THE LONGITUDINAL HEALTH STUDY: VISUAL CHARACTERISTICS OF 750 SUBMARINERS

Jo Ann S. Kinney, et al

Naval Submarine Medical Research Laboratory
Groton, Connecticut

19 December 1974

NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

SUBMARINE BASE, GROTON, CONN.

REPORT NUMBER 800

THE LONGITUDINAL HEALTH STUDY: VISUAL CHARACTERISTICS OF 750 SUBMARINERS

by

Jo Ann S. Kinney
Alma P. Ryan
S. M. Luria
Helen M. Paulson
Christine L. McKay
and
Mark S. Strauss

Bureau of Medicine and Surgery, Navy Department
Research Work Unit MF51.524.006-1002.04

Released by:

R. L. Sphar, CDR MC USN
COMMANDING OFFICER
Naval Submarine Medical Research Laboratory

19 December 1974

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 RESEARCH LABORATORY	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3 REPORT TITLE

THE LONGITUDINAL HEALTH STUDY: VISUAL CHARACTERISTICS OF 750 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, Alma P. Ryan, S. M. Luria, Helen M. Paulson, Christine L. McKay, and Mark S. Strauss

6 REPORT DATE 19 December 1974	7a. TOTAL NO OF PAGES 19	7b. NO OF REFS 36
8a CONTRACT OR GRANT NO b. PROJECT NO MF51.524.006-1002 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) NSMRL Report No. 800 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	

10 DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11 SUPPLEMENTARY NOTES	12 SPONSORING MILITARY ACTIVITY Naval Submarine Medical Res. Lab. Box 900, Naval Submarine Base Groton, Connecticut 06340

13 ABSTRACT

A number of tests of visual health and ability are included in the ongoing Longitudinal Health Study of submariners. This paper reports on the findings to date on these visual measures for 750 submariners. The results show that the visual and ocular health of the men is good; color vision, intraocular pressures, and artery to vein ratios in the fundus are all normal. On the other hand, the men evidence poorer acuity, more myopia, a tendency toward esophoria and less accommodative ability than is expected from population statistics.

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
Vision of submariners						
Visual acuity						
Fundus photography						
Refractive error						

THE LONGITUDINAL HEALTH STUDY: VISUAL CHARACTERISTICS OF 750 SUBMARINERS

by

J. A. S. Kinney, Ph.D.
A. P. Ryan
S. M. Luria, Ph.D.
H. M. Paulson, BA
C. L. McKay, MA
and
M. S. Strauss, LT MSC USNR

NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY
REPORT NUMBER 800

Bureau of Medicine and Surgery, Navy Department
Research Work Unit MF51.524.006-1002.04

Reviewed and Approved by:

Charles F. Gell

Charles F. Gell, M. D., D.Sc. (Med)
SCIENTIFIC DIRECTOR
NavSubMedRschLab

Approved and Released by:

R. L. Sphar

R. L. Sphar, CDR MC USN
COMMANDING OFFICER
NavSubMedRschLab

(b)

SUMMARY PAGE

THE PROBLEM

The visual characteristics of submariners are measured as a part of the Longitudinal Health Study investigating the effects of prolonged submarine exposure on men.

FINDINGS

The data for 750 submariners reveal the men to have good ocular health but more myopia than average.

APPLICATION

These results will help identify medical risks for submariners before they evolve and can serve as a basis for alleviating visual problems aboard submarines.

ADMINISTRATIVE INFORMATION

This investigation was conducted as part of Bureau of Medicine and Surgery Research Unit MF51.524.006-1002. The present report is Number 4 on this work unit. It was submitted for review on 2 December, approved for publication on 19 December, and designated as NavSubMedRschLab Report No. 800.

PUBLISHED BY THE NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

ABSTRACT

A number of tests of visual health and ability are included in the ongoing Longitudinal Health Study of submariners. This paper reports on the findings to date on these visual measures for 750 submariners. The results show that the visual and ocular health of the men is good; color vision, intraocular pressures, and artery to vein ratios in the fundus are all normal. On the other hand, the men evidence poorer acuity, more myopia, a tendency toward esophoria and less accommodative ability than is expected from population statistics.

Clip and Mail Form for Change of Address:

- -

To: Commanding Officer, Naval Submarine Medical Research Laboratory

Subj: Change of Address

1. I/We wish to continue to receive NavSubMedRschLab Reports, however, the following change of address should be noted:

New Address: _____

_____

_____

Old Address: _____

_____

_____

THE LONGIDUDINAL HEALTH STUDY: VISUAL CHARACTERISTICS OF 750 SUBMARINERS

INTRODUCTION

The Longitudinal Health Study is a multiphasic investigation of the health of submariners and divers being conducted at the Naval Submarine Medical Research Laboratory. The entire program and its rationale are described in NSMRL Rep. No. 786[1] and the computer program for data storage and analysis in No. 733.[2] The wide assortment of vision tests administered as part of the examination include both tests of visual performance, such as acuity, and measures of visual and ocular health, such as ocular pressure.

Measurement of visual function shares the same goals as the other tests being conducted on these men: concern for the effects of the unusual and specialized environments on the eye; the desire to identify visual problems and medical risks before they evolve, in order to find means to alleviate them; and the need to provide normative data on visual health.

In addition, another question, specific to vision, has been raised in previous investigations: whether or not confinement to a near environment causes an increase in myopia. There are several reasons for suspecting that this is true. In 1951, a group of 1064 submariners were given a battery of visual tests in order to assess the visual characteristics of submariners at that time.[3] The men, in general, had excellent vision, due to stringent acuity standards in effect, but unaccountably their vision was poorer than a comparable group of Submarine School candidates. The suggestion was then made that the confining nature of the submarine, with its constant requirement for accommodation and convergence, might cause a visual impairment.[4] Fifteen years later a sample of 51 individuals of the original group was retested on the same battery in order to determine the effects of long-term submarine duty of vision.[5] It was found that certain changes had taken place over the 15-year period, most notably a loss of visual acuity at both near and far, and a tendency toward esophoria. Some decrement in vision is expected as a function of age, of course, but these changes were larger than that predicted for men of their age-level.

Additional support for the thesis of an effect of confinement on vision comes from a study of the vision of submariners before and after a single 60-day patrol. While there was no change in acuity or refraction stemming from this extended patrol, definite increases in esophoria were found which could be considered precursors of other changes.[6] Finally, a recent comparison of the degree of myopia among Submarine School candidates and actual submariners revealed significantly greater amounts in the latter group.[7]

These findings conform to research data from various other areas. For example, a strong negative correlation

between visual acrity and academic achievements has been well documented over the years.[8-11] Although the reason for the correlation is still a hotly debated issue,[12] one possibility is that the continuous accommodation required in extensive near visual work is conducive to the development of myopia.[13,14] Consistent with this explanation is the fact that extreme myopia can be induced in monkeys reared in confined areas.[15-17] Similarly, loss in acuity and increases in myopia have been recorded among personnel confined for extensive periods of time to "Minutemen" underground, launch-control centers.[18]

The evidence cited thus far is consistent with the hypothesis of extensive, near visual tasks causing continuous accommodation which in turn leads to esophoria and myopia. There are however other possible alternatives. For example, a comparison of current data with that of cross-sectional data on the effect of age is confounded by the fact that the older men were born and raised at a much earlier and different cultural time; differences in nutrition, experience, and socioeconomic background could affect their acuity.

Ironically, it may be that today's youth has poorer acuity than yesterday's for the same reasons that the submariner may be affected - an increase in indoor activities (for example, watching TV) at the expense of outdoor ones. Indeed it has been shown that black youths have better acuity than white[19] and that rural white children have better acuity than urban.[20] The final answer must await the results on men brought up at the same time but differing in the degree of confinement; this then is one of the major reasons for some of the vision tests in the LHS.

This report documents the results of the visual tests given, to date, to 750 submariners. It does not purport to answer the questions posed above but provides the baseline data for future answers.

THE TESTS EMPLOYED

1. The Ortho-Rater. This is a device used for mass screening of visual acuity; it provides a rapid measure of both monocular and binocular acuity under controlled lighting at both near (13 inches) and far (simulated 26 ft) viewing distances. The acuity test is a checkerboard which the subject must differentiate from three gray squares of equal size.

Also included in the Ortho-Rater are measures of phoria, both vertical and horizontal, for near and far distances, and a test of depth perception based upon binocular disparity.

2. Accommodation. A simple ruler with sliding fine print is used to test the ability of the eye to accommodate or focus at close distances. Measures are made of the distance from the cornea to the plane of clear focus. Four separate determinations of this near point are made and averaged; this distance is expressed in diopters. There is a general relationship between age and the ability to accommodate, younger individuals being able to exert greater dioptric power.

3. Refraction. A standard manifest refraction is performed on the right eyes of the men using a Bausch & Lomb Phoropter and an American Optical Co. Projecto-chart. The current prescription is measured with an American Optical Co. Lensometer.

4. Schiotz Tonometer. Intraocular pressure is measured for both eyes and recorded in mm. of mercury.

5. Fundus photographs. A Zeiss Ikon Fundus camera is used to photograph the right eye. A procedure worked out previously for measuring retinal vessels is used.[21] The same field of view, which included the optic disc and temporal vessels in the lower field, is always photographed and measures made of the temporal artery and vein calibres at the same location. Artery/vein ratio is one indication of hypertension; therefore blood pressure measures are also noted. Additionally, a photograph of the anterior portion of the eye - commonly called the red reflex - if obtained and any abnormality noted. Since the pupil must be dilated for the fundus photographs, no pictures are attempted for men whose ocular pressure is abnormal.

6. Color Vision. Three tests are employed to assess the men's color vision: the American Optical Pseudo-Isochromatic Plates, the Hecht-Shlaer Anomaloscope, and the Farnsworth-Munsell 100-Hue Test. The plates and the anomaloscope are routine screening tests for color vision defect; taken together a determination is made of the presence and type of defect. The 100-Hue test is a simple but sensitive measure of the ability to discriminate colors. It consists of almost 100 plastic cups on which a wide array of different colors are mounted. The colors, which encompass the color circle from red through yellow, green, blue, purple, and back to red, are divided into four panels with two endpoints each. The subject's task is to arrange the colors in the order of regular color series from one endpoint to the other. The test has been used extensively to separate persons with normal color vision according to their ability to discriminate hues, to measure the color confusions of color defective individuals, and to study acquired deficiencies of color vision.[22,23]

7. Non-visual Measures. Other data are gathered routinely on men because of their pertinence to the visual results. These include age, number of years spent in submarines, and blood pressure.

TEST ADMINISTRATION AND SUBJECTS

Volunteers for the test program are scheduled to take the entire series of tests in one and one-half days. Since some of the tests in the general battery are relatively time-consuming, it is not possible to give all tests to all men. Therefore, when men enter they are randomly assigned to one of two groups: one group receives all the tests and the second, a selected portion of the tests. Among the vision tests, color vision and fundus photography are given to only about 40% of the men; all men receive all of the remaining tests.

This report includes data collected on submariners only; there have been 750 measured to date. The Ortho-Rater and accommodation tests and the standard refraction were administered to all 750 men. In addition, color vision tests and fundus photographs were given to slightly more than 300 of these men. While divers are included in the general Longitudinal Health Study, they have been purposely excluded from this analysis; a comparison of the results for a selected group of 50 divers and submariners is available in NSMRL Rep. No. 767.[7]

RESULTS

The average results for the 750 submariners on the various tests in the Ortho-Rater are given in Table I. The average binocular acuity at distance, .94, is almost at the 20/20 level (an acuity of 1.0), indicating that the majority of the men have good vision. The actual distribution of men having various acuity levels is given in Fig. 1 and Table II. Sixty-three percent of the men have vision of 20/20 or better, binocularly. Of the remainder, most are myopic or nearsighted, as is indicated by the facts that the average near acuity for the 750 men is very high and that 62% have an acuity of 1.2 at near, the highest acuity level tested in the Ortho-Rater.

Phoria measures for the vertical dimension show very small amounts of deviation, as is typical of the general population. Lateral phorias tend to be slightly esophoric at far and greatly exophoria at near, according to the norms given in the Ortho-Rater manual. The average values for the 750 submariners fall within the limits indicated as normal. The actual distributions of phorias are given in Table III.

The average depth perception score of the 750 men was 4.5 out of a possible nine. This result, however, is somewhat misleading since the distribution of scores was distinctly bimodal, as is shown in Fig. 2. Fifty percent of the men have a score of 90% or greater, about as good as is possible on the test, while another 25% have virtually no steroacuity.

Table I. Average values for 750 submariners on the Ortho-Rater tests

Test	Mean	Standard deviation
Acuity at Distance (1/min.visual angle)		
Binocular	.94	± .26
Right eye	.88	.30
Left eye	.89	.30
Near Acuity		
Binocular	1.12	.14
Right eye	1.06	.19
Left eye	1.07	.19
Phorias (prism diopters)		
Vertical - far	0.13 LH	.46
Vertical - near	0. 0 LH	.37
Lateral - far	+0.48 (eso)	2.45
Lateral - near	-5.34 (exo)	4.86
Depth Perception		
Ortho-Rater score (out of 9)	4.5	2.9
Fry-Shepard Scale *	86.4%	

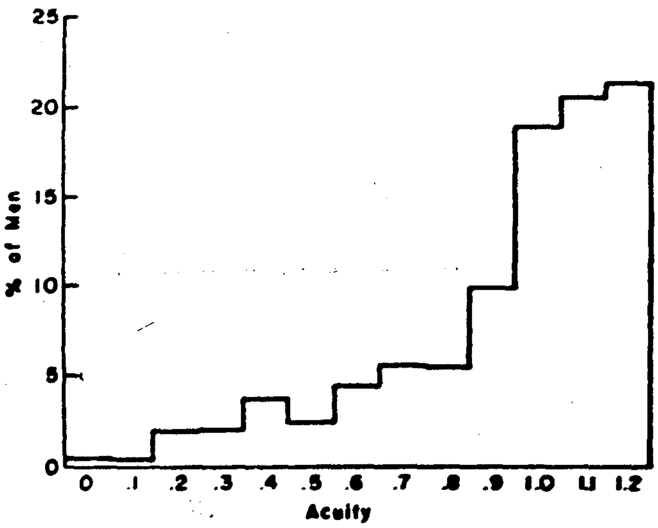

Fig. 1. The distribution of binocular visual acuity at distance of 750 submariners

Table III Percentage of 750 men with varying amounts of phoria

Vertical			Lateral			
ΔD.	Far	Near	ΔD.	Far	ΔD.	Near
LH>2.0	1.2	-	>8.0	[illegible].1	>6.0	0.9
2.0	1.1	0.7	7.3	1.3	6.0	0.8
1.5	1.7	1.2	6.3	0.5	4.5	0.7
1.0	4.3	3.1	5.3	1.2	3.0	2.1
0.5	15.1	14.8	4.3	3.2	ESO 1.5	4.9
0.17	37.5	43.5	ESO 3.3	6.3	0.0	7.5
RH 0.17	29.5	29.6	2.3	12.1	-1.5	9.6
0.5	8.0	5.7	1.3	14.9	-3.0	12.1
1.0	0.9	0.7	0.3	20.3	-4.5	12.4
1.5	0.7	0.3	-0.7	15.9	-6.0	12.8
2.0	-	0.7	-1.7	12.7	EXO -7.5	9.3
			-2.7	5.9	-9.0	7.9
			EXO -3.7	2.1	-10.5	6.8
			-4.7	1.1	-12.0	3.8
			-5.7	0.4	-13.5	2.8
			-6.7	1.1	>-13.5	6.0

Normal values are indicated by dashed lines; limits for 2/3 of population by solid lines, according to Ortho-Rater Manual.

Table II Percentage of 750 submariners at each acuity level

Acuity	Distant			Near		
	Binocular	Right	Left	Binocular	Right	Left
0	0.4	[illegible]	2.0	-	[illegible]	0.1
1	0.5	[illegible]	1.2	-	[illegible]	[illegible]
[illegible]	1.9	1.7	1.1	-	0.6	[illegible]
[illegible]	1.9	[illegible]	3.1	0.5	[illegible]	[illegible]
[illegible]	3.6	[illegible]	4.1	-	0.1	0.5
[illegible]	2.5	5.1	3.1	1	1.2	[illegible]
[illegible]	4.4	2.5	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	5.7	[illegible]	7.6	[illegible]	1.7	[illegible]
[illegible]	[illegible]	7.6	8.5	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	4.5	[illegible]	[illegible]
[illegible]	[illegible]	21.4	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21.0	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	41.1	42.[illegible]

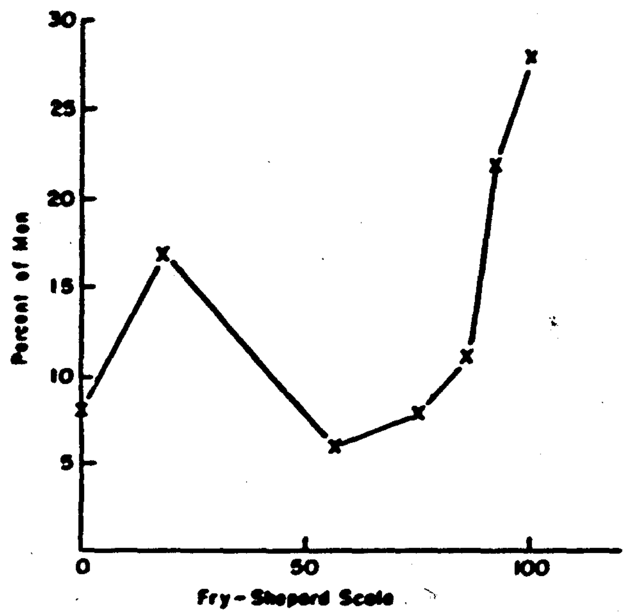

Fig. 2. The distribution of scores on the depth perception test of 750 submariners

Table IV gives the average results for the remaining measures, some visual and some auxiliary data. The average near-point of accommodation for the men is 7.1 diopters. The distribution of accommodation by age is shown in Fig. 3; the younger the man, on the average, the greater the power of accommodation. The correlation between near-point and age is -.50.

The average amount of refractive error for the 750 men is -0.75 diopters. Figure 4 gives the distribution of refractive errors. Most of the men have a small amount of refractive error with the modal point between zero and -0.49 diopters. The distribution is skewed toward the minus or myopic side, as was indicated by the near and far acuity data. Less than one percent of the men have hyperopia of greater than one diopter, while 26 of the men have myopia of greater than one diopter.

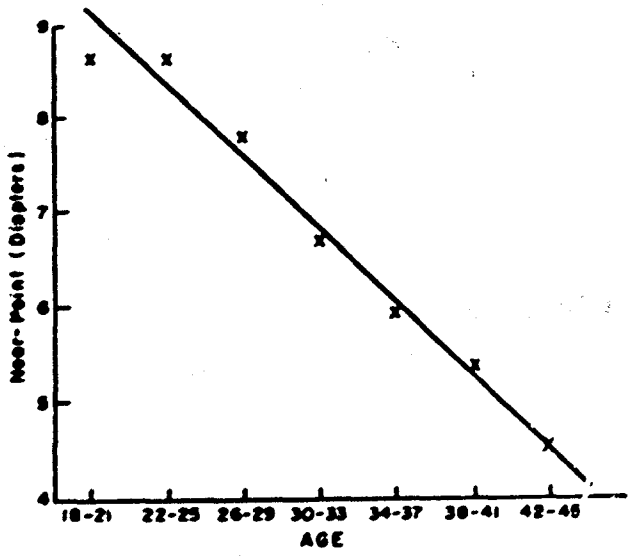

Fig. 3. The near point of accommodation as a function of the age of the men

Table IV. Average values for 750 submariners on remaining visual tests and other pertinent measures

	Mean	Standard deviation
Accommodation (in diopters)	7.1	± 1.5
Refractive Error (in diopters-spherical equivalent)	-0.75	1.99
Tonometry (in mmHg)		
O.D.	16.6	2.9
O.S.	17.0	2.9
Age (years)		
Total	27.8	5.7
Enlisted men	27.5	5.7
Officers	30.7	5.0
Time spent on subs (in months)	19.8	23.1
Blood pressure		
Systolic	122.0	10.1
Diastolic	75.5	9.2

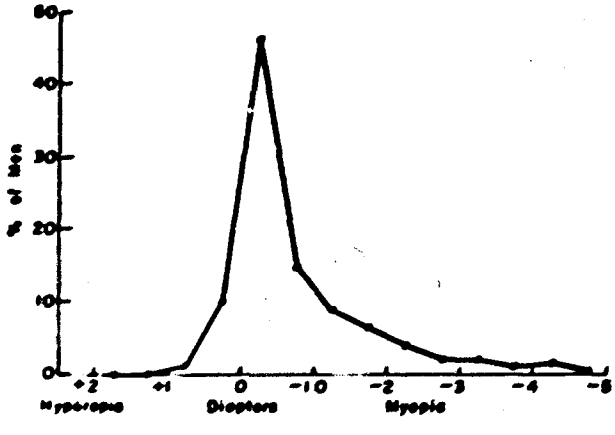

Fig. 4. Distribution of refractive error of the 750 submariners

The average intraocular pressures of 16.6 and 17.0 mm mercury are near the center of the distribution of the normal population.[24]

Table V gives the data from fundus photography and its relationship to blood pressure for the same 314 men. Measures are made of the temporal artery and the temporal vein in comparable, specified locations: the ratio of the artery to the vein (A/V) is calculated from them. The average vessel calibres and the A/V ratios are almost exactly the same size as found in the previous investigation.[21]

All average values for the group for both vessel size and blood pressures are completely normal and the corrections between blood pressure and artery/vein ratios are very small. This would be expected for a group of healthy, young men, for subnormal A/V ratios are found generally

Table V. Retinal vessel calibre and its relation to blood pressure

	Mean	Standard deviation	Correlation with A/V Ratio
Vessel size in microns			
Artery	103.6	±12.8	
Vein	142.6	15.8	
A/V Ratio	.73	.09	
Blood pressure			
Systolic	122.3	10.1	-.12*
Diastolic	74.6	9.1	-.09

* Significant at .05 level

in the hypertensive population. Only one of the 314 men would qualify as hypertensive by the 155/90 value used by Leatham in his study of the fundus.[25] Nonetheless, both correlations are properly negative and one, the systolic, is significant at the .05 level. The relationship between blood pressure and A/V ratio is obviously one to watch as the submariners get older.

The color vision tests were administered to 345 men. The results for the pseudo-isochromatic plates are given in Table VI; this test is used primarily to categorize an individual as color normal or color defective. The criterion for passing the test is four or fewer errors in identifying the figures on the plates. On this basis, 331 of the men were classified as color normal; the vast majority of these men made no errors on the test.

Fourteen of the men were classified as color defective: they made between 7 and 14 errors on the plates. These men were further classified according to type and degree of defect by the additional tests from the NSMRL test battery.[26] Four of these men turned out to be moderate or complete dichromats. Since standards for acceptance into submarine training allow only color normals or mild defectives, these four men were not qualified and presumably entered through improper procedures.

The anomaloscope is used primarily to classify color defective individuals for type and degree of defect. For example, a complete dichromat will match the entire range of green through red hues with the standard yellow;

Table VI. Results of 345 men on Pseudo-Isochromatic Plates

Number of errors	Number of men	% of Color normals
0	275	83.1
1	41	12.4
2	14	4.2
3	1	0.3
4,5,6	0	0.0
7-14	14	Color Defectives 10 mild deuteranopes 1 moderate deuteranope 1 moderate protanope 2 complete protanopes

protanopia is revealed by a large increase in the amount of red used in the match. The device works well because color normal individuals make matches which fall in a very restricted range of possibilities. This was true of the color normals in this study whose red/green match, in arbitary units, was 47.7 ±1.6 and whose brightness match was 38.4 ±1.9. Both variables are normally distributed.

The results on the 100-Hue test for the 331 color normals are given in Fig. 5 which shows the percentage of men obtaining various error scores, and Table VII, which gives the average errors. The mean error score for these color normals is 33.9 ±21.1. The distribution is skewed with a median score of 28. This is somewhat better overall than Verriest's data[23] for 86 twenty to thirty year old males, for whom the mean score was about 43 ± 23. The distribution of errors is quite comparable, however, since Verriest's data show considerably more errors in the blue-green region (caps 43-50) than any others, for all age groups.

As would be expected, the color defective individuals made more errors on the test with a mean score of 74.9 ± 41.0. It should be noted however that the total errors per se are not means of determining color defective vision on the 100-Hue test, but rather the pattern of errors.[22] In fact, some color normals with poor discrimination make more errors than the color defectiveness, but the distribution of the normals' errors is random.

DISCUSSION

Comparison of the data from various measures with that found in the literature for the general population reveals some differences. In 1960 to 1962, the Department of Health, Education and Welfare surveyed the acuity of a probability sample of the entire adult, civilian, non-institutionalized population. Almost 80% of the males under 45 years had unaided binocular acuity of 20/20 or better.[27] The comparable figure for the submariners is 63.5%. The older studies of the distribution of refractive error in the general population yielded average values around +.5 diopters for young adults without disease or pathology.[28-32] Our average refractive error is -.75 D, and the incidence of myopia is also much

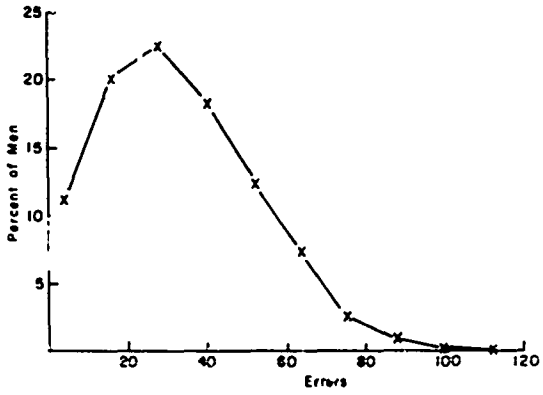

Fig. 5. Distribution of errors on the F-M 100-Hue test of color vision made by 331 color-normal men

Table VII Mean data for 331 color normal subjects on Farnsworth-Munsell 100-Hue test

Panel #	Cap #	Hues	Mean Error	Standard deviation
1	85-21	red to yellow	6 6	± 6 1
2	22-12	yellow to blue-green	7 5	6 8
3	43-63	blue-green to purple-blue	11 3	8 6
4	64-84	purple-blue to red	8.5	6 8
Total			33 9	21 1

higher than in the older surveys.

A comparison of the near points of accommodation of the 750 submariners with Duane's[33] classic data of 1908 shows a striking difference. The younger submariners have decidedly poorer near points than did Duane's 6000 subjects, as is shown in Fig. 6. The original study, however, was done on eyes that were carefully corrected to emmetropia and employed a scoring technique much more lenient than our mean score.[34] Therefore, our data were reanalyzed according to Duane's method, using only the 153 men in the group who had no spherical error. This analysis is also plotted in Fig. 6 and does not change in general conclusion at all.

While the phoria data are within normal limits, as indicated by the manual,[35] these limits are rather gross. The measures were therefore compared with data taken at the San Diego Fair in 1948 on the same tests.[36] Our group of 750 submariners is more esophoric at far and more exophoric at near than the San Diego group. The reasons for the differences are not known but may relate to testing conditions since they allowed the use of glasses in their tests and we did not. If we compare the data of only submariners with no refractive errors and San Diego men with no glasses, the differences between the groups disappears at near, but the submariners remain more esophoric at far.

Other measures made on the men showed no signs of pathology; blood pressure, occular pressures, and the artery-to-vein ratios were normal. Thus, the picture that emerges of the average submariner is of a healthy, young man, whose distant acuity is somewhat below average and who has more myopia and less accommodative power than normal. This picture is completely consistent with all of our previous data on the acuity of submariners and with various theoretical positions found in the literature on the genesis of myopia.

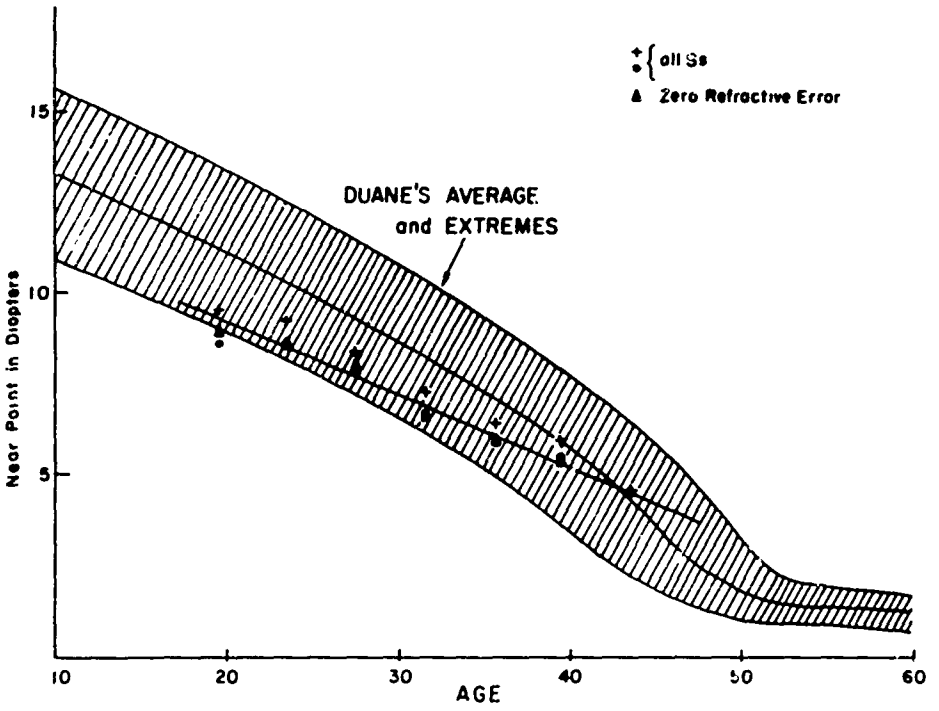

Fig. 6. A comparison of the accommodative ability of the submariners with the data from Duane's classic study. • refers to the data of 750 men using an arithmetic mean of the four measures of accommodation; + is the data for the same men using the largest value only; and Δ is the data for 153 emmetropes.

Determining the cause of this syndrome is one of the reasons for the Longitudinal Health Study, as pointed out earlier. One possibility - that it is a function of different tests, testing conditions and testers - can probably be discounted because of the consistency of the myopia profile. The other - that man today simply has poorer vision than yesterday - cannot be so easily dismissed and must await future analyses of the LHS data.

REFERENCES

1. Tansey, W. A. The longitudinal health study: a multiphasic medical surveillance program for USN Submarine and Diving personnel. NavSubMedRschLab Rep. No. 786, May 1974.

2. Sawyer, R. N. and J. H. Baker, The longitudinal health survey: I. Description. NavSubMedRsch Lab Rep. No. 733, Dec 1972.

3. Schwartz, I. and N. E. Sandberg. Visual characteristics of the submarine population. NavSubMed RschLab Rep, No. 252, Jun 1954.

4. Schwartz, I. and N. E. Sandberg. Effect of time in submarine service on vision. NavSubMedRschLab Rep. No. 253, Aug 1954.

5. Weitzman, D.O., J. A. S. Kinney, and A. P. Ryan, A longitudinal study of acuity and phoria among submariners. NavSubMedRschLab Rep. No. 481, Sep 1966.

6. Luria, S. M., H. Newmark and H. Beatty. Effect of a submarine patrol on the visual process. NavSubMed RschLab Rep. No. 641, Sep 1970.

7. McKay, C. L. and A. P. Ryan. Visual characteristics of submarine school candidates, submariners and Navy divers: Information derived from the Longitudinal Health study. NavSubMedRschLab. Rep. No. 767, Feb 1974.

8. Veldman, D.J. Correlates of visual acuity in college freshman. Percept Mot Skills 30, 551-558, 1970.

9. Hirsch, M.J. The relation between refractive state of the eye and intelligence test scores. Am J Optom & Arch Am Acad Optom 36, 12-21, 1959.

10. Young, F. A. Myopia and personality. Am J Optom & Arch Am Acad Optom 44, 192-201, 1967.

11. Hayden, R. Development and prevention of myopia at the United States Naval Academy. Arch Ophthal 25, 539-547, 1941.

12. Hirsch, M. J. Summary of current research on refractive anomalies. Am J Optom & Arch Am Acad Optom 43, 755-762 1966.

13. Lanyon, R.I. and J. W. Giddings. Psychological approaches to myopia: a review. Am J Optom & Physiol Optics 51, 271-281, 1974.

14. Sato, T. The Causes and Prevention of Acquired Myopia, Kanehara Shuppan Co., Ltd. Tokyo, Japan, 1957.

15. Young, F. A. The effect of restricted visual space on the refractive error of the young monkey eye. Invest Ophthal 2, 571-577, Dec 1963.

16. Young, F. A. Visual refractive errors of wild and laboratory monkeys. EENT Digest 27, 55-71, Aug 1965.

17. Young, F. A., G. A. Leary and D. N. Farrer. Four years of annual studies of chimpanzee vision. Am J Optom & Arch Am Acad Optom 48, 407-416, 1971.

18. Greene, M. R. Submarine myopia in the minutemen launch control facility. J Am Optom Assoc 41, 1012-1016, 1970.

19. National Center for Health Statistics: Visual acuity of youths 12-17 years, United States. Vital and Health Stat PHS Pub. No. 1000-Series 11-No. 127. Public Health Service. Washington, U. S. Government Printing Office, May 1973.

20. National Center for Health Statistics: Visual acuity of children, United States. Vital and Health Stat PHS Pub. No. 1000-Series 11-No. 101. Public Health Service. Washington, U. S. Government Printing Office, Feb 1970.

21. Kinney, J. A. S., C. L. McKay and A. P. Ryan. The measurement of blood vessels in retinal photographs of submariners. NavSub MedRschLab Rep. No. 619, Mar 1970.

22. Farnsworth, D. The Farnsworth-Munsell 100-Hue and dichotomous

tests for color vision. J Opt Soc Am 33, 568-578, Oct 1943.

23. Verriest, G. Further studies on acquired deficiency of color discrimination. J Opt Soc Am 53, 185-195, 1963.

24. Allen, M. J. and G. J. Wertheim. Corneal and scleral tonometry with the Plunger Lifter modified Schiotz tonometer. Am J Optom & Arch Am Acad Optom 43, 364-369, 1966.

25. Leatham, A. The retinal vessels in hypertension. Quart J Med 18, 203-215, 1949.

26. Paulson, H. M. Comparison of color vision tests used by the military services. NavSubMedRschLab Rep. No. 685, Oct 1971.

27. National Center for Health Statistics: Binocular acuity of adults, United States, 1960-1962. Vital and Health Stat PHS Pub. No. 1000-Series 11, No. 3. Public Health Service. Washington, U. S. Government Printing Office, June 1964.

28. Duke-Elder, S. The Practice of Refraction. St. Louis: The C. V. Mosby Company, 1954, p. 61.

29. Sorsby, A., M. Sheridan, G. A. Leary, and B. Benjamin. Vision, visual acuity, and ocular refraction of young men. Br Med J, 1, 1394-1398, 1960.

30. Sorsby, A., B. Benjamin, J. B. Davey, M. Sheridan and J. D. Tanner. Emmetropia and its aberrations: A study of the correlation of the optical components of the eye. Med Res Council, Special Report Series No. 293, London: Her Majesty's Stationery Office, 1957.

31. Borish, I.M. Clinical Refraction, 3rd Edit. Chicago, Ill.: Professional Press, Inc. 1970.

32. Wulfeck, J. W., A. Weisz and M. W. Raben. Vision in military aviation. Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, WADC Tech. Rep. 58-399, Nov 1958, p. 53.

33. Duane, A. Normal values of the accommodations at all ages. J. A. M. A. 59, 1010-1013, 1912.

34. Duane, A. The accommodation and Donders' curve and the need of revising our ideas regarding them. An experimental study. J. A. M. A. 52, 1992-1996, 1909.

35. Bausch & Lomb Optical Company, Rochester, N. Y. Instructions for Master Ortho-Rater and Modified Ortho-Rater 3rd edition, third printing.

36. Lichtenstein, M. San Diego County Fair Vision Survey. A study of visual skills: their distributions and interrelations. Nav Electr Lab, San Diego, Calif. Rep. 215, Dec 1950.