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Technical Report 206-28

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SIX YEARS OF RESEARCH ON HUMAN FACTOR PROBLEMS IN ASW: A SUMMARY (U)

Technical Report 206-26

Robert R. Mackie

Prepared for

Personnel and Training Branch
Psychological Sciences Division
Office of Naval Research
Department of the Navy

by

Human Factors Research, Incorporated
Santa Barbara * Los Angeles * San Diego

November 1964
Contract Nonr 2649(00)
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"It is essential that the sonar designer be informed as to the characteristics of observers as well as to the characteristics of the transmitting medium. Sonar, then, is bounded on one side by oceanography and on the other by psychophysiology . . . .

"The primary purpose of every indicator or recorder used in sonar is, in some way or other, to make the signal perceptible to the observer . . . the quantitative evaluation of the performance of the instrument involves defining the limiting conditions under which the effect to be produced is adequately perceptible. This implies that the operation of any instrument is a joint enterprise in which the instrument is one partner and the observer the other. In stating the performance of the instrument quantitatively, therefore, certain physiological and psychological characteristics of human beings are quite as relevant as the nature and behavior of acoustic waves in the sea, or as the properties of the system by which these waves are caused to influence the instrument."

From: The Fundamentals of Sonar,
by Dr. J. W. Horton

FOREWORD

In 1958 a contract was established between ONR and HFR for the broad purpose of determining, in objective quantitative terms, the capabilities and limitations of Navy personnel in relation to the performance of various ASW systems. Target classification was the most pressing problem at the time, and much of the early work was concentrated in that area. More recent work has been directed toward measurement of the human role in target detection and equipment calibration and maintenance.

For the most part, the investigations have been experimental rather than analytical in nature. The scene of the experiments has varied with the problem: the laboratory, the ASW Schools, aboard ships and aircraft underway. Attention has been focused on the routine performance problems faced by operating and training personnel in attempting to maximize the performance of systems to which the Navy is fully committed. Little emphasis has been placed on future systems although much of value has been learned that should be applied to future systems.

The emphasis on existing systems has resulted in a far different orientation and a more basic appreciation of the Navy's operating problems than otherwise would have been the case. Project personnel have operated some equipment, calibrated sonar equipment, repaired sonar equipment, designed data collection exercises, directed exercises from CIC, studied the ASW problem through the eyes of seamen, petty officers, and captains, ridden destroyers, submarines, airplanes, and helicopters, and have heard all of the standard rationales for why things don't work better.

The results of this work have been, in some cases, obvious and concrete; in others they have been subtle, constituting more of an influence than an objective achievement. Twenty-seven technical reports have been issued; films, slides, magnetic tapes and technical manuals have been prepared and distributed, the staff has served in working groups concerned with the analysis of ASW systems, the design of sonar trainers, and the conduct of evaluational tests.

This summary report has been prepared as a means of reminding those who design, purchase, or use ASW equipment that the Navy has supported a good deal of research that logically should influence decisions concerned with the "joint enterprise in which the instrument is one partner and the observer the other." In addition, it hopefully will be a more convenient reference than the 27 technical reports, some classified, some not, that by now may be scattered in diverse files, drawers, and libraries.

With apologies, we must confess that the results of psychological experiments are not always reported in a form that immediately suggests the way to apply them in the practical environment. Of course, this is true of nearly all "basic" research. However, many of the findings summarized here have been applied and many others could be with very minor efforts at translation.

ACKNOWLEDGEMENTS

Continuing support of several Navy agencies has made possible a better planned and more coherent research program than would otherwise be possible. Regular support has been provided by ONR (Codes 458 and 466) and the Bureau of Ships (Code 689). In addition, periodic support has been received from the Bureau of Personnel (Pers 152).

Scientific cognizance has rested with the Personnel and Training Branch, Psychological Sciences Division, ONR. Additional guidance regularly has been received from Undersea Programs, ONR, the Surface Sonar Branch, Bureau of Ships, and the Signal Recognition Branch, Navy Electronics Laboratory.

Execution of the research has been aided in no small way by the commands of the ASW Schools and by the personnel of a substantial number of Navy ships and aircraft squadrons; by training personnel at various fleet activities and NTC, San Diego; and by countless individual officers and men who have offered an opinion, provided information, or served as experimental subjects.

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SIX YEARS OF RESEARCH ON HUMAN FACTOR PROBLEMS IN ASW: A SUMMARY

INTRODUCTION

The investigations conducted under this contract can be grouped into nine basic areas. Few studies belong exclusively to a single area, and it will be seen that findings from a single study are sometimes appropriately classified under more than one of the following headings:

I. Development of fundamental concepts of target classification

II. Analyses of clues displayed by operational equipment

III. Determination of operator capabilities in target classification

IV. Research on experimental display techniques

V. Determination of the operator's role in target detection

VI. Studies of operator vigilance

VII. Recording of target data at sea

VIII. Determination of calibration and maintenance skills of sonar technicians

IX. Analyses of ASW systems in operation

In the sections that follow, the specific findings in each of the above areas are concisely summarized. The technical report from which each finding or conclusion was taken is indicated at the end of each statement by the number in parentheses. The full title of each referenced report is listed at the end of this summary.

I. DEVELOPMENT OF FUNDAMENTAL CONCEPTS OF TARGET CLASSIFICATION

In December 1958, HFR conducted a workshop in target classification at the U.S. Navy Tactical ASW School, Norfolk, Virginia. Discussions centered around fleet experience in relation to the findings of several years of previous research on target classification that had been conducted by NEL and HFR. It became evident during the workshop, which was attended by representatives of almost every ASW operational and training command, that there were many diverse opinions concerning the value and role in target classification of various displays and the clues they presumably provided. Consequently, HFR assumed the oblication of developing a logical framework for target classification that would encompass all displays, clues, and procedures known to be of value in classifying with active, scanning sonars.

Specific Results

1. The logical basis for target classification with scanning sonars was established. It was shown how classification depends on determining the target's motion, size, reflective structure, aspect, and depth. The role of each display in contributing partial, complementary information about one or more of these target attributes was described (0).*

2. It was shown why target classification should be based on a test of the "submarine hypothesis" and why previous emphasis on identifying various classes of nonsubmarine targets was neither necessary nor desirable (0).

3. The value of using displayed target aspect (orientation in the sound beam) as the basis for correlating and evaluating all other displayed clues was established (0).

*This first report issued under Contract Nonr 2649(00) did not bear a series number as did subsequent ones. For convenience it is referred to here as report No. 0.

4. It was shown how each clue and various combinations of clues relate to estimations of the major characteristics of the target (motion, size, reflective structure, aspect depth) and how these characteristics, in turn, are combined to establish the probable nature of the target (0).

5. It was shown how classification is made more or less difficult depending on the target's speed, depth, range from the A/S vessel, apparent aspect, aspect changes, and geographic location (11).

6. It was shown that evaluation of classification evidence is hindered, in part, by the fact that U. S. systems provide no direct information about target depth (10).

Importance to the Navy

The first technical report issued under this contract, Target Classification Using Active Scanning Sonars, has been adopted, unchanged, as an official NAVPERS publication on the subject of classification. It serves as the standard text for target classification training courses in the ASW Schools and has directly influenced the design considerations of engineers concerned with the construction of specialized equipment for target classification. This publication is also serving as a model for a similar one being developed for the British Navy by personnel attached to H.M.S. VERNON.

II. ANALYSES OF CLUES DISPLAYED BY OPERATIONAL EQUIPMENT

The precise character and significance of target clues in displayed sonar echoes cannot be determined in advance of actual trials at sea with targets that are representative of the classification problem. HFR has collected and analyzed thousands of feet of motion picture records and tape recordings of displayed signals from a wide variety of sonar contacts.

Specific Results

7. Detailed descriptions of usable clues from the audio, PPI, and graphic recorder displays of the SQS-4 and SQS-29 were developed. The probability of occurrence and perceptibility of each clue by operators and the manner in which clues vary or change as a result of equipment control settings, sonar conditions and target maneuvers was described (0).

8. The number, description, and usefulness (validity) for classification of target pip shapes displayed by the SQS-23 PPI was determined. It was shown that the pip shape categories developed for earlier scanning sonars were not adequate for the SQS-23 (22).

9. It was shown that pip shapes are not highly related to target nature in a direct sense, but, in the case of submarine targets, often provide evidence of target orientation that is highly useful for evaluating the total clue pattern (22).

10. It was shown that the usefulness for classification of SQS-23 pip shapes was heavily dependent upon the range scale in use, that meaningful shapes occur very infrequently when using the 5000-yard (or greater) range scale. The relationship between the type of pip shape obtainable from a submarine target and the PPI centering mode in use (SCD or TCD) was determined (22).

11. The extreme difficulty of analyzing the motion of

either slow-moving or non-moving targets with present displays and plotting equipment was reported, and the superior capability of some European sonar systems in this respect was described (23, 27).

Importance to the Navy

Continuing analyses of clue patterns are essential to progress in target classification since any change in either the transmission, reception, or processing features of a sonar is likely to introduce corresponding (and unknown) changes in the meaningfulness of the clue patterns. Significant details and relationships are not effectively determined from regular fleet operations or ASW exercises. Furthermore, even the advent of successful automatic classification systems will not eliminate the need for [illegible] basic analyses to determine the meaningful information [illegible]

The results of these analyses to date have indicated three important needs for improved display design:

(1) There continues to be an urgent need for a simple, reliable electronic aid to doppler discrimination.

(2) The display of target axis information at ranges considerably greater than those obtainable with present PPIs is essential.

(3) Improved means for establishing target motion and target track by the sonar team is urgently required.

The lack of suitable displays for assessing the motion of slow-moving (or non-moving) targets in the shortest possible time is seriously hampering classification. The discrimination of doppler by operators is unreliable; the DRT plots and the computed fire-control solution are both too slow and too inaccurate for classification purposes. (It must be remembered that a fast, or even

moderately fast-moving submarine is not a classification problem, although it may well be a tracking and a fire-control problem.)

A sensitive semi-automatic target plot fed by data generated by equipments already in typical shipboard sonar systems would be a major step toward improving classification.

III. DETERMINATION OF OPERATOR CAPABILITIES IN TARGET CLASSIFICATION

It is extremely difficult to make fair, objective assessments of the more subtle capabilities of sonar personnel on the basis of their performance in the actual operating environment. Unlike radar operations which routinely provide the opportunity for radarmen to practice and develop operating techniques, sonar operations simply do not regularly enable sonarmen to exercise and reinforce the complex skills involved in detecting, classifying, and tracking underwater targets. The result is that specific performance deficiencies often go undetected for months, if not years. Furthermore, ASW exercises do not readily permit the diagnosis of the strengths and weaknesses of individual team members, since they are primarily designed and evaluated on the basis of the tactical and weapons-delivery phases of the problem.

The measurement of specific operator capabilities and weaknesses serves at least three very important needs: (1) it enables intelligent training emphasis to be placed on those aspects of the job that are most difficult; (2) it enables meaningful performance standards to be established for evaluating new displays requiring human monitors; and (3) it provides criteria for assessing the capabilities of machines that are proposed as substitutes for functions traditionally performed by men.

Specific Results

12. Both practical and written tests of target classification skills and knowledge have been constructed. "Trained" sonar operators have been found typically to score between 50% and 70% correct on practical tests comprised of fairly difficult classification problems. They score somewhat higher on written tests (10).*

*Chance performance on a balanced test permitting only two con-

13. Marked individual differences have been found among sonarmen in ability to assimilate target classification training (10).

14. Target classification training has been shown to be more effective among operators who have had sea experience than among trainees just out of basic training (10).

15. Sonar trainees make frequent perceptual errors in clue recognition even at the completion of training. Performance is somewhat better on clues displayed by the graphic recorder than on the audio or PPI--presumably because of the "memory" characteristic of that display (10).

16. Present sonar displays are not well suited to accurate clue recognition. Thirty (or more) successive echoes are frequently required for correct classification concepts to form. A major source of errors results from inability to form correct conclusions about the target's aspect and movement (10).

17. The average sonar operator requires about 22 cps of doppler for accurate doppler recognition using SQS-4 and SQS-29 series sonars. Depending on the model, reliable discrimination thus requires a submarine speed component of from 2.2 to 3.9 knots in the direction of the sound beam (12).

18. The average sonar operator can reliably discriminate about 12 cps of doppler with SQS-23 sonars. This is equivalent to about 3.5 knots of target speed in the direction of the sound beam (23).

19. Operators experience difficulty in recognizing "no" doppler as well as small amounts of "up" and "down" doppler. However, a judgment bias noted with older sonars toward reporting "up" doppler when no doppler was present was found to be less prounounced with RDT-modified sonars (12, 23).

20. There are large individual differences among sonar operators in doppler recognition ability. Task assignments within the team should reflect these differences (23).

---

clusions (i.e., "submarine" and "nonsubmarine") is 50%. Thus the performance level reflected by these figures is 0% to 20% above what would result from sheer guesswork.

21. Only marginal improvement in doppler recognition (2 to 3 cps) occurs with training once the concept has been initially grasped. However, experienced operators may occasionally recognize secondary cues in the echo that aid in arriving at a correct judgment (23).

22. A moderate correlation typically is found between Sonar Pitch Memory Test scores and performance on tests of doppler discrimination. Higher cut-off scores on this test or use of an actual doppler discrimination test would result in improved selection of operators for this task. Improved selection is a surer road to improved performance than is increased training (12).

Importance to the Navy

Improvement in target classification performance can be expected, provided that: (1) fundamental improvements in the display of certain clues are achieved; (2) training in classification techniques is concentrated on those who are highly screened from an aptitude and motivational point of view. Display improvements are essential; capitalization on individual differences in aptitude and interest is only sensible.

Before investing in expensive new displays or automatic processing devices that are proposed as replacements for functions traditionally performed by men, the performance of such devices should be compared with that of properly trained operators using appropriate problem material. In spite of their limitations, men have actually performed much better on some tasks involved in classification than have some fairly expensive electronic substitutes.

IV. RESEARCH ON EXPERIMENTAL DISPLAY TECHNIQUES

Thorough consideration of the man-machine interface is essential to the proper design of any complex system. In sonar, more effort seems to have been spent trying to design the man out of the system than in optimally designing it for his use.

It seems unlikely that signal analysis and interpretation will become fully automatic in the foreseeable future. In the meantime, there appear to be many opportunities to design displays that take better advantage of the unique capabilities of men.

Specific Results

23. The optimal audio frequency for doppler recognition is about 500 cps in contrast to the 800 or 1000 cps typically used in sonar systems (23).

24. A proposed technique for speed-translating sonar signals to enhance doppler effects was shown to produce no systematic improvement in doppler discrimination (12).

25. An experimental device designed to display doppler visually was found to be less effective than aural discrimination by the average sonar operator (12).

26. There is a critical need for achieving an interpretive match between the meaning of a classification display to the tactical officer and the discriminating capabilities of the sensing and data-processing equipment. There is a lack of understanding among many ASW decision-makers of the probabilistic nature of sonar target classification that naturally results from imperfect sensors and information displays (21).

27. Use of the traditional 3-way classification scheme ("probable submarine," "possible submarine," "nonsubmarine") results in serious losses of information for the tactical decision-maker. Displays of the type used with MITEC are much better but require training in interpretation (21).

28. The output of target classification aids or computers should be directly related to likelihood ratio (probability that the target is a submarine divided by the probability that it is not) if the number of correct tactical decisions is to be maximized (21).

Importance to the Navy

The perceptions, judgments, and decisions of humans will continue to be critically important in any existing or probable future sonar system. The nature of the demands may change, or they may be imposed at a different point in the processing and evaluating sequence, but they will remain critically important to successful functioning of the overall system. Not only will it continue to be necessary to deal with human decision functions, but it will remain desirable to capitalize on the flexibility that only man can bring to the problem.

Research thus far suggests that far greater skill is necessary in coupling machine and man functions in sonar systems than has been demonstrated in the past. Output displays generally need to be made more meaningful; training in interpretation must be made more uniform and sophisticated.

V. DETERMINATION OF THE OPERATOR'S ROLE IN TARGET DETECTION

No other requirement has so dominated sonar equipment design requirements over the past 20 years than that of extending the target detection range. The resulting increase in equipment complexity and predictable accompanying maintenance problems have created serious doubt that the detection performance of the newer systems is, in fact, uniformly better than that of older, simpler ones.

A great deal of improvement in sonar detection could be forthcoming, however, through increasing attention to the complementary capabilities of man and machine. Human operators are exceptionally adept at the detection of complex aural and visual signals in heavy background noise. However, they are often very poor at sustaining attention for such signals over prolonged periods of time, especially if the signals occur very infrequently. Machines can be built that are perfectly attentive and have infallible memories but to date their pattern recognition performance has not matched the flexible and adaptive capabilities of man for recognizing a variety of signal types in backgrounds of non-random noise.

There is little doubt that improvement in target detection performance is achievable. There is also little doubt that it will require more effective man-machine coupling than has been typical of past systems. Several HFR studies have been directed toward these problems.

<u>Specific Results</u>

29. There are large individual differences among operators in detecting targets on PPI displays. Performance on watch is moderately predictable from short samples of performance during "alerted" conditions (16).

30. The requirement to search the entire PPI scope results in about 13% fewer detections on the average than when the operator is "alerted" to the target's probable bearing. (A performance loss of 3.5 db with respect to a reference signal that is just barely detectable.) (16)

31. Operators more quickly detect targets at mid-range on the PPI scope than at close or far range. The explanation may lie in the visual search patterns adopted by operators (20).

32. There are large, stable individual differences among operators in ability to detect weak infrequent signals (2).

33. Repeated presentations of a target signal (up to 5 echoes) are often necessary to elicit valid detection reports (5).

34. Operators have different personal criteria of what constitutes a sonar target signal. The relative leniency or stringency of each operator's criterion substantially affects the likelihood of a detection being reported and the false alarm rate (5).

35. Faint echo detection is a function of training and experience in addition to basic operator sensitivity (5).

36. Target detection performance is unrelated to traditional achievement scores in sonar operator courses or to scores on presently used aptitude tests (16).

37. In accord with observations by Horton (Fundamentals of Sonar), the range between 10% and 90% probability of detection on a PPI scope is only about 4.5 db; the range between "almost never" and "almost always" detecting a target is about 10 db. Thus display design features (or operating procedures) that improve systems performance as little as 1 db are well worth the trouble (16).

38. Setting the PPI scope brightness at "visual reference intensity," as often recommended in technical manuals, adversely affects target detection. The optimum brightness is well above this setting (17).

39. Sonar operators typically do not adjust CRT bias and gain optimally for detection performance. Targets producing low intensity signals can be detected with much greater frequency using experimentally determined optimum settings than when using settings "preferred" by operators (20).

40. A 3-db gain in detection performance of an operating SQS-23 was obtained when ship's operators used experimentally determined optimum bias and gain settings in contrast to their normally preferred settings (26).

41. Search radars in patrol aircraft (P2Vs and P5Ms) are also likely to be operated at non-optimum brightness levels; ambient illumination in the P5M aircraft is sufficiently variable to introduce serious losses in detection probability.

    There are also adverse effects on target detection of the relatively high compartment illumination in the HSS-2 and of the consequent requirement that a viewing hood be used (17, 18).

Importance to the Navy

The use of cathode ray tubes as detection displays requires continuing research into the questions of optimal design and operator procedures. It is clear that the actual detection capability of a complex sensor system may be far different from its theoretical capability, as a result either of inappropriate control settings or non-optimum visual search procedures, or both.

Target detection performance also can be improved by proper selection of personnel and more comprehensive training. Selection should be directed toward obtaining personnel who are highly vigilant for the type of displays used for sonar (see Topic VI). Training should be directed toward procedures for calibrating the displays properly, optimum visual search patterns, and echo recognition. Existing training equipment is not properly designed for training these activities, although some films and tapes of sonar echoes are appropriate for training in echo recognition.

VI. STUDIES OF OPERATOR VIGILANCE

HFR studies in vigilance have been conducted at a very fundamental level. Vigilance is defined as the ability to sustain attention over prolonged periods of time for an event (signal) that has a relatively low probability of occurrence. An additional characteristic of most situations requiring vigilance is that it is critically important that the signal be detected at the earliest possible moment. Furthermore, failure to detect a signal can be disastrous.

The sonar watchstander is confronted with a vigilance task that is unique in many respects. He may spend hundreds of hours on watch without experiencing a target signal. He monitors both aural and visual displays that present unique, partially redundant information. The search task is demanding, yet boring, and the opportunities for a sense of contribution and reward are few. Sonar operators can expect to be virtually ignored for long periods of time by the personnel of other ship's activities, by the watch officers, and even by the command.

<u>Specific Results</u>

42. A vigilance decrement (loss) occurs in the first few minutes of a sonar watch. On the average about 20% fewer detections are made of signals that are of such intensity as to be readily detectable when the operator is fully alerted (16).

43. There are large, stable individual differences among operators in ability to sustain vigilance for the types of aural and visual stimuli associated with sonar signals (2).

44. Individuals who are vigilant for visually displayed signals are not necessarily vigilant for auditory signals and vice versa (2).

45. The more difficult it is to recognize the signals on the display, as defined by percentage of detections under alerted conditions, the greater the performance decrement as time on watch progresses (8).

46. The frequency of "non-observing" responses (looking away from a visual detection display) increases with time on watch and is positively related to the number of signals missed (14).

47. Signals can be missed when even the eyes are fixated on the detection display (14).

48. If probability of signal occurrence on a visual and an auditory display is equal, and both displays are being monitored by the same operator, more signals will be detected on the auditory display (8).

49. Operators monitoring more than one display are inclined to attend selectively to the display having the more easily recognizable signals. If the displays are not redundant, this can adversely affect detection probability (8).

50. Detection performance on redundant auditory and visual displays is superior to that on either display used alone (8).

51. Under routine watchstanding conditions there appears to be less performance decrement with auditory than with visual displays (2).

52. The probability of signal detection is (within limits) positively related to the rate of signal occurrence. The less frequently signals appear, the more severe will be the loss in detections due to the vigilance decrement during the watch (1).

53. Signal detection performance is related to "expectancy" on the part of the operator. If the operator has been conditioned to expect signals at very irregular intervals, the probability of signal detection decreases as a function of the amount of time elapsed since the last detection. In contrast, if he is conditioned to expect signals regularly, the probability of detection increases as a function of time since the last detection. Operators expecting long intervals between signals are particularly prone to missing signals that occur soon after one that has been detected (9).

54. Immediate knowledge of how well he is doing (performance feedback) reduces the operator's vigilance decrement (1).

55. The introduction of artificial signals increases the probability of detecting infrequent real signals (1).

56. The level of vigilance maintained by the operator is also a function of environmental stimulation from sources other than the detection displays. If the extra stimulation is not actually distracting, the added "arousal" it provides serves to facilitate vigilance (6).

57. Vigilance decrements are less severe in complex monitoring situations than in simple ones although the absolute level of performance may be lower for the complex display (1).

58. When the signal rates on a visual display are low, a variety of auditory stimuli reduces the vigilance decrement (7).

59. Environmental noise reduces vigilance performance on complex vigilance tasks (1).

60. Short, frequent rest periods are better for sustaining vigilance than long, less-frequent ones (1).

61. Performance on vigilance tasks is not reliably predicted from scores on conventional psychological tests of aptitude, temperament or motivation. Traditional sensory threshold measures are only slightly predictive of vigilance performance (4).

62. Detection performance during a short test of vigilance is predictive of vigilance during prolonged watchstanding. Men most sensitive to the discriminations required by the operational display show the least decrement in performance (2).

Importance to the Navy

There is little doubt that sonar target detections are made less frequently and with greater delay as a result of losses in vigilance on the part of operators. The often reported differences

in detection ranges between routine and "alerted" search during actual sonar operations is an additional objective reminder of this fact. More serious, however, is the unknown number of detectable targets that go completely unnoticed.

Failure to detect detectable targets is also, of course, the result of factors other than vigilance loss, such as equipment calibration, operating technique, and visual search pattern. What to do about some of the non-vigilance problems has been discussed elsewhere in this summary. Concrete steps can also be taken to help minimize the vigilance decrement:

a) The differences among operators in susceptibility to vigilance loss while monitoring sonar displays can be measured and used in qualifying them for various watchstanding tasks.

b) Injection of synthetic signals is a feasible means of increasing signal rate and consequently combating the effects of the vigilance decrement. Minor modifications to presently existing shipboard equipment (signal injectors) would be quite adequate for this purpose. However, successful implementation would require the involvement and understanding of all watch officers. Signals should be programmed and performance monitored by officers on watch, not by other members of the sonar team.

c) Synthetic signals can also be used to provide much needed recognition and performance feedback to operators. It would be possible to extend the technique to include shipboard training in search techniques, making proper bias and gain settings, calibration of displays, etc.

VII. RECORDING OF TARGET DATA AT SEA

The recording and analysis of representative submarine and nonsubmarine contacts made while using operational equipment at sea is a fundamental requirement for determining the classification capability of an ASW system. Such data are needed to determine the quantity and quality of clues producible by the equipment. Furthermore, the recordings also can be prepared in test form for measuring the abilities of ASW personnel in clue recognition and actual classification.

The first systematic collection of target data specifically directed at the classification problem was made by NEL, with HFR assistance, using SQS-10/11 equipment.* Since that time, HFR periodically has made additional collections as the fleet received new equipments or important modifications to older equipments. In each case, analyses have been performed to redetermine the adequacy of the displayed information for classification.

Specific Results

63. Representative samples of submarine and nonsubmarine contacts as displayed by the SQS-29 series sonars (including VDS) were recorded and analyzed (22).

64. Representative samples of submarine and nonsubmarine contacts as displayed by the SQS-23 sonar were recorded and analyzed (22).

65. The first system for recording target data from the displays of an airborne (helicopter) sonar system was designed and developed. Successful recordings of contacts as displayed by the AQS-10 sonar were made (15).

66. The first sound motion pictures for training and testing recognition of faint target signals presented by scanning sonars was developed (5).

*Under an earlier contract.

67. The only effective doppler performance tests for SQS-4, SQS-29, and SQS-23 sonars were constructed. These tests were comprised entirely of actual target recordings with doppler values determined under carefully controlled conditions (12).

68. Seven motion picture tests of SQS-23 contact data were developed for use in measuring the classification skills of ASW personnel and testing the utility of special classification aids such as HHIP and MITEC.*

Importance to the Navy

The motion picture tests have been reproduced and distributed by the Bureau of Personnel to all ASW training facilities. They constitute the only existing effective aids to SQS-23 target classification training.

Target recordings have also been distributed to industry on a limited basis when requested by the Navy. These have had an important influence on design concepts for specialized classification equipment now in various stages of development.

Doppler tests, slides of graphic recorder traces, and films designed to train faint echo detection have also been made available on an informal basis to the ASW Schools.

*No report describing these films was issued under this contract. A full analysis and an instructor's guide was published under a separate contract with the Bureau of Personnel.

VIII. DETERMINATION OF CALIBRATION AND MAINTENANCE SKILLS OF SONAR TECHNICIANS

It has been evident for some time that the complexity of sonar equipments has been increasing at a faster rate than have the abilities of sonar technicians to cope with the calibration and maintenance requirements that are the inevitable result of such complexity.

Until recently little attention has been focused on the capabilities and limitations of sonar technicians in the area of maintenance. There are several reasons for this, and they are largely unique to sonar operations: (1) no easy means exists for checking the actual operating status of the sonar; (2) it is difficult to separate the effects of sonar (water) "conditions" from equipment conditions in evaluating sonar equipment performance; (3) except during ASW exercises, little attention is paid to sonar equipment performance since no means exists for encountering contacts on any but a chance basis; (4) the ASW officer generally is not sufficiently trained to challenge statements of the technicians about the status of the equipment.

Work by HFR in this area has been directed toward the objective determination of the status of equipment, on the one hand, and the corresponding skills and knowledge of sonar technicians, on the other.

<u>Specific Results</u>

69. A test of calibration proficiency for the SQS-23 was developed which showed that the average rated technician lacks the knowledge necessary to understand the effects of various calibrations (24).

70. The "cookbook" calibration procedures outlined in the technical manuals were found not to produce a fundamental understanding of the effects of various adjustments on the status of the equipment (24).

71. Substantial errors of calibration were found to be the rule rather than the exception in a sample of SQS-23 destroyers. For example, the average error in range calibration was well beyond officially stated tolerance levels (24).

72. An improved procedure for bearing alignment with the SQS-23 was developed (24).

73. An analysis was performed to determine how various calibration errors are specifically related to performance deficiencies in detection, target classification, tracking, and fire control (24).

74. An analysis was performed showing that the training given to U.S. Navy sonar technicians is far less extensive than that given to European technicians with similar maintenance responsibilities (27).

Importance to the Navy

A multitude of interrelated technical and administrative problems have limited progress in developing maintainable sonar systems in the U.S. Navy. Substantial improvement can be predicted, if: (1) the effort to assess technicians' capabilities by objective testing procedures is continued; (2) training programs are extended or modified in accordance with the findings of such assessments; (3) equipment designers are compelled to employ techniques and components that reflect the current state of the art in designing for maintainability.

IX. ANALYSES OF ASW SYSTEMS IN OPERATION

Although the majority of the investigations conducted by HFR under contract Nonr 2649(00) have been experimental in form and directed toward very specific questions, a few have consisted of broad systems analyses encompassing all phases of operation of a complex ASW system. To date these have been concentrated on airborne systems, usually at the request of an operating command.

Specific Results

75. Object evidence concerning the actual capabilities of MAD, JULIE, and Sonobuoy systems in the hands of typical operators is extremely limited (18).

76. Training exercises typically do not provide opportunities for false positives, that is, the possibility of reporting contacts when, in fact, no submarine is present. Exercises should be designed so that "expectancy" is not a contributing factor in measuring operator detection capability (18).

77. There is much room for improved operating procedures in the use of the weapons system trainer for ASW patrol aircrews. A similar conclusion holds for needed improvement in team communication procedures in the aircraft itself (18).

78. Better use can be made of ASCAC in evaluating the mission performance of ASW aircraft teams (18).

79. The trainer developed for AQS-10 sonar operations is useful for routine procedures training only. It is totally inadequate to meet the needs for team training or training in target detection or classification (17).

Importance to the Navy

ASW systems continue to grow in complexity. While some functions will be almost completely automated in systems now under development, humans will continue to play key roles, at some stage

or another, in the processing of data and the making of decisions. Many past dissatisfactions with human performance in ASW stem from the limited capabilities of the system's sensors, from poor displays, and from the limited opportunities the personnel have to practice basic acquired skills in the operating environment.

The substitution of automatic data processors for human ones will not solve the fundamental problems of limited sensors, less-than-optimum displays or insufficient ASW experience. Rather, the likely result is a substantial increase in calibration and maintenance problems that are just as difficult to cope with, or more so, than the operational problems the automatic processor was designed to eliminate.

Side-by-side comparisons of the performance capabilities of new complex systems with older, simpler systems, under representative operating conditions, appear to be somewhat unpopular, if their number is any criterion. There is a growing suspicion, however, that many of the newer systems have not only failed to achieve their theoretical performance level in the hands of the fleet, but actually do not perform as well, from an overall systems point of view, as some of their grandparents.

There must be a more adequate solution to the Navy's operating problems than the simple substitution of next year's model for last year's, at several times the cost. It would seem that the point has been reached where more improvement might result from concentration on the human problems rather than on the electronic problems.

PROJECT PERSONNEL

The following personnel have made substantial contributions to the success of the research summarized in this report. The number of persons does not reflect the level of effort since only a few of them have been regularly assigned to the project. The average level of effort has been approximately 4.5 man-years.

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REPORTS ISSUED UNDER CONTRACT NONR 2649(00)

Number	Title	Authors
0	Target Classification Using Active Scanning Sonars (U) (1959) CONF.	Mackie, Gavin and Parker
1	Review and Critique of the Literature on Vigilance Performance (1959)	McGrath, Harabedian and Buckner
1S*	A Bibliography of Research on Human Vigilance (1961)	McGrath
2	A Study of Individual Differences in Vigilance Performance (1960)	Buckner, Harabedian and McGrath
2S	Subjective Reactions of Vigilance Performers (1960)	McGrath
3	The Probability of Signal Detection in a Vigilance Task as a Function of Intersignal Interval (1960)	Harabedian, McGrath and Buckner
4	An Exploratory Study of the Correlates of Vigilance Performance (1960)	McGrath, Harabedian and Buckner
4S	Cross-validation of Some Correlates of Vigilance Performance (1961)	McGrath
5	The Development of an Experimental Motion Picture Sonar Target Recognition Test (U) (1960) CONF.	McGrath, High and Mackie
6	The Effect of Irrelevant Environmental Stimulation on Vigilance Performance (1960)	McGrath
7	Irrelevant Stimulation and Vigilance Under Fast and Slow Stimulus Rates (1961)	McGrath and Hatcher
8	A Comparison of Performances on Single and Dual Sensory Mode Vigilance Tasks (1961)	Buckner and McGrath
9	Signal Detection as a Function of Intersignal Interval Duration (1962)	McGrath and Harabedian

*S = Supplement to principal report.

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10	Further Experimentation in Training Target Classification Principles Applicable to Active Scanning Sonars (U) (1961) CONF.	Gavin, Mackie and Harris
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12	Three Studies of Sonar Doppler Discrimination: RDT Versus Omnidirectional Transmission; Effects of Speed Translation; Use of the NRL Doppler Discriminator (U) (1961) CONF.	Harabedian and Parker
206-13	The Accuracy of Judgments of Eye Fixations: A Methodological Note on Vigilance (1961)	McGrath and Hatcher
206-14	Human Performance During Five Days Confinement (1962)	McGrath, Maag, Hatcher and Breyer
206-15	Feasibility Study and Suggested Program for Collecting Recorded AQS-10 Detection and Classification Materials (U) (1962) CONF.	Gavin
206-16	A Study of Target Detection by Trained Sonar Operators (1962)	Baker and Harabedian
206-17	Notes on the Problem of Training Operators for the AQS-10 Sonar (U) (1962) CONF.	Baker
206-18	Notes on Some Human Factors Problems in Fixed Wing ASW (U) (1962) CONF.	Baker
206-19	Unpublished	
206-20	Improvement in Sonar Operator Detection Performance Consequent to the Use of Optimum Bias and Gain (1963)	Baker

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206-22	Further Study of PPI Pip Shapes in Relation to Sonar Target Classification (U) (1963) CONF.	Rittger, Tabachnick and Mackie
206-23	Studies of Doppler Recognition Using SQS-23 Sonar (U) (1963) CONF.	Harabedian and Mackie
206-24	The Effect of Calibration Accuracy on Basic Sonar Operations (U) (1964) CONF.	Parker
206-25	The Relationships Between Echo Envelope Characteristics and the Judgment of Echo Quality	Dossett, Gavin and Seltzer
206-26	Sonar Operator Detection Performance at Sea (1964)	Baker, Parker and Rittger
206-27	Sonar Operation, Maintenance and Research: Some Contrasts Between the U.S. and Western European Navies (U) (1964) CONF.	Mackie

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The results and implications of six years of investigation into the problems associated with the operation and maintenance of ASW systems are described under nine topical headings:

1. Development of Fundamental Concepts of Target Classification
2. Analyses of Clues Displayed by Operational Equipment
3. Determination of Operator Capabilities in Target Classification
4. Research on Experimental Display Techniques
5. Determination of the Operator's Role in Target Detection
6. Studies of Operator Vigilance
7. Recording of Target Data at Sea
8. Determination of Calibration and Maintenance Skills of Sonar Technicians
9. Analyses of ASW Systems in Operation

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