen revealed only a very few incidents of mechanical breakdown of a FaLant. In addition, a recent check with the manufacturer revealed no records of any breakdown. Nevertheless, the maintenance check by activities using the FaLant is recommended on the basis of SMRL experience with the FaLant and because several official communications to SMRL, enclosing copies of conflicting FaLant results in health records, have posed mechanical breakdown and use of incorrect lamp as possible causes of FaLant unreliability in the field. Use of incorrect lamps should not be a cause of unreliable results because a lamp was selected with a very long life, a dead man's switch was installed so that the lamp would not be left burning when lights were not being exposed, and a spare lamp is attached to the base of each lantern.

SMRL experience with the FaLant has shown faults in the rotor locating assembly (MacBeth Corporation Blueprints for the Farnsworth Lantern, Drawing No. 11931-D), which positions accurately behind the two apertures the cylinder containing the filters. The faults are: (1) loss of tension in the spring which holds the locating arm against the bakelite cam; and (2) cracking of the bakelite cam. The first fault is repairable — the spring has an adjustment screw. SMRL action taken regarding the second fault is two-fold: SMRL has already initiated, with the manufacturer of the lantern, an improvement in the material being used in this cam; the scoring template, (see Appendix E) directs testers to refrain from spinning the knob violently when selecting lights at random.

4. A check of filter stability was suggested in our 1962 letter to BuMed and it is now recommended in view of the facts that (1) again, official communications to SMRL have posed filter fading as a possible cause of FaLant unreliability in the field and (2) in the

survey of color vision test records there were several reports that the "white" light in the lantern at San Diego Boot Camp (where the FaLant receives considerable usage) was "yellow"—so yellow that the FaLant tester told the examinees that the colors were "red, green and yellow." Although the filters used in the FaLant are supposed to be permanent, there has been no empirical check of this assumption.

5. The recommendation that the two aids to administration, designed by SMRL, Appendices D and E, be provided to all Naval activities using the FaLant was made in O-in-C, MRL 1962 letter to BuMed. It specified that they should be forwarded to all Naval activities currently possessing FaLants, and further, they should accompany all new issues of FaLants. A recent purchase contract for FaLants included the production of these aids; future purchase contracts should continue to do so and a special contract should be let for production of these aids to supply the 250 Naval activities already possessing FaLants.

The first aid (Appendix D) is a template containing a copy of the set of instructions to be given the examinee (Appendix A, Section 1, Rules 1 and 8). The 1962 letter stated as follows about this template:

> "It appears that Rules 1 and 8 under 'Administration and Scoring' are rarely followed accurately and completely. It is imperative that all examinees receive **exactly the same complete** set of instructions, if the test results are to be valid and reliable. It is understandable that, with a hundred or more men tested daily, the examiner often shortens or eliminates some of these instructions. Therefore, it is recommended that this template be handed to each examinee to read immediately before he is tested."

For reasons stated above and in the section of this paper dealing with FaLant performance in the field as to why FaLants occasionally fail a Class II (and even an occasional Normal), the issuance and use of this template is again recommended.

The second aid (Appendix E) is a template for testers' use in recording responses of the examinees and in scoring the test, with directions for use on the back of the template. The 1962 letter stated about this template:

> "It appears that Rule 3 under 'Administration and Scoring' is rarely followed with accuracy. Either all nine lights are not presented or the lights are not presented in random order. It is understandable that without data pads it is difficult, if not impossible, to administer the nine pairs of lights in a random order, for the tester has no record of which of the lights have been presented and which are left to be presented. Without data pads for recording this information, the tester is inclined to present the lights in one or two fixed orders. It is imperative that random order, varied over administration, be followed if color defective examinees who have memorized the lights by serial order are to be detected. In addition, some aids are needed to record errors (Rule 6 under 'Administration and Scoring' requires averaging the errors of the last two runs). Instead of data pads, it is our recommendation that this template, suitably mounted, be supplied to each activity. The template has instructions for its use printed on the back and can be used indefinitely; it converts any ordinary supply of paper to data pads."

For the reasons stated above and in the section of this paper dealing with FaLant performance in the field as to why FaLants oftentimes pass Class III—V's, the issuance and use of this template is again recommended.

6. The recommendation that the Naval Training Film MN-8246 "Color Vision Deficiencies—Definition and Evaluation" should be included in the course of study for corpsmen and in indoctrination of medical officers was made in the 1962 letter to BuMed. It stated as follows:

> "Assuming that Hospital Corpsmen usually administer color vision tests in the

U. S. Navy, it is strongly recommended that the two Naval Hospital Corps Class "A" Schools (at San Diego and Great Lakes) include in their course of study the Naval training film MN-8246. This film was made at the suggestion of this Laboratory, and under its supervision, for the following purposes: to correct existing misinformation about color vision; to explain exactly what a color vision defect is; to show how serious errors can be made by color defectives in the performance of Naval tasks; and to illustrate accurate administration of the Plate Test and the Lantern Test. In addition, we had hoped that the film would inspire color vision testers to do a conscientious job. We would also suggest that it be seen by Medical Officers, who oftentimes are called in for consultation by the Corpsmen when an examinee is having trouble with the test."

For the reasons stated above and because our questionnaire to corpsmen revealed such a great need for and complete lack of training in color vision testing, this recommendation is made once again.

SUMMARY

The Farnsworth Lantern as used at SMRL over the past ten years has rendered excellent service. It has proven valid and reliable and our data show it has internal validity as well. An investigation following the suggestion of a possible change in the FaLant Pass Score revealed that the current pass-fail cut-off score should be maintained. A survey of the color defective Submarine School applicant population reporting to New London before FaLants were in use in the field, compared with that shortly after its introduction into the field, and that of today shows a continually increasing beneficial effect of their issuance to field activities.

An investigation of the performance of the FaLant in the field has indicated a need for improvement. Its use has occasionally failed those examinees who should be passed and more than occasionally passed those examinees who should be failed. Based on the results of our history taking of referrals' previous FaLant test experiences and the results of the questionnaire administered to corpsmen, the reasons for this are improper administration, improper entries in health records, and improper procedures. Six recommendations are made for improving the performance of the FaLants in the field.

CONCLUSION

I. A man's FaLant results should be the same wherever and whenever he is tested because:

(a) Color vision defects are not acquired during a man's life but are inherited.

(b) Color vision defects do not change (in type or degree) with age.

(c) There are at present no known cures or remedies for this defect which might account for different results accumulating on the same examinee at different places and times of examination.

(d) FaLants should be diagnostically the same at all places because, since the beginning of the issuance of FaLants to field activities, SMRL has checked the colored filters before FaLant production and these filters are reported to be permanent.

(e) The FaLant, as used at SMRL, has almost perfect test-retest reliability.

II. It is believed that the performance of the FaLant in the field will improve considerably if the six recommendations made in this paper are adopted.

III. Such an improvement in FaLant performance will be of benefit to the Navy for the following reasons:

(a) Safety of Naval men and equipment will be insured.

(b) Dollars and time will be saved by rejecting "color vision unsafe" applicants at their current station instead of upon arrival at the school.

(c) Schools will be better able to meet their quotas and plan their programs with improved color vision pre-screening in the field.

(d) Damage to the morale of Navy men who are currently being sent to school only to be rejected, once there, for a congenital color vision defect will cease.

(e) Confusion in the minds of the examinees and the FaLant testers, caused by conflicting FaLant results, will be eliminated.

(f) There will be a reduction in the official letters to SMRL, enclosing conflicting FaLant results in health records, and reduction in lengthy replies by SMRL.

(g) The reputation of the FaLant will be enhanced, thereby producing confidence in the operational forces in Navy physical examination procedures.

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APPENDIX A

Set of Instructions Affixed to Every FaLant

FARNSWORTH LANTERN FOR TESTING COLOR VISION

ADMINISTRATION AND SCORING

1. Instruct examinee, "The lights you will see in this lantern are either red, green, or white. They look like signal lights at a distance. Two lights are presented at a time—in any combination. Call out the colors as soon as you see them, naming first the color at the top and then the color at the bottom. Remember, only three colors—red, green, and white—and top first."

2. Turn knob at top of lantern to change lights; depress button in center of knob to expose lights. Maintain regular timing of about 2 seconds per exposure.

3. Expose the lights in random order starting with a RG or GR combination (Nos. 1 or 5), continuing until each of the 9 combinations has been exposed.

4. If no errors are made on this first run of 9 pairs of lights, examinee is passed.

5. If any errors are made on this first run, discard results and give two more complete runs.

6. Average the errors of these last two runs. If examinee has an average of more than one error per run, he is failed. If examinee has an average of one, or less than one, error he is passed.

7. An error is considered the miscalling of one or both of a pair of lights; if an examinee changes his response before the next light is presented, record his second response only.

8. If examinee ordinarily uses glasses for distance, he should wear them.

9. If an examinee says "yellow", "pink", etc., remind him, "There are only three colors—red, green, and white."

10. If an examinee takes a long time to respond, tell him, "As soon as you see the lights, call them."

OPERATION OF LANTERN

1. Give the test in a normally lighted room; screen from glare; exclude sunlight. Examinee should not face the source of room illumination.

2. Only one man should be tested at a time. (Others shall not be allowed to watch.)

3. Station examinee 8 feet from lantern.

4. Examinee may stand or sit; tilt lantern by adjusting screw at back of lantern so that the aperture in the face of the lantern is directed at head of examinee.

5 Operate on 110-120 volts, AC or DC. Use only Airport Marker Lamp, clear, 40 watt, 115 volts, T8, Code 40T8/3. (Government Code 17-L-2275, Sub item AS-43a, 115 volts—G.S.A. Schedule.) Keep spare lamp in base of lantern in socket provided.

APPENDIX B

Effect of FaLants on Color Defective Population Reporting for Submarine School—USNR

A. BEFORE FALANTS IN THE FIELD

Time	Total Applicants	Total C.D.'s	Color Defectives: Degree Mild	Mod	Sev&Dic	Type Deut	Prot
1/49-6/49*	571	18	6	5	7	14	4
1/50-6/50*	483	16	9	4	3	1[illegible]	4
7/50-6/51	829	32	12	9	11	25	7
7/51-6/52	746	37	13	8	16	29	8
7/52-6/53	511	19	9	5	5	17	2
7/53-6/54	597	25	5	6	14	18	7
TOTAL N:	3737	147	54	37	56	115	32
PERCENT:		3.9	36.7	25.2	38.1	78.2	21.8

*No records available of total number of applicants for period 7/49-12/49—hence no tally for this period.

B. AFTER FALANTS IN USE IN THE FIELD

Time	Total Applicants	Total C.D.'s	Color Defectives: Degree Mild	Mod	Sev&Dic	Type Deut	Prot
7/56-6/57	455	17	10	4	3	14	3
7/57-6/58	447	10	8	0	2	8	2
7/58-6/59	282	8	3	1	4	5	3
TOTAL N:	1184	35	21	5	9	27	8
PERCENT:		3.0	60	14.3	25.7	77.1	22.9

C. CURRENT TALLY

Time	Total Applicants	Total C.D.'s	Color Defectives: Degree Mild	Mod	Sev&Dic	Type Deut	Prot
7/65-6/66	983	36	25	4	7	31	5
PERCENT:		3.7	69.4	11.1	19.4	86.1	13.9

APPENDIX C

Detailed Case History of the Color Vision Testing of One Particular Navy Man Over a Four-Year Period, as He Reported It to Us

1. April 1958—enlisted at Post Office. Set of plates administered; Subject failed; not recorded.

2. A week or two later—arrived at Boot Camp. Set of plates administered; Subject failed; not recorded.

Note: Subject reported that the plates were very large (a foot or more in size) and mounted on the side of a wall.

3. Sept 1958—enrolled at ET School. No color vision test was given, although ET School requires normal color perception.

4. May 1959—sent to a Naval Air Station to do electronic repair work on radar (ground work).

5. May or June 1960—volunteered for submarine duty. Sent to Dispensary at the Naval Air Station for physical; Subject failed plates and failed Holmgren Wool Test (both administered by a Corpsman). Subject sent to the Naval Hospital for Farnsworth Lantern test. A Naval Doctor gave Subject FaLant over and over again—for a half hour; Subject kept guessing at lights and failing; darkened room; 5-foot distance, approximately. Doctor finally said, "This is your last chance—I am going to give you three lights (not 3 runs) and, if you pass the three, you can go to New London." Subject guessed at lights. Doctor recorded "Pass FaLant."

6. July 1960—Went through Physical Exam Section of SMRL. Subject (ET 3/c at that time) failed FaLant but asked the S2/c, who gave him the test, to pass him—which the S2/c did, and so Subject never referred to SMRL color vision referral facility.

7. Attended Submarine School.

8. Attended Basic Nuclear Power School.

9. Attended SIC (Sub 1st Core).

10. Attended school at Westinghouse's Bettis Plant.

11. Sent to a Nuclear Submarine for TD aboard while being constructed and for ultimate duty aboard when finally commissioned.

12. March 1962—Reenlistment Physical at Dispensary of a Naval Station; failed plate test (administered by a Corpsman). Subject was sent to Naval Hospital for Farnsworth Lantern test; Corpsman gave Subject the FaLant at two-foot distance and Subject failed; Corpsman gave it to him again (same distance), and Subject also failed. Subject also asked this Corpsman to pass him, but this Corpsman told him that he was in too much trouble himself at the moment and couldn't afford to take the chance. Corpsman took the results of the 2nd set of 3 runs—average of 3.5 wrong—and showed them to the Doctor; Doctor recorded "Fail FaLant" and signed the record.

13. Subject back to his Submarine with this record; the Captain, the Executive Officer, and Corpsman discussed his case; sent him back to personnel at Naval Hospital with a request for them to determine his degree of defect.

14. Subject returned to Naval Hospital and a different Corpsman gave him FaLant—still at 2-foot distance; darkened room; Subject was given about 20 runs and the best 3 runs were selected (1.5 average error score). During the tests Subject was allowed to position his own chair at distance he could see lights best, and was told to look away and rest his eyes between every set of 3 lights presented. Corpsman took this record to same Doctor who had written "Fail FaLant" the day before; Doctor was upset at the improvement in Subject's record, and so Doctor tested Subject—gave him 3 runs and Subject still failed (still at 2-foot distance). Doctor wrote on the paper (where he had written "Fail FaLant" the previous day) an additional note to the effect that Subject had mild (?) or

slight (?) color defect.

15. Subject back to his Submarine. Captain and Executive Officer gave Subject 2 tests which they devised:

(1) Asked him to name colors of coded wires.

(2) Asked him to name colors of colored geometric form test they designed; (they took six 3 x 5 cards, cut different geometric form in center of each, put 6 different colored papers behind 6 cards; colors used: Red, Green, Blue, Orange, Yellow, Black).

16. A request was sent to BuMed for a waiver for the Subject.

17. Subject was referred by BuMed to SMRL for classification.

18. 23 April 1962—SMRL classified Subject as a Class IV Deutan. When we here at SMRL asked Subject if he didn't think, when he was coercing the color vision tester into passing him for Submarine School, that someday his severe color vision defect would be uncovered and be cause for rejection from submarine duty, he replied, "Yes, but I figured that by that time the Navy would have spent too much money and time on schooling and training me to oust me from my duties."

APPENDIX D

Template No. 1

FARNSWORTH LANTERN
INSTRUCTIONS FOR EXAMINEE

The lights you will see in this Lantern are either red, green, or white. They look like signal lights at a distance. Two lights are presented at a time in any combination. Call out the colors as soon as you see them, naming first the color at the top and then the color at the bottom. Remember, only three colors, red, green, and white—and top first.

NOTE: If you use glasses for distance, please use them during this test.

APPENDIX E

Template No. 2

FRONT SIDE

FARNSWORTH LANTERN
SCORING TEMPLATE

1	2	3	4	5	6	7	8	9	
GR	WG	GW	GG	RG	WR	WW	RW	RR	Errors

BACK SIDE

Instructions for use of template

Use this template for **every** examinee.

Place template on top of a sheet of paper. Present to examinee a GR or RG first, record his response in the appropriate space below the template. Put a check mark when response is correct; write the examinee's response when it is incorrect. Randomly select another light, present it, and again record. Continue selecting different lights at random until each of the nine lights has been presented once. If no errors are made, one run is sufficient; if errors are made on this first run, continue testing for two more complete runs.

Slide template down to unused portion of paper for recording next examinee's responses. Start again with GR or RG, use another random order, and proceed as above.

NOTES: (1) Do not spin knob violently in selecting lights at random.

(2) Unless tester adheres to all 15 rules printed on the back of the Lantern, the test results are meaningless.

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13. ABSTRACT

The Farnsworth Lantern is a color vision test which presents specially selected pairs of red, green, and white lights. It was developed for Naval use by the late CDR Dean Farnsworth, MSC, USNR, when he was attached to the Submarine Medical Research Laboratory. Whereas the set of pseudo-isochromatic plates which is the other color vision test commonly used by the Navy was designed to pass normals and fail all color defectives, the Farnsworth Lantern was designed to pass normals and the mild color defectives and to fail the moderate, severe, and dichromatic color defectives.

Good color vision is required for acceptance to many Naval training schools because, upon completion of the training, the man will be called upon to make critical color judgments as part of his Naval duties. When plates were sued as the qualifying color vision test for acceptance to these schools, all color defectives - ten per cent of the applicants - were rejected (when the plates were correctly administered). With the introduction of the FaLant as a qualifying test, thirty per cent of the color defective population is being salvaged,(that is, the FaLant passes three of the ten men in a hundred who are color defective) by rating them as safe for making accurate color judgments.

This Farnsworth Lantern has been in use at the Submarine Medical Research Laboratory and at various Naval activities, such as hospitals, training schools, air stations, et cetera, for some ten years. The present paper analyzes its performance here at SMRL and in the field during this period (1955 - 1965).

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