Submarine Medical Research Laboratory
NAVAL SUBMARINE MEDICAL CENTER, NAVAL SUBMARINE BASE
Groton, Connecticut 06340

MEMORANDUM REPORT NO. 70-6

A HISTORY AND RATIONALE OF VISUAL ACUITY STANDARDS FOR SUBMARINERS

M4305.08-3001D.05

7 August 1970

Investigator:

Jo Ann S. Kinney, Ph.D.
Head, Vision Branch

Reviewed and Approved by:

Charles F. Gell, M.D., D.Sc.(Med)
Scientific Director
SubMedResLab

Reviewed and Approved by:

J.D. Bloom, CDR MC USN
Officer-in-Charge
SubMedResLab

Approved and Released by:

J. E. Stark, CAPT MC USN
COMMANDING OFFICER
Naval Submarine Medical Center

SUMMARY PAGE

THE PROBLEM

To summarize the experimental evidence and rationale on visual acuity standards for submarines.

FINDINGS

Both the increasing demands for manpower and the technological advances in submarine systems have necessitated periodic re-evaluation of acuity standards. The result has been a gradual relaxation of requirements from 20/20 to 20/70 or less.

APPLICATIONS

Questions concerning the aptness of physical standards for submariners often arise because of new developments in submarine systems and personnel requirements. This summary is aimed at assisting those who must make operational decisions by providing a background of pertinent information.

ADMINISTRATIVE INFORMATION

This investigation was undertaken as part of Bureau of Medicine and Surgery Work Unit M4305.08-3001D, Development of Visual Screening, Display, and Illumination Standards for Submarine/Shipboard Personnel. The present report is No. 5 on this Work Unit. The manuscript was approved for publication on 7 August 1970. This report has been designated as Memorandum Report No. 70-6.

PUBLISHED BY THE NAVAL SUBMARINE MEDICAL CENTER

ABSTRACT

The visual tasks aboard submarines can be analyzed according to the demand for visual acuity placed upon the men performing them. Such assessments have been made on several occasions in the past, in response to increasing shortages of manpower, and have often resulted in relaxation of standards. These studies are summarized, the rationale for current standards stated and other solutions to the problem of using men with inadequate vision are discussed.

A HISTORY AND RATIONALE OF VISUAL ACUITY STANDARDS FOR SUBMARINERS

The submarine force has always had visual acuity standards for its men; at one time the standard was 20/20 vision. However, as demands on the submariner change, so too must the standards, and a number of investigations have been made at the Submarine Medical Research Laboratory to assure that the physical capabilities of the men are compatible with their duties.

A major reason for high acuity standards for submariners, originally, was that a large proportion of the men served as lookouts. Not only was excellent vision necessary for this task in the daylight. but it became even more important at night. The vision of all men under these conditions suffers severely; a man with borderline vision at high intensities may be completely incapable under dim illumination.[1]

A survey of the visual tasks within the submarine in 1951 revealed that uncorrected vision of 20/30 was adequate for all duties.[2] Thus there were only two deterrents at that time to lowering visual acuity standards for submariners: (1) the requirements for visual performance outside the submarine, and (2) capabilities required inside the submarine in low level, red illumination.

Visual aids--Binoculars and periscopes--were available to lessen the problems of performance outside the submarine. Standard Navy instruments have individually focusing eyepieces which can be used to correct spherical refractive errors of the user. An investigation of visual acuity through binoculars showed that these eyepiece adjustments could adequately correct for all spherical errors between +3.00 and -4.00 diopters of refractive error. However, performance was handicapped for men with over .5 D. of astigmatism; there is, of course, no correction available for cylindrical errors of refraction in the binoculars.[3] The operational reason for the first astigmatism requirement for submariners (.75 D. or less) was thus lookout duty or periscope observations; men with poor vision due to simple spherical error--myopes, for example--can use the periscope just as well as a man with 20/20 vision, but men with astigmatism cannot similarly correct for their aberrations.

The second deterrent, reduced visual acuity under the low levels of red illumination prevalent on the older submarines, also was a major problem. When visual acuity standards were reduced to 20/60 in the late 1950s, it was recommended that the minimum light level for red lighting be raised to 0.6 foot-candles to provide adequate visibility for those personnel with less than normal vision.[4] Raising the level of red illumination, of course, reduces the amount of night vision sensitivity possible but this was a compromise; the night vision was partially sacrificed to assure adequate performance inside the submarine.

With the technological advances achieved in nuclear submarines and

Polaris ships, a number of far-reaching changes occurred. The philosophy that each man on a submarine be capable of performing all duties began to weaken in the light of the increasing specialization required for some tasks. The physical interior of the submarine also became more compartmentalized with some areas no longer employing red light at all. Finally, of course, the need for night vision or good far vision dissolved for all except periscope operators.

For these reasons, a complete reanalysis of the vision requirements was performed on Polaris ships.[5] Each duty station requiring visual monitoring was assessed; the illumination, the critical visual detail, the distances from the operator and the type of task were measured. For the most part, the visual detail that had to be resolved was large and easy to read. Acuities of 20/30 to 20/50 would be adequate for the majority of the tasks. However, there was, at each station, at least one visual task which required considerably better acuity, usually 20/20.

Since the minimum standard for submariners about this time had been lowered to 20/70 unaided acuity in each eye, an additional evaluation was performed. For younger men, the most likely cause of poor acuity is myopia (near-sightedness). While near-sighted men by definition do not see distant objects normally, they may see clearly if the object is brought sufficiently close to them. Calculations show that 50 to 75% of men who have 20/70 acuity for distant objects because of simple myopia, will have the equivalent of 20/20 vision without correction for objects two or three feet away--the distance at which submarine operators view their displays. For supervisors, this value drops to 25 to 50%.[6]

This analysis, based upon the closeness of the visual displays within the submarine, applies only to simple myopia. Astigmatic error of a diopter or more will reduce acuity to 20/70 or worse, but blurred vision will result at all distances; thus the high astigmats could not be expected to perform the duties on Polaris ships without glasses. Similarly hyperopes (far-sighted individuals) and presbyopes* would be severely hampered without correction.

Consoles aboard submarines were re-inspected in 1967 and display panels at the Fleet Ballistic Missile Department of Submarine School were assessed in 1970. The conclusions concerning the acuities required at each of the stations remained the same as in the previous report.[5]

Since manpower shortages make it unreasonable to revert to higher acuity standards, other solutions are continually sought. Different standards for different rates are enforced. A more sophisticated standard of visual acuity, BVE (binocular visual efficiency), has been substituted for monocular standards; this measure is based upon the well-known fact that binocular vision is as good or better than that of the best eye.[6] Finally, it is emphasized that men with subnormal visual acuity should have two pairs of glasses available and

**Loss of acuity due to loss of accommodative ability with age.*

that they be impressed with the importance of wearing them on duty.

Another solution is, of course, available in new construction codes designed to eliminate the troublesome tasks. If the material to be read is too small, perhaps it can be enlarged by proper redesign of the console face. Contrast can be increased either by increasing the brightness of the signal or by decreasing the brightness of the background against which it appears.

Examples of the magnitude of the changes required are shown in Table I which gives the average size of alphabetical material which would be required by men of varying visual ability. The man with 20/100 vision requires the material to be five times as large at 20 ft. as the man with 20/20 vision. Extrapolating to 24 inches, as has been done in the table, must be done with caution for men with abnormal vision (ametropia), since, as noted previously, the reason for the abnormality becomes important; the hyperope or presbyope may be poorer at 2 ft. than 20 ft. and the myope better. The values in Table I are given as exemplifying the overall average ametrope without considering the cause.

Table II gives the visual acuities achieved by a man with 20/20 vision when the contrast is reduced below the optimum level. If the contrast drops to 5 or 10%, visual acuity is 1/5 its normal value; thus the ability of this man is essentially the same as that of a man with 20/100 viewing a black-white target.

In general, the most difficult acuity tasks in modern submarines are computer read-outs. Some employ typed material of very small size; others use lighted numerals which provide poor contrast against their lighted background. In some cases the read-outs combine the disadvantages of small size and low contrast for practically complete illegibility. These read-outs convey valuable information on the status of essential systems; their redesign should be given proper consideration.

Table I. Visual acuity for high contrast targets *

Snellen Designation	Visual Acuity (1/size (min.))	Size of Detail (min. of arc)	- At 24" -	
			Size of Detail	Normal Letter Size
20/20	1.0	1.0	.007"	.035"
20/40	.5	2.0	.014	.070
20/70	.286	3.5	.024	.120
20/100	.20	5.0	.035	.174

**Visual acuity is normally or routinely tested using high contrast targets (as black lettering on white background) at a distance of 20 feet; it is a measure of the smallest detail a man can see under these standard conditions. For a man with 20/20 vision, this detail is one minute in size: that is, .07 inch at a distance of 20 ft. or .007 inches at a distance of 2 feet. The standard letters are five times as large as the size of the detail.*

Table II. The acuity achieved by a man with 20/20 vision under low contrast conditions

Contrast*	Size of Detail Perceived (min.)	Comparable Acuity Level
Near 100%	1.00	20/20
35%	.50	20/40
12%	.28	20/70
10%	.20	20/100

**Contrast is defined as* $\frac{L_T \cdot L_B}{L_B}$ *where*

L_T is the luminance of the target, and
L_B is the luminance of the background; it can be either negative or positive in value. Thus, near 100% contrast refers to either black on white or white on black; examples of 35% contrast would be a gray of 32.5% reflectance against a 50% reflectance background, or a light of 67.5 foot-Lamberts viewed against a 50 ft-L background.

REFERENCES

1. Pratt, C. and F. L. Dimmick, An ophthalmological study of visual acuity under dim illumination. Naval Submarine Medical Center, Groton, Conn., SMRL Rep. No. 173, June 1951.

2. Dimmick, F. L., and Dean Farnsworth, Visual acuity tasks in a submarine. Naval Submarine Medical Center, Groton, Conn., SMRL Rep. No. 178, Oct 1951.

3. Kinney, J. A. S., and C. Pratt, The effect of refractive error on acuity through binoculars. Naval Submarine Medical Center, Groton, Conn., SMRL Rep. No. 245, Apr 1954.

4. Dimmick, F. L., Recommendations for minimal red light levels on board submarines. Naval Submarine Medical Center, Groton, Conn., SMRL Memo Rep. No. 60-2, Jan 1960.

5. Connors, M. M., and J. A. S. Kinney, Survey of the visual acuity tasks on Polaris submarines. Naval Submarine Medical Center, Groton, Conn., SMRL Rep. No. 413, Oct 1963, (Confidential).

6. Kent, P. R., A review of the rationale of the visual standards for submarine duty. Naval Submarine Medical Center, Groton, Conn., SMRL Rep. No. 428, May 1964.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*

NAVAL SUBMARINE MEDICAL CENTER, Submarine Medical Research Laboratory

2a. REPORT SECURITY CLASSIFICATION

Unclassified

2b. GROUP

3. REPORT TITLE

A HISTORY AND RATIONALE OF VISUAL ACUITY STANDARDS FOR SUBMARINERS

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Interim report

5. AUTHOR(S) *(First name, middle initial, last name)*

Jo Ann S. KINNEY

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
7 August 1970	5	6

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. M4305.08-3001D.05	SMRL Memorandum Report No. 70-6
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Naval Submarine Medical Center Box 600 Naval Submarine Base Groton, Connecticut 06340

13. ABSTRACT

The visual tasks aboard submarines can be analyzed according to the demand for visual acuity placed upon the men performing them. Such assessments have been made on several occasions in the past, in response to increasing shortages of manpower, and have often resulted in relaxation of standards. These studies are summarized, the rationale for current standards stated, and other solutions to the problem of using men with inadequate vision are discussed.

DD FORM 1 NOV 65 1473 (PAGE 1)

S/N 0102-014-6600

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Visual acuity for tasks in submarines						