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MEDICAL RESEARCH DEPARTMENT

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New London

CONSIDERATION OF SUBMARINE MEDICAL PROBLEMS
AND
CURRENT STATUS OF INVESTIGATIONS
AT
U. S. NAVAL MEDICAL RESEARCH LABORATORY

21 February 1948

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PROBLEMS IN SUBMARINE MEDICINE

Submarine medical problems include the ever-present demands of the past, which are now augmented by improved methods, equipment and construction enabling deeper submergence, greater submerged speeds, and more prolonged effectiveness of the submarine.

For the benefit of the soldiers and surface-sailor readers, a submarine is a cigar-shaped craft the length of a football field, divided into nine water-tight compartments, powered for surface cruising by diesel electric drive, and for submerged running by electric motors powered from storage batteries. Ventilation on the surface is effected through air induction lines leading from the conning tower. Upon submergence, the air contained in the hull is recirculated and conditioned by refrigeration units. As necessary, air maybe revitalized by bleeding oxygen into the ship and absorbing carbon dioxide. Contrary to common belief, a negligible increase in pressure is experienced within the submarine during a normal dive.

Duration of submerged running is limited by the battery capacity. In order to prolong submerged operation, the snorkelling device was developed. The snorkel is a rigid, stream-lined, retractable housing containing two air conduits sufficiently large to respectively supply intake air and serve as engine exhaust. The length of the snorkel is sufficient to enable the submarine to run at periscope depth. The top of the snorkel is fitted with a water-closing valve which is activated when the snorkel head becomes awash through loss of depth control or advance of seas. Since the engines continue to function, this closure causes a partial vacuum to be induced in the hull of the submarine to the point where a switch automatically is activated to shut down the engines. In a seaway there is continuous and rapid fluctuation of ambient pressure induced by frequent closures of the head valve.

In snorkelling, submeriners physiologically have become aviators. A slightly decreased pressure is present in the boat during all snorkelling. Upon sudden closure of the snorkel head valve, the physiological altitude within the submarine rapidly increases, so that personnel are subjected to a rarified atmosphere reaching the order of 7,000 feet altitude. Upon surfacing and reopening of the head-valve, air at atmospheric pressure flows into the boat at a rate comparable to a vertical dive-bombing run of about 7,000 feet per minute.

This fluctuation of pressure requires patency of sinus ostia and continuous opening of the Eustachian tubes to compensate pressure in the middle ear and sinuses. Although selective screening of submarine personnel includes ability to compensate for increased pressure, a majority of individuals experience difficulty from time to time in clearing ears and sinuses. With continued snorkelling, the problem becomes more acute inasmuch as this is a voluntary process and not effected during sleep.

Acute pain in the ears and sinuses with induction of a traumatic otitis media result from failure to compensate for pressure fluctuation.

An adequate evaluation of the seriousness of this problem must await more prolonged periods of snorkel operation. This work is currently in progress. Findings to date have been of less magnitude than originally anticipated.

Due to the relatively small volume of air contained in the engine room, it is not operationally feasible to limit the snorkel induced fluctuation of pressure to that space. However, fluctuation-free sanctuaries may be necessary in portions of the ship for use of sleeping personnel and those temporarily experiencing inability to compensate for pressure variations.

Research and therapeutic use of radium applications to adenoid tissue of the nasopharynx has been carried on since 1944 in the submarine examining section of the laboratory. The method used follows the Crowe-Burnam technique originated in and validated since 1931. This procedure gives promise of prophylaxis or salvage of over 85% of those submariners unable to compensate for pressure fluctuation.

Carbon monoxide, carbon dioxide or hydrocarbon content of air in our snorkelling submarines has not been found in deleterious concentration.

No evaluation has yet been possible of the crew's emotional reaction to almost continuous submergence in prolonged snorkel operation, but it is believed with current selection procedures and adequate inter-patrol rest and recreation periods, that stability and effectiveness of the crew will be maintained.

It has long been realized that it is unsafe to man submarines with the general run of the population, due to the fact that certain individuals lack the attributes of intelligence, judgment, and emotional maturity, enabling them to serve aboard submarines with safety to the ship. A submarine is an intricate, highly complicated piece of machinery. It is a tremendously effective, but particularly vulnerable weapon of war. Since the organization of the Submarine Force, a degree of selection has been exercised by ex-submarine officers on other duty, and by attrition during submarine training. During the recent war, selective screening processes were developed, which have been retained and are in current use.

A selection screening program to the uninitiated carries a connotation of mystery; actually, it has been found that requirements are met by the following process:

(1) Elimination of personnel below median intelligence;

(2) Maintenance of reasonably rigorous physical requirements, particularly as regards special senses and freedom from chronic disease;

(3) Acceptance of only those men highly motivated for the Submarine Service;

(4) Elimination of personnel considered to be unstable emotionally, immature, and temperamentally ill-adapted to close living conditions aboard submarines on long patrol, the neurotics and others having psychopathic tendencies. Physical and mental status of individuals are amenable to measurement; the temperament, emotionality and psychiatric evaluation of the individual are obviously more difficult of determination and subject to errors. A judgment of these factors is made on the basis of written personality inventory tests, used only as a rough screening measure; by means of a personal interview conducted by a medical officer trained in submarines and employing a psychiatric approach; and by emotional reaction of the candidate during submarine escape training. This is an important, difficult, and fertile field for continuing study.

PROTECTIVE CLOTHING

Topside watch-standers on submarines have always been wet in inclement weather. In rough seas and cold weather, their physical tolerance has often been limited to 30 minutes. Spray is

commonplace; green seas, waist-deep, not unusual. For dryness, something comparable to a diving suit is required. Efforts have been directed toward the development of waterproof and warm clothing, without bulk, easily dried and economically stowed.

Working in conjunction with BuS&A, several experimental suits have been tested at sea during the past year, culminating in a contract for 500 of the resultant prototype for large-scale testing beginning this Fall. The current model is a one-piece, nylon, neoprene-coated, gusseted, zipper-closed, hooded, coverall type of garment, with snug wrist closure, and boots attached. The hood is designed separately from the garment with a waist-length inflatable skirt, to produce a Mae West type life-preserver. This suit, built large, and worn over warm woolen clothing, is found to be comfortable in cold wet weather. For extreme cold a study is being made of an electrically-heated undersuit. The greatest problem remaining is that of producing gloves which are warm and waterproof, yet non-slip and flexible.

LIGHTING

Throughout the Navy, lighting of ships is inadequately designed and executed. Submarines are no exception. Advances are being made in the lighting of instruments and illuminating for specific operational tasks, but the problem of general illumination remains.

Mass visual testing done on submariners two to three years ago showed clearly that those with two years in the service, as a group, had considerably poorer vision than submarine qualification requirements. This may be due to poor lighting in bunks. Men will read in bunks, and the problem cannot be remedied by saying they should not. On the other hand, other causes may need investigation.

A study is current under the cognizance of the Bureau of Ships, for improvement of lighting. It is believed that innovations aboard submarines will include specifications of color for working and living spaces, re-design of lighting fixtures, decrease of contrast ratios, and provision for adequate illumination for bunk reading.

SUBMARINE ESCAPE AND RESCUE

One of the hazards of submarine operations is accidental flooding of the hull to a degree that positive buoyancy cannot be attained by blowing ballast. This occurred in the SQUALUS disaster in 1939.

If the depth of the water is such that the hull is not crushed, it is likely that a considerable portion of the crew will be safe within the ship.

Two plans are in vogue for saving the crew. One is the submarine escape device, commonly known as the "lung", which is a rubber bag, equipped with a mouthpiece and carbon dioxide absorbent, so that oxygen may be breathed while floating to the surface. The second is the rescue chamber which requires that a diver attach a down-haul cable to a hatch of the disabled submarine, following which the 9-ton pear-shaped steel chamber pulls itself down and forms a seal over the hatch, which is then opened to remove the submarine's occupants for delivery to the surface. This method was employed on SQUALUS at 240 feet for removal of 33 men.

With stronger hull construction, deeper submerged operations are possible and submarine crews may be safely entombed within a disabled submarine at depths not feasible at this time for deep sea diving operations. Experiments are underway to develop measures enabling a disabled submarine to release a buoy which will surface the cable for hauling down the Rescue Chamber, obviating the necessity of employing a diver. Results to date have been unsatisfactory due to fouling of the cable.

Submarine escape by the breathing device, or "lung", has depth limitations due (1) to oxygen toxicity under increased pressure, if oxygen be used as the respiratory gas, due (2) to nitrogen narcosis and attendant confusion in flooding the escape trunk, particularly at pressures greater than 200 feet, and due (3) to the physical shock induced on contact with cold sea water.

Studies of augmented training and improved techniques of escape from disabled submarines have been begun, but currently are limited by personnel shortages. These studies include: (1) improved doctrine and augmentation of training to effect greater facility in the use of the present submarine escape appliance; (2) studies in feasibility of free escape, wherein a man without benefit of a breathing device maintains positive buoyancy and floats to the

surface, exhaling continuously to compensate for decreasing ambient water pressure; (3) a variation of free escape in which a man wears a flotation vest of about 25 lbs. positive buoyancy, thus greatly increasing speed of ascent and requiring that expiration be maximal throughout the ascent, and (4) (an absolute necessity for escape in very cold water), a water-proof coverall garment. It is recognized that at water temperatures of 32° - 34° F. shock ensues and death may occur within 10 minutes. This protecting garment is visualized as a light-weight, snag-resistant, hooded, plastic coverall, economical in stowage and slow in deterioration, which if free escape be found feasible for general training, will supplant the present submarine escape appliance. It is planned that helium-oxygen mixture be breathed during the flooding-down period preparatory to escape.

MEDICAL RESEARCH LABORATORY

Inasmuch as the Medical Research Laboratory, Submarine Base, New London, is the center of medical and psychological research, development and testing for the Submarine Force, it is considered pertinent that a resume be given of work in progress there. The Laboratory is inadequately staffed as to numbers, but those present are of high caliber. The application of the work being effected in a large part is not limited to submarine problems, but is basic in fields of vision, night vision, color vision, audio-research, and the psychophysiology of personnel selection. The heads of each of the facilites, --Forrest L. DIMMICK, Dean FARNSWORTH, J. Donald HARRIS, and Ellsworth B. COOK, were asked to assist in preparation of a resume of work in progress in each facility.

The General Visual Facility is at work on two problems in Night Vision:

The first deals with evaluation of tests for night vision. One of the duties of the examining medical officer is to eliminate for night look-out watch standing, men who are deficient in night vision. The subject of "night blindness" remained largely an academic matter until the imperative need in the last war led to the invention of a number of night vision tests. One of these, known as the Radium Plaque Adaptometer, was adopted as standard for the Navy. During the several years of its use this test has proved of considerable worth, yet it seems never to have been entirely satisfactory and many substitutes have been offered. A study is current in evaluating and comparing five adaptometers and attempt-

ing to develop an improved device for determination of night visual ability.

(a) The Radium Plaque Adaptometer consists of a black silhouetted "T" against a luminous disc of low brightness. The disc is always presented in the lower quadrant of the field of parafoveal vision. The orientation of the "T" silhouette can be changed and the test requires recognition of the correct position of the "T".

(b) It has been suggested by Livingston that a man's facility with night vision depends in large measure, if not entirely, upon the size of the central blind spot in scotopic vision, urging therefore that this central scotoma be measured and used as a test criterion.

(c) Following the same argument Korb has proposed determination by means of a diaphragm, the largest luminous area of low brightness that remains just invisible. Obviously (b) and (c) involve the same clinical principle.

(d) More recently, a mechanical device has been offered by Draeger and Lee of NMRI for presenting the stimulus by which scotometric measurements are made.

(e) Since the Hecht-Shlaer Adaptometer gives one of the more basic measurements of low adaptation levels, data are being obtained with it on all subjects used in the other tests.

(f) On the basis of experience with the foregoing and other night vision tests, a new instrument is under construction following the suggestions of Farnsworth, in an effort to attain a truer measure of night vision.

Since all tests of night vision depend upon some standard level of dark adaptation or its equivalent, it became necessary to determine the relative merits of dark goggles, red goggles and complete darkness in obtaining the necessary adaptation level. The study of these relationships has been completed and a report is now in preparation.

The second problem concerns the effect of illumination on visual acuity, taking into account the optometric corrections of the subject. The present emphasis is upon acuity at a low level of illumination.

The project originated under the late Dr. Franklyn D. Burger, an ophthalmologist, and emphasized the clinical approach. The original scope has been enlarged to endeavor to answer certain basic questions, such as: Does true "night myopia" exist? If so, what is its fundamental nature and what are the conditions which give rise to it? If it is true myopia, to what extent can it be corrected, or if it is pseudo, in what way can it be prevented?

The plan of procedure begins with the determination of acuity for checkerboard target resolution at light levels below 1 ft-L down to or beyond .0001 ft-L. This range is to cover primarily the scotopic levels.

The second group of measurements will be made in the region of combined scotopic and photopic vision which is being called mesopic.

In all determinations a wide range of subjects, from myopic to hyperopic will be used both with and without ophthalmic corrections.

Another section of the Visual Facility is continuing its evaluation of commercial optical devices for measuring such visual functions as acuity, phorias, and stereopsis. These include the Bausch & Lomb Ortho-Rater, the American Optical Sight Screener, and the Keystone View Telebinocular. All of these instruments are far from ideal, but a comparison of their performances with the standard clinical method is warranted since the commercial devices are especially suited to situations where time, space, and optometrically trained personnel are at a premium. In this work, the standard of comparison is the New London chart which uses letters constructed according to Snellen specifications but equated for difficulty of seeing, and with more gradations of acuity at the critical level between 20/20 and 20/15.

The reliability of measurement with screening instruments, following procedures prescribed by the manufacturers, was found to be slightly inferior to that of meticulously conducted letter-chart tests. Visual screening devices are as reliable, apparently, as the clinical methods for the measurements of heterophoria.

A factor analysis study of this data conducted by the Adjutant General's Office revealed the presence of several independent factors which played a definite role in the variance of test scores obtained. These acuity factors were labelled "retinal resolution", "lens accommodation", "form (letter) perception", "depth perception", and "resistance to interference", the last being definitely a machine factor. In the phoria data the factors were identified

as "lateral phoria", "near lateral phoria" (or convergence efficiency), "vertical phoria", and "anti-fusion". There seems to be a general lack of relationship between the acuity and phoria factors. Results of investigation stress avoiding assumptions of interchangeability of either interpolation of scores or validities from one machine or method to another. Non-pertinent factors account for a sizable portion of test scores, varying with each instrument and method.

To determine whether the differences in scores obtained between screening devices and clinical visual testing is attributable to the instruments themselves or to the different test objects used, an experiment was done in which the machine test targets were photographically enlarged so that the same visual angle was subtended on wall charts as on the machine targets. These data are currently being analyzed.

As time and personnel permit, future plans include continuance of efforts to separate and examine causes of test variance.

The Color Vision Facility is devoting an increasing amount of time to problems involving normal, rather than abnormal, color vision. Color blindness is so fascinating, and in some ways so mysterious, a phenomenon that it has always received an undue amount of publicity. Because the facts of color blindness are intricate and beyond the scope of knowledge of most doctors and personnel specialists, it becomes the job of the laboratory to explore and develop these facts into easily usable tests.

The Navy Lantern is a case in point. Since 1900, it has been generally accepted that lantern tests provide the most valid method of testing color vision for maritime, naval, railroad, and, in later years, the aviation service. The names of these lanterns are familiar: the Board of Trade Lantern in England, the Williams Railroad Lantern in America, the Royal Canadian Navy Lantern, the Royal Canadian Air Force Lantern, and the Edridge-Green. Since 1942, the Laboratory has been studying such lantern tests and incorporated the results of continuous independent research to produce a test for color vision, now known as the Navy Lantern.

This device is believed to be the answer to the long-time troublesome problems of screening the unsatisfactory color blinds from the usable border-lines and near-normals, and removing the variables inherent in testing for color deficiency by unspecialized examiners. Twenty-five finished trial models of the Navy Lantern will be completed this month for field distribution and final test.

It is designed to satisfy the following conditions:

(a) reject the dangerously color defective,

(b) pass the borderline and near-normal group (who are likely to distinguish color codes as are normals),

(c) eliminate most of the variables in testing which have been responsible for the confusion in the past, and

(d) give a definite pass-fail response, which requires no personal judgment nor experience on the part of the operator.

The study of color vision has much broader fields of use to the Armed Forces. The majority of the laboratory's work in Color Vision is devoted to color applications for normals in such fields as:

(a) the use of color in instrumentation; interpretation and transmission of data;

(b) reinforcement to shape, position, symbols in indicators, dials, meters;

(c) the examination of thresholds of color sensation, signal strengths and visibility ranges;

(d) influence of color on habitability;

(e) relation of illumination to color and color to illumination;

(f) transmittances in sunglassware for eye protection and for color rendition; and

(g) use of color in specialized devices such as recognition, restricted signalling, orientation, confusion of the enemy, selection of color codes, dark adaptation, and fluorescence.

The Sound Facility of the Laboratory is engaged in three areas of auditory research which have direct bearing on sonar selection, training, and doctrine: these areas are, first: auditory acuity, the ability to hear very weak sounds; second, pure tone discrimination, both for pitch and for loudness; and third, the effect on such discrimination of a masking background of noise.

In auditory acuity, a region of 2-6 decibels has been recently found between the point at which an indefinite sound can be detected, and the point at which it can be recognized as a pure tone. This region has been named the "zone of detectability" by Hallowell Davis and represents a very useful range of intensities, now largely overlooked in sonar training and doctrine. This zone varies with frequency, and with level of background noise.

Sound level measurements have been taken recently of a fleet-type Submarine while cruising on the surface. These readings indicate that no compartment except the engine room generates sufficient noise to be of serious psychological or physiological consequence. Whatever deleterious effects on vital processes occur may be rather quickly overcome by adaptation to the noise. The noise spectrum is not an excessively annoying one, being peaked below 500 cps; a General Radio wave analyzer was used.

In the engine rooms, overall levels from 109 to 124 db were recorded for various maneuvers and microphone positions. This is somewhat less than the earlier boats, and is within the limits of tolerance which Davis has shown can be learned by normal subjects.

In the area of pitch discrimination, a psychophysical technique has been devised which overcomes nearly all the constant errors and which produces a true differential threshold. It is found that the accepted concepts of discriminability must be altered. For example, at 4000 cps, the traditional view from the work of V. O. Knudsen and of Shower and Biddulph is that the average person can discriminate about 12 cps. But if their warble method is superseded by a technique which allows only a second or less to elapse between the standard and the comparison stimulus, this figure of 12 cps rises to 50 or more. We are at present covering the auditory area with this technique.

In the field of loudness discrimination, discriminability for complex noises is being investigated. The only published data report decibels discriminable solely for an increase in loudness; we find a distinct difference between increases and decreases. Data have been collected on discrimination as a function of time interval between standard and comparison noises. These data bear on the doctrine of listening with sonar gear.

In studies concerning pitch discrimination in a noise background, research is nearing completion on cycles discriminable as a function of signal/noise ratio. The parameters of overall noise level have been drawn, and of frequency up to 2000 cps. These data bear on the extent of training needed in echo-ranging, and on echo-ranging doctrine in general.

In a joint psycho-physiological-medical study in personnel selection the laboratory instituted research in 1946 to study the 17-ketosteroid excretion and blood lymphocyte changes in connection with stress situations, induced in the Submarine Escape Training Tank.

This project was instigated by studies from the Worcester Foundation for Experimental Biology which indicate that stresses result in changes in adrenal cortical activity and are reflected both in the urinary output of 17-ketosteroids and in alterations in lymphocyte count. Variations in these responses were found to be related to fatiguability and psychological factors significant to success in the military service.

In addition to a study of the ketosteroid functions the project included other areas of investigation such as anthropometric measurements and body typing, physical fitness tests, psychiatric and psychological tests, and blood cellular alterations. Subjects used were 120 enlisted candidates for the Submarine School. The various tests were administered by qualified submarine medical officers. Every effort was made to maintain conditions of extreme uniformity throughout the testing period, including standardization of diet and conditions of leisure-time activity.

From this program some 400 variables were obtained on each subject. For purposes of convenient handling of such a quantity of data, the results were grouped into sub-studies of thirteen such areas or matrices. Each matrix was subjected to a factor analysis in order to reduce the 400 variables to some 10 or 15 independent and significant factors. The statistical analysis is progressing. The data would appear to indicate that each matrix is composed of definite factors which should explain the intercorrelations obtained between the various items composing each group. By way of illustration, it seems that three distinct factors emerge from the physical fitness study - a pulse rate factor, a blood-pressure factor, and a hand dynamometer factor. The blood data appear to indicate that in the differential counts there is a distinct factor for each type of blood cell, and in many cases, a separate factor for the stress and psychological samples.

This program was not designed in anticipation that its results would be immediately or directly applicable to the selection of candidates for submarine duty. The hope is, rather, that on the basis of this study it will be possible to establish a simple selection battery consisting of the primary physical, physiological and psychological data, and that these may then be validated in a second study, simpler in design and consequently larger in scope, the results of which might have direct application in selection procedures.

In addition, a number of perhaps more valuable by-products are anticipated from the project. The massiveness of the data makes available for the first time the possibility of inter-relating in a single population, measures from a number of related but distinct scientific fields, such as the medical, the anthropometrical, the psychological, the psychiatric, the physiological, and the biochemical. Investigations include for example, the relationships of two independent scorings of the Rorschach ink-blot tests now so popular among psychiatrists. The correlational relationship in healthy male adults between the various types of white blood cells is investigated here in a sizable population for the first time. A repetition is included of one of the leading studies of body types and the relation of such types to other measures. Finally, initial studies are being made into the biochemistry of nervous stability.