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THE FOURTH UNDERSEA MEDICAL SOCIETY WORKSHOP

THE DEVELOPMENT OF STANDARDIZED ASSESSMENT OF UNDERWATER PERFORMANCE

Naval Medical Research Institute

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4-5 October 1973

Workshop Chairman

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UNDERSEA MEDICAL SOCIETY, INC.
9650 Rockville Pike
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THE DEVELOPMENT OF STANDARDIZED ASSESSMENT
OF
UNDERWATER PERFORMANCE

ARTHUR J. BACHRACH, PH.D.

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The Fourth Undersea Medical Society Workshop

THE DEVELOPMENT OF STANDARDIZED ASSESSMENT OF UNDERWATER PERFORMANCE

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4 October 1973

Session I

0900 Session Chairman: Dr. Glen H. Egstrom, UCLA

0900 Dr. Egstrom
Introduction & Review of ONR/UCLA Workshop - October 1, 2, 1973

0930 Dr. Peter B. Bennett, Duke University
"Systems of Underwater Performance Assessment"

1000 Coffee break

1020 LCDR Thomas E. Berghage, Experimental Diving Unit
"The Background of SINDBAD"

1100 General Discussion:
Discussion Leader: Dr. K. N. Ackles,
Defence Research Board of Canada

1130 Lunch

Session II

1315 Session Chairman: Dr. George Moeller,
Naval Submarine Medical Research Center

1325 Dr. Edwin Fleishman, American Institute for Research
"An Ability Rationale for Test Selection"
Comments: CDR L. W. Raymond, Naval Medical Research Institute

1345 Dr. Gretchen Kolsrud, BioTechnology, Inc.
Dr. James Parker, Jr., BioTechnology, Inc.
"The Measurement of Human Capacity in an Operational Setting"

1415 PANEL: Dr. Warren Teichner, New Mexico University
Dr. Glynn Coates, University of Louisville
Dr. W. Dean Chiles, Federal Aviation Administration

1500 Coffee break

October 4, 1973

Session II

1530 General Discussion:
Discussion Leader: Mr. Gerald Malecki, ONR

1630 End of Session II
Hus leaves for Linden Hill

October 5, 1973

Session III

0900 Session Chairman: Dr. James W. Miller, NOAA

0910 LCDR Thomas E. Berghage, Experimental Diving Unit
"Preliminary results obtained on SINDBAD"
Comments: Dr. Warren Teichner

0940 Comments: Dr. Glynn Coates, University of Louisville

1000 Coffee break

1015 PANEL: Dr. Glynn Coates, University of Louisville
LCDR Robert S. Kennedy, Naval Missile Center
Dr. Alan Baddeley, University of Stirling
Dr. John Adolfson, Swedish Royal Naval Staff

1100 General Discussion:
Discussion Leader: Dr. R. W. Hamilton, Jr., Ocean Systems, Inc.
Comments: LCDR R. S. Kennedy

1130 Lunch

Session IV

1315 Session Chairman: Dr. Paul D. Nelson, Bureau of Medicine & Surgery

1325 Dr. R. Bornmann, BuMed
"Scientific and Operational Needs for Performance Assessment"

1400 Summary of Conference: Dr. Paul D. Nelson

1430 General Discussion:
Discussion Leader: Dr. Glen Egstrom, UCLA

1515 Coffee break

October 5, 1973

Session IV

1530 Overview and Recommendations: Dr. Arthur J. Bachrach

1600 End

INTRODUCTION

Arthur J. Bachrach

There has been a growing concern among researchers in underwater performance that a lack of standardized administration of tests exists, and, a lack of standardized tests makes cross-comparison of the many studies difficult, if not impossible. As an example of the problem, Baddeley (1966), an experienced underwater researcher, compared his research on manual dexterity in the open sea with the work on manual dexterity of Kiessling and Maag (1962). But, Baddeley used a screw-plate nut and bolt assembly--an arm-hand test which does, according to the factor analyst, measure manual dexterity; Kiessling and Maag used the Purdue Pegboard, which requires finer coordination and would be classified as a test of finger dexterity. These studies are therefore not comparable in the way that Baddeley suggested.

Another crucial source of error in the various studies is subject variability. A look at major studies reveals that inexperienced and experienced divers have been used in studies as a theoretically homogeneous population, a particular source of concern in view of the studies that suggest experience is a crucial factor in diver performance (e.g., Shilling and Willgrube 1937).

There is good reason to be concerned about the lack of standardization in the administration and use of performance measures in underwater research. The purpose of this conference was to bring together authorities with different orientations in performance, to consider the problem, and (hopefully) to develop a means of solving it.

A significant part of the program was devoted to a discussion of the uses and limitations of The SINDBAD System, which has been proposed as a standardized assessment of underwater performance. Presented in this report are selected statements and comments from participants which reflect their views on the content of the Workshop.

SYSTEMS OF UNDERWATER PERFORMANCE ASSESSMENT

Dr. Peter B. Bennett

The constraints of pressure and volume in accordance with Boyle's Law are such that it is necessary for diving gas to be supplied at the pressure of the water surrounding the diver. The effects of these gases at increased pressures plus the pressure itself are responsible for much of the performance decrement of the diver. These effects fall into two major categories: those due to raised nitrogen partial pressures and those due to helium or pressure.

Nitrogen Narcosis

A phenomenal number of tests have been devised and used to quantify various aspects of performance decrement due to nitrogen or other inert gases. As early as 1937, Shilling and Willgrube used single and multi-choice reaction time together with an arithmetical multiplication test. Various forms of arithmetic tests have been used with some success by many workers (Shilling and Willgrube 1937; Case and Haldane 1941; Rashbass 1955; Miles and Mackay 1959; Bennett and Glass 1961; Albano, Criscuoli, and Ciulla 1962; Barnard, Hempleman, and Trotter 1962; Baddeley 1966; and Ackles and Fowler 1971) and have been criticized by others (Kiessling and Maag 1962). Similarly, reaction time has been popular (Shilling and Willgrube 1937; Kiessling and Maag 1962; Frankenhaeuser, Graff-Lonnevig, and Hesser 1963; Hesser 1963; Adolfson 1964, 1965; Adolfson and Muren 1965; Bennett, Dossett, and Ray 1964; Bennett, 1965). Such tests have been utilized in studying the effects of work, oxygen, carbon dioxide, and adaptation to inert gas narcosis.

Among psychomotor tests that have been used are the Purdue Peg-board (Kiessling and Maag 1962; Bennett 1967; Bennett and Towse 1972), the Ball Bearing Test (Bennett 1965; Bennett and Towse 1971a, 1972), and the Nut and Bolt or Screwplate Test (Adolfson 1964, 1965; Adolfson and Muren 1965; Baddeley 1966; Davis, Osborne, Baddeley, and Graham 1972; Schreiner, Hamilton, and Langley 1972). Other less widely-used tasks have varied from Moede tracking and the Stroop test (Hesser 1963; Hesser, Adolfson, and Fagreus 1971), conceptual reasoning (Kiessling and Maag 1962), mirror drawing (Hesser 1963), card sorting (Poulton, Catton, and Carpenter 1964; Bennett, Poulton, Carpenter, and Catton 1967), the Wechsler Bellevue Digit Symbol Test (Bennett and Towse 1972), handwriting size (Cabarrou 1964, 1966; Zaltsman 1961, 1968) and more recently statometry (Adolfson, Goldberg, and Berghage 1972).

Many of these tests are prone to a wide variability due to problems of motivation and variety of subjects, learning and adaptation, various rates of compression and inert gas and oxygen partial pressures, temperature, working or resting diver, distractions, illumination, poor communications, experiments in water or simulated in the dry.

These variables have made comparison of results between workers virtually impossible. Statistical correlations are often equally impossible since full data is not given and in many cases only mean points are plotted without SD or SEM.

Due to these difficulties attempts have been made to use physiological rather than psychological tests; in particular, the electroencephalogram utilizing frequency analysis and cortical evoked potentials (Bennett and Glass 1961; Zaltsman 1968; Bennett, Ackles, and Cripps 1969; Ackles and

Fowler 1971; Kinney and McKay 1971; Bevan 1971; Townsend, Thompson, and Sulg 1971; Schreiner, Hamilton, and Langley 1972; and Bennett and Towse 1972).

High Pressure Nervous Syndrome (HPNS)

A number of the tests above have been used also in quantifying the changes due to breathing helium at pressures greater than 15 ATA as discussed in a recent review by Hunter and Bennett (1974). Thus, arithmetic and the ball bearing test have been used (Bennett 1965; Bennett and Dossett 1967; Buhlmann, Matthys, Overrath, Bennett, Elliott, and Gray 1970; Bennett and Towse 1971b; Fructus, Brauer, and Naquet 1971) to quantify the intellectual deficit and the psychomotor effects due to the tremor.

Although (as with nitrogen narcosis) there have been many kinds of tests tried by different individuals, there are two aspects of the HPNS that have merited a more novel approach. These are in terms of quantification of the tremors and changes in the electroencephalogram. The former tests of postural and intentional tremor by transducers using frequency analysis have been reviewed by Bachrach and Bennett (1973).

EEG changes have been noted by many workers, especially those using evoked potentials or frequency analysis (Zaltsman 1968; Bennett and Towse 1971b; Fructus, Brauer, and Naquet 1971; Fructus 1972; Proctor, Carey, Lee, Schaefer, and van den Ende 1971).

In conclusion, it is evident from the large variety of tests and techniques that there is a need for standardization of the number and type of tests and the form of analysis of the data. SINDBAD may be the answer to this problem as will be considered during this workshop. However, it would seem that the number of tests used by this device need to be reduced from the large number presently available, otherwise the difficulties of correlation between results from different investigators will continue.

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A MEASUREMENT OF HUMAN CAPACITY IN AN OPERATIONAL SETTING

Dr. Gretchen Kolsrud
Dr. James Parker, Jr.

Drs. Kolsrud and Parker distributed a report entitled "An Integrated Measurement System for the Study of Human Performance in the Underwater Environment--The Sindbad System," which appears as the Appendix to this report. Much discussion centered around this material.

COMMENTS ON SINDBAD

LCDR Thomas E. Berghage, MSC, USN

An outline of the human performance problem was presented in which human performance is viewed as a function of four main classes of variables. These classes of variables are: (1) the environment, (2) the equipment, (3) the human, and (4) the procedures. The performance tests that have been used to date were designed primarily to evaluate a single class of variables, the most common class being the environmental variables. All of the various performance tests that are used throughout the diving research community have some utility in assessing performance in one or more of the above mentioned categories.

The SINDBAD test battery was designed to evaluate man's cognitive and perceptual motor abilities in wet or dry hyperbaric environments. It may also have some utility in evaluating the effects of various environmental factors, however, there are probably more sensitive measures available. The question of how man responds in the high pressure environment is an important one and should be pursued in a systematic way. SINDBAD provides a systematic approach based upon a great deal of theoretical work.

Up to this time, 30 U.S. Navy divers from the Experimental Diving Unit have been tested on SINDBAD in a dry surface environment. The normative data gathered on this test series has been analyzed; the results have appeared as an EDU report.* Preliminary results presented at the meeting indicated there

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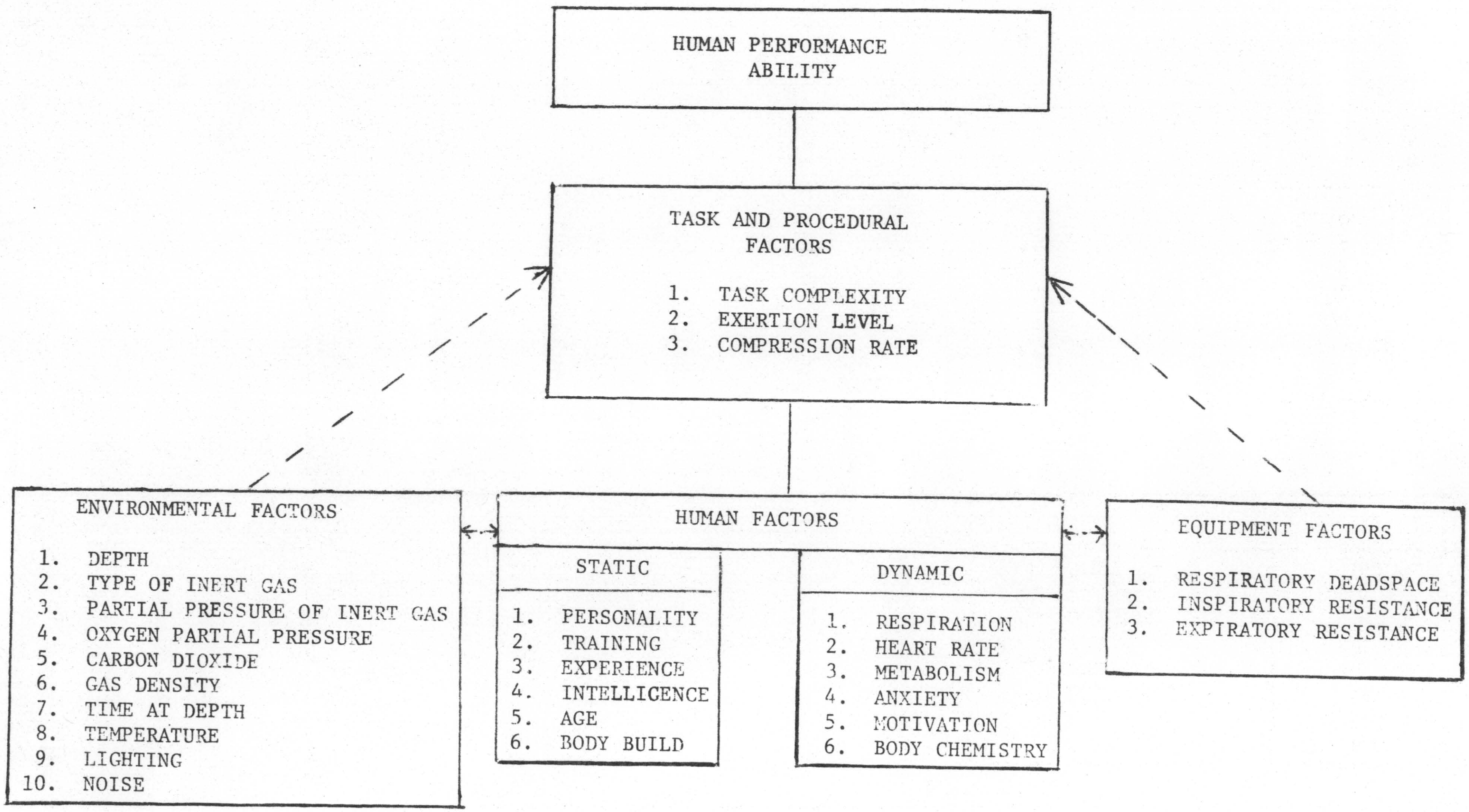
*Bain, E. C., III, and T. E. Berghage. 1974. Evaluation of SINDBAD tests. Report 4-74, U.S. Navy Experimental Diving Unit, Washington, D.C., 1 June.

is very little correlation between the 22 various tests administered. It appears that the tests within the battery conform to the theoretical factorial structure originally hypothesized.

An important question remains: How do the tests incorporated in SINDBAD relate to real life work tasks? A validation study is needed to answer this question. Most of a diver's activities require gross motor abilities and this type of ability is not taped by the SINDBAD test battery. Future advances in the undersea environment may well require high levels of human skill and will thus be more aligned with the SINDBAD system.



ADOLFSON-PERCEPTION FIG. VII-II W-100

COMMENTS by Dr. W. Dean Chiles

The development of techniques for the assessment of underwater performance required attention to a set of problems that are encountered in any effort that attempts to secure measures of human performance which will be of relevance to operational environments. Foremost among these problems is the criterion problem, i.e., what is it, in quantitative (and qualitative) terms, that we are trying to predict in the operational situation? In other words, we must be able to specify with at least some degree of precision those behaviors that are involved in, and especially, those that are crucial to, the operational performance of interest. The ultimate test of the validity of the research approach used depends upon the availability of reliable measures of such operational performance.

The absence of reliable measures of operational underwater performance (and most other operational performances) severely complicates the research problem and forces the use of indirect approaches. Specifically, attention must be directed toward the development of tests and test devices that it is hoped will permit the following kinds of statements: if a man performs satisfactorily on (laboratory) (synthetic) (simulated) task A under certain water pressure, temperature, and breathing-air conditions, then he should be able to, for example, repair such and such a device under comparable operational conditions; or, if a man cannot perform...etc., then he will not be able to repair...etc. From this point of view, it is clear that the operational value of the research products will depend on the extent to which the important behavioral functions required in the operational performance are tapped by the experimental test devices. Thus, the behavioral scientist must depend upon expertise (his own, if he has it) in the particular operational field of inquiry for the identification of the specific behavioral functions to be measured. Once these functions have been identified, particular tests can be selected or devised which will both satisfy the generally-agreed-upon research criteria the tests should meet and, again going back to appropriate expertise, appear to measure the behavioral functions of importance to the operational situation (i.e., the tests must, at a minimum, have content validity). Of course, given sufficient time and resources, large numbers of tests could be screened and the final selection made from among those that appear "to do the job," but time and resources in the amounts required to use this approach are usually luxuries not available to problem-oriented research efforts.

My own particular methodological biases lead me to suggest that the best approach to the general problem of assessing underwater performance is: first, define the kinds of behaviors the diver must exercise in those situations on which research attention is going to be focused; second, with the help of experts on such behaviors, devise tasks, the performance of which appears (content validity) to embody those behaviors, third, synthesize a task complex that affords the proper degree of approximation to the complexity of the operational situation; and, fourth, assure the collection of appropriate background data on the components of the task complex (e.g., reliabilities and task interactions). (It should be noted that the fourth element of this suggested approach is crucial to any approach that hopes to achieve generality and, in the process, standardization in the assessment of (underwater performance.)

It can be argued successfully that the ultimate utility of the particular approach to be followed is an empirical question. Only time and research can tell us whether tests deriving from externally-defined ability-categorization schemes, synthetic performance batteries, or maximum fidelity simulation provide the most useful information with satisfactory levels of efficiency. However, I would insist on one very important qualification to this statement: it is necessary that the performance required by the experimental test device approximate the complexity of the operational performance. This is especially true when it is clear that the operational performance involves the time-shared execution of discrete behavioral functions. The present state of development of the art of performance measurement does not afford analytical techniques that can be used to specify how the performance of various individually-measured task elements will be affected when those task elements are combined into a task complex. The closeness with which experimental task complexity must approximate operational task complexity cannot be specified as a generalization; each operational situation must be considered in the entirety of its behaviorally-relevant properties. It can be argued, of course, that my qualification relating to complexity is itself also ultimately an empirical question, but I am quite confident about the <u>general</u> nature of the ultimate answer to that question.

COMMENTS by Dr. Warren H. Teichner

Investigators active in the measurement of undersea performance appear to be approaching the problem of performance effects from one of two general points of view. The first of these is represented by "tests" based on factor analytic solutions which in turn make use of correlations among the performances of individuals on devices which it is hoped require different abilities for their operation. It is important to note that the tests are the same in kind as those used in the second approach to be described below.

In this first approach the factor analytic solution provides indices of the degree to which individuals operating the testing devices can be identified in terms of a set of abilities which is smaller than those which were originally hypothesized for the tests. The point is that the factor analytic solution provides a means for evaluating individual differences in performance abilities. Ignoring any evaluation of how well it does that, and ignoring everything but the existence of the original tests, the tests themselves stand as proposed performance devices of no greater validity or reliability than those used for the second approach. In fact, as tests they are indistinguishable.

The second approach appears to start with a desire to measure basic psychological functions and to relate the effects of environmental conditions on those functions to physiological changes. At least in terms of what I heard presented at the meeting, the psychological functions being investigated are being treated from a very unsophisticated viewpoint. The level of understanding appears to be that of the early days of studying the effects of altitude associated with the development of the airplane. One finds a search for tests which are "sensitive." A sensitive test is defined circularly as one that shows effects. The results of different studies are quite inconsistent, however, even when the same device is used largely due to a failure of investigators to use available information for establishing the conditions of normal or control testing. As an example, simple reaction times are used because they are assumed to represent some vaguely implied process, but no attention is given to well-established stimulus intensity and duration functions. Clearly, whether an effect will occur will depend importantly on whether it can occur. The example of simple reaction time is also a good one for illustrating a general failure to ask why a particular process would be expected to be affected in the first place; that is there appears to be a general lack of attention to predictions that could be made from available theory.

In summary, my reaction to what I have heard is that the field of undersea performance research is characterized by trial and error thinking rather than an exploitation of the basic information and theory in the field. I should add (on a somewhat different note) that I sensed that part of the reason for the rather primitive state of this effort is a lack of understanding and acceptance by medical and physiological persons of what can actually be done.

Summary of the Workshop

COMMENTS by CDR Paul D. Nelson, MSC, USM [1]

During the past few days we have been a part of stimulating, and occasionally controversial, discussions about performance assessment in the underwater world of divers and swimmers. We have also talked at times as though we have in mind a common concept of the underwater environment, the man in that environment, of what he is supposed to be doing in that environment, and of our research goals related to his performance. Such is, however, not the case; we actually represent a far more heterogeneous set of concepts regarding all of those matters.

If we are to make such progress in developing reliable tests or other measures of human performance capability, sensitive to individual differences and/or intraindividual change in the same, for application to the underwater work environments of divers, we should I think pay a bit more attention than I sense we have (at least during this workshop) defining our similarities and differences in point of view about the object of our research.

We began the week by reviewing what we know (and what we don't know) about the diver's work capacity, his sensory and perceptual capabilities underwater, about his cognitive functions, and his task skills in underwater environments. That discussion led, by nature as well as by design of the workshop, to our discussion during the past day or more of assessment or performance measurement methods essential to observing man in the underwater

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[1] Head, Human Effectiveness Branch, Research Division, Bureau of Medicine and Surgery, Department of the Navy.

work environment, in hopes that some standardization of measurement techniques might allow us a more systematic source of data about the diver's tolerance for the stresses inherent in his work and working environment. We chose, additionally, to focus on the SINDBAD test system as a possible "strawman" about which to rally in that endeavor. But I think it clear, though some may disagree, that there is no single performance test or measure, even combinations thereof, which will be equally useful to all the participants of this workshop, nor the communities they represent, for the particular problems they have. For such is seldom the case in science nor is it typically the case in clinical applications of technologies derived from science, as in the field of medicine itself.

First, let's examine some broad classes of objectives which we collectively share. I find Dr. Bachrach's comments useful in this regard where he suggests that our research efforts to date reflect at least two major objectives. One of these is to develop techniques by which to monitor CNS integrity, to include, as I would interpret, man's thought processes, his sensory, perceptual, and motor skills, as well as neurophysiologic behaviors related thereto. This orientation is especially prominent in research on saturation diving wherein pressures and breathing gas mixtures have, at least hypothetically, effect upon man's Central Nervous System and perhaps its performance corollaries.

The second broad category of research objectives seems to pertain to endurance and work tolerance capacities of divers or swimmers, more prevalent an orientation among those studying shallow water diving, wherein such variables as water temperature and turbidity, work loads and schedules, and diver/swimmer equipments appear more restrictive as conditions of work and environment than those conditions presumed to more directly affect the Central Nervous System integrity. These appear to be related but somewhat different orientations, though common to both is a concern for measuring human functions or capacities of significance to a diver's work performance. Both are important, too, for Navy diving. But the way we study divers in these two broad categories of objectives, and the environments as well as diving operations they represent, are likely to be quite different, if only by virtue of the constraints levied upon the investigator by the very environmental conditions in which the diver is being observed.

Where do we go from here to pull these somewhat different orientations together? One thing needed in my opinion is a standard taxonomy of swimmer/diver operations, by which to classify types of dives, types of diving procedures, and work tasks to be performed: environmental parameters of significance: and even perhaps the nature of the diver or swimmer involved (e.g., how is he trained, equipped, even motivated). This might require task analysis procedures applied in a broad sense to the variety of diving operations currently conducted or anticipated. Perhaps this information is already known by those of you closer than I to diving and diver performance research. If so, it might have been a starting point for this workshop so that we could have had somewhat more of a common orientation (especially those participants totally unfamiliar with diving operations). I suspect, however, that a systematically-developed taxonomy of value to biomedical and behavioral scientists does not yet exist.

From such a taxinomy we might better proceed in our efforts to outline:

(1) those human functions, physiological and behavioral, most critical to different diving situations;

(2) those environmental or procedural constraints most likely to affect such human functions; and

(3) those tests or measures of such functions which appear feasible either by construct validity or by practicality.

We must also be concerned, as has already been suggested at this workshop, with the potential applications of data and knowledge we develop from measuring human functions. Are we, for example, concerned with diver selection and training; perhaps with human engineering design of diver equipment or supporting habitat; possibly with developing work schedules or other procedural guidelines for divers; maybe with monitoring divers on the job for the purposes of safety? All may be legitimate applications for various types of diving operation, but each makes some difference, too, in the types of tests or measures we develop, the testing procedures themselves, the design of our research, and the analyses we conduct of the data so generated.

Finally, it seems to me that we should pool what information we already have about diver performance measures or tests. I would guess that not all participants of this workshop intend to put a SINDBAD test battery into their laboratories or research design; and that is probably as it should be. But for those who either have such capability at present, or intend to have in the near future, there should be coordination of research such as to develop the types of information needed to standardize SINDBAD tests under certain diving operations, perhaps to further refine it for greater utility in the future, and to employ in conjunction with the SINDBAD test system other tests or measures of human functions, both similar and different in apparent nature from those tapped by SINDBAD tests, so that questions concerning equivalence of measures can more readily be ascertained. Each of the participants here undoubtedly has his own "pet" measures or tests of such human functions and knows of still others at large, presumably useful to those who employ them, which should be documented in standard manner (e.g., what does the test involve, how is it administered, how are observations scored, what is its reliability, its concurrent, construct, or predictive validity, and so forth). And here I would even include the possibility of such subjective rating scales pertaining to emotional states, fatigue, or motivation as perhaps have been worked out and found useful by researchers in other than diving operations.

Such a collection of tests and other measurement techniques, with supporting information of their nature, should be carefully screened and put together initially as a package for distribution to all interested researchers. Communication among researchers employing common techniques might thereby be enhanced and, if multiple tests are employed in research, we would have, again, a better opportunity to assess test equivalencies or lack thereof.

The problems we have discussed in relation to diver performance are, unfortunately, not unique to research conducted in the operational field.

They represent problems we still have, as psychologists, physiologists, and physicians alike, in our endeavor better to assess human performance in general. But I feel we have an opportunity in the focused, though heterogeneous, activities of diving to contribute to the development of a better technology in performance assessment including the systematic procedures essential to that development. I have, in that sense, enjoyed being a part of this workshop.

APPENDIX

to

Fourth UMS Workshop Report

An Integrated Measurement System
for the Study of Human Performance
in the Underwater Environment

--The SINDBAD System--

AN INTEGRATED MEASUREMENT SYSTEM FOR THE STUDY OF HUMAN PERFORMANCE IN THE UNDERWATER ENVIRONMENT

-The Sindbad System-

Developed by

Raymond E. Reilly
Bernard J. Cameron

BioTechnology, Inc.
Falls Church, Virginia

Office of Naval Research Contract N00014-67-C0410
Work Unit No. NR 196-074

Installed at

Naval Experimental Diving Unit
Washington, D.C.
1968

SINDBAD I:* AN INTEGRATED PERFORMANCE MEASUREMENT SYSTEM

Developed By: BioTechnology, Inc.

Under Contract To: Office of Naval Research

As man's role in the sea continues to expand, the need increases for basic information concerning his ability to function in the undersea environment. The required development effort includes test equipment and techniques appropriate for high pressure underwater conditions and tests and measures clearly related to the operational tasks performed by divers.

The SINBAD I system was designed for use in the environmental chambers of the Navy Experimental Diving Unit. The system enables measurment of human mental and perceptual-motor functions at ambient pressures of up to 444 lb/in^2, equivalent to a depth of 1,000 feet. The equipment will operate in wet or dry surroundings.

System development began with the identification of a set of potential primary abilities and related performance measures applicable to present and anticipated diver activities. From the alternative tasks or tests identified for each selected ability factor, the particular measure to be included in the system was selected. Selection involved the application of three basic criteria. These were:

1. methodological considerations (e.g., factorial purity, range of ability levels covered, sensitivity);
2. engineering constraints; and
3. practical considerations.

Hardware conceptualization, design, fabrication and testing was then completed.

Figure 1 is an artist's rendering of the system in operation in the Experimental Diving Unit. The system consists of: an experimenter console, an electronics package containing digital and electronic circuitry, a visual display system and a subject console with ancillary equipment.

*System for Investigation of Diver Behavior at Depth.

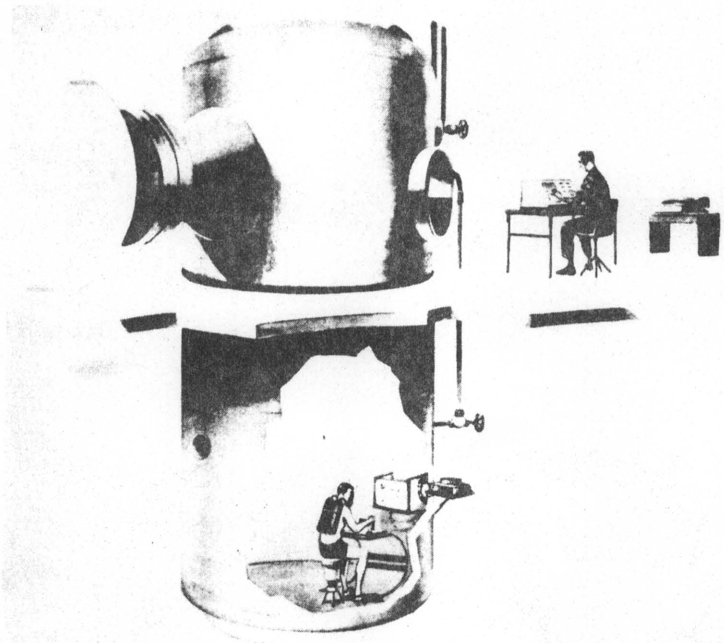

Figure 1. Artist's rendering of operational SINDBAD I system.

All tests are selected and administered from the experimenter console shown in Figure 2. Programming and scoring are accomplished almost entirely by solid-state integrated circuits. Subject responses are presented to the experimenter by means of optical digital displays, three electromechanical counters and a microammeter.

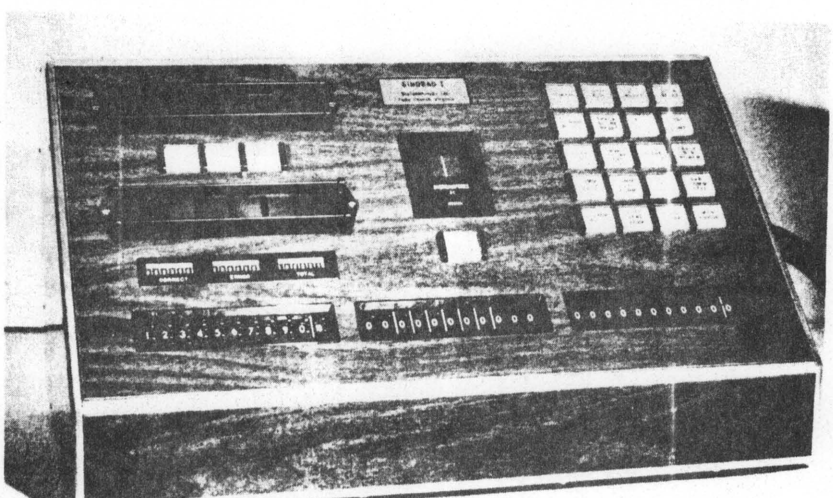

Figure 2. Experimenter console.

The subject response apparatus is shown in Figure 3 and includes a keyboard, magnetic stylus (upper right corner of keyboard), photocell stylus (at left) and dual tracking controls (not physically attached to the keyboard). The keyboard includes the letters A through F and digits 0 through 9 which are used to generate numeric and alphabetic responses to various cognitive and perceptual tests. A reaction time stimulus light and response key and a key to indicate "ready," "test complete," etc. are also included. The response apparatus also provides feedback of subject correctness or error if desired. Additional equipment used for display of problems to the subject includes a random-access slide projector, an oscilloscope (for manual tracking performance), and an optical display for presentation of digits (as in the Digit Span test).

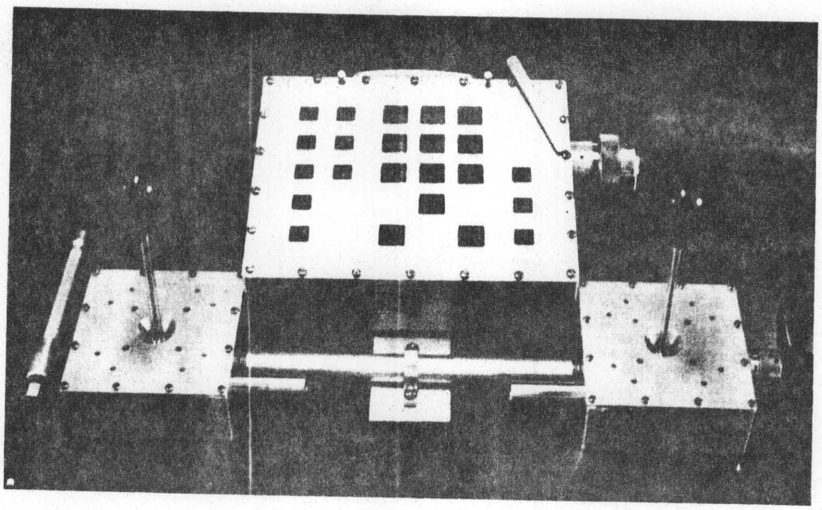

Figure 3. Subject response apparatus.

The SINBAD I test battery provides for remote administration and scoring of 26 specific tests ranging from simple reaction time to complex tracking and from monitoring a simple display to solving difficult mental arithmetic and symbolic problems. Figures 4, 5, 6 and 7 illustrate the subject visual display and response apparatus in use for four of the tests included in the battery. One of the features of the response apparatus is a set of keyboard overlays or templates which mask or display keyboard positions as appropriate for such tests as Manual Dexterity, Finger Dexterity and Response Orientation. Ancillary objects (containing permanent magnets) are used with the keyboard in performing these tests. The templates greatly increase the flexibility of the apparatus (see Figures 6 and 7).

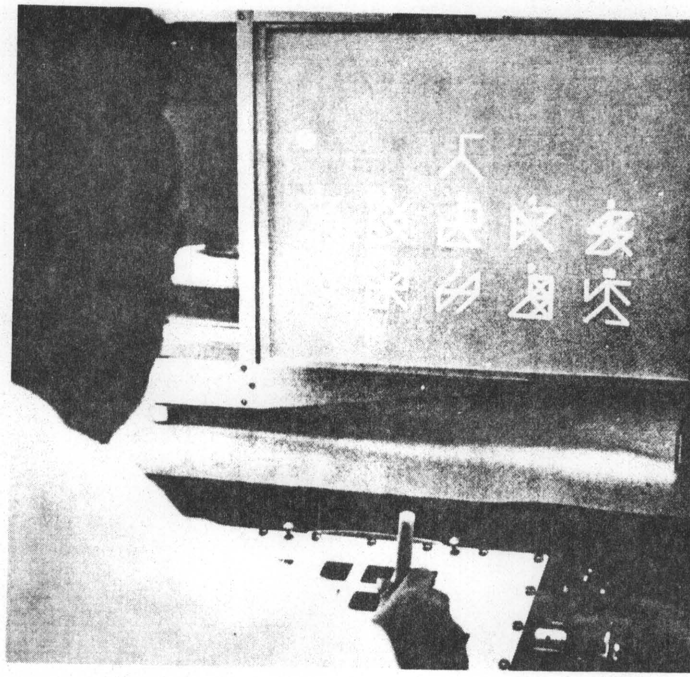

Figure 4. Subject working the Hidden Patterns test.

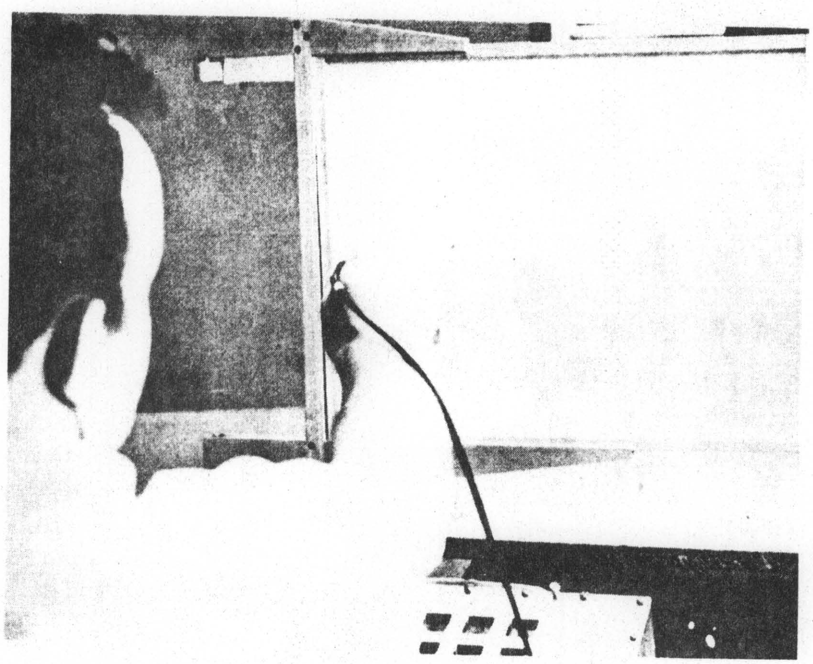

Figure 5. Photocell stylus being used in the Arm-Hand Steadiness test.

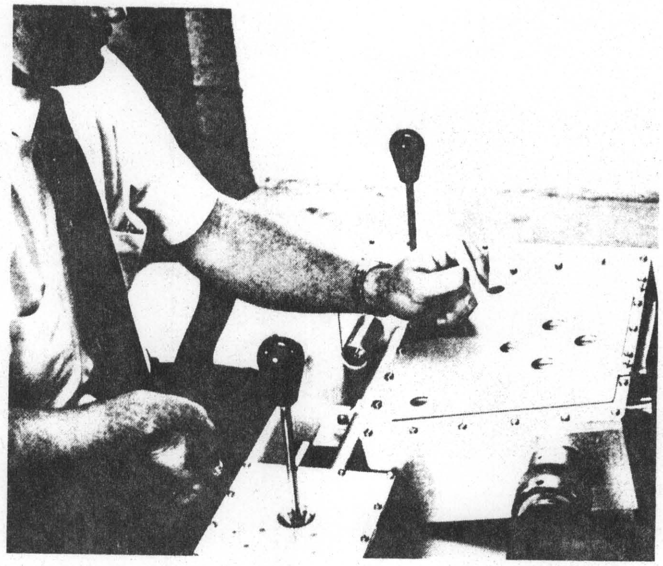

Figure 6. Subject performing Response Orientation test.

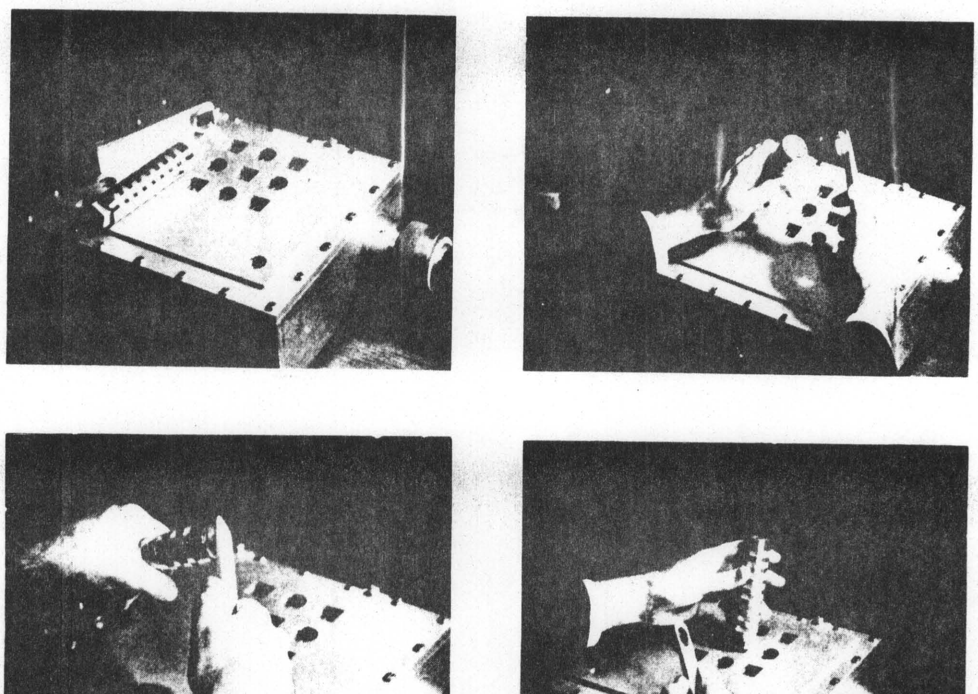

Figure 7. Manual Dexterity test (Wrench and Cylinder).

Although the SINBAD I system was designed as an integrated battery of tests, it is also a highly versatile research tool. The slide projection system and alphanumeric keyboard permit considerable latitude in test development or modification. As a formal test battery and general research tool, the system is applicable to:

1. specification of human underwater performance capabilities;
2. delineation of factors of the diving environment which affect performance; and
3. development of diver selection criteria.

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The conference highlighted a need for a method of assessment agreed upon by laboratories engaged in underwater performance research. The large number and varied type of performance measures used in the past makes cross-studies comparison difficult. Means of achieving standardized assessment were proposed.

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