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CRITICAL FACTORS IN SONAR OPERATION:

A SURVEY OF EXPERIENCED OPERATORS

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Critical Factors in Sonar Operation: A Survey
of Experienced Operators

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Abstract

A survey questionnaire was administered to 538 sonar operators (surface and submarine) of various rates and experience to investigate and document their perceptions of: a) factors important to sonar operation; b) job stressors; and c) operational problems. Results indicated a high level of agreement among sonar operators across types of service and rate. Primary factors rated as "very important" to sonar operation included: ability to stay alert, ability to integrate visual and auditory information, fatigue, work cycle factors, one's motivation to perform, quality of equipment, and amount of sea experience. The most commonly nominated stressors were fatigue, length of sea tour, length of watch, poor leadership, and collateral duties. Operational problems most frequently noted were poor leadership, lack of sleep, collateral duties, and visitors in sonar. Overall, the results suggest that greater consideration be given to issues of fatigue, workload, attention, the quality of supervision in sonar, and training that includes realism, teamwork, and increased classification efficiency.

Introduction

Over the last ten years advanced technology has significantly modified the shipboard work environment. Many of these changes have occurred in order to take advantage of recent advances in human factors technology. The primary interest of most researchers is to develop techniques to enhance human performance. For example, there has been considerable research investigating sonar operator performance and various conditions which influence sonar operation (Lewandowski & Kobus, 1989). However, comparatively little research has examined what operators themselves think are important aspects of their job. A few dated studies have utilized questionnaires to determine the attitudes of sonar operators toward a wide variety of issues. Typically, these were small scale studies asking a crew what they thought of a new system or specific type of equipment (Abrams, Seposh, Cohen, & Young, 1977). A more recent study employed an interview format to determine what sonar operators thought about visual and aural alarms and cues, headset and lighting preferences, and equipment arrangement in the sonar work area (Miller, 1987). However, the results of this study pertained only to submarine sonar and were highly dependent upon the class of submarine and specific equipment used by the operator. There was little information that could be applied generally to the sonar operator population. In addition, there was limited information regarding what types of operational problems were perceived by the operators and no discussion of problems with stress.

The sonar operator has a wealth of knowledge regarding operational issues that is rarely solicited. It was not until very recently that an applied research study attempted to utilize the trained operator as a direct resource. Kobus and Lewandowski (1990) administered a modality perception questionnaire to both submarine (STS) and surface (STG) sonarmen to determine operator preferences for auditory or visual information in sonar tasks. They found that most operators preferred and relied upon visual

signals (47.4% STS; 65% STG) in the performance of a sonar task. This finding was not too surprising given the recent advances in display technology. Overall, the majority (99%) of operators agreed that sonar, once considered to be a purely auditory task (for submarines), has become primarily a visual task. Yet, only 54% of the operators designated their "best" modality to be visual. These and other results suggested that operators had important information to offer researchers and system developers concerned with sonar performance, selection of personnel, and training. In addition, the Navy has voiced concern about how operators perform in complex environments while under stress. This concern has led to related research investigating operational and team performance.

The purposes of the present study were to document which aspects of sonar operation and training were considered to be highly important (or less important) to experienced operators, as well as elicit those aspects of the job that are stressful and problematic. In addition, the questionnaire was given to both surface and submarine sonarmen to examine consistencies and/or differences between the subgroups, as well as throughout the sonar rating.

Method

Subjects

A sample of 538 sonar operators was recruited from the Fleet Anti-Submarine Warfare Training Center Pacific (FLEASWTRACENPAC) and the operational (fleet) community in San Diego. Both submarine and surface groups were similar in age, years of experience, and amount of sea duty. All subjects had a minimum of one year of operational (at sea) experience. The profile of sample characteristics is shown in Table 1. It was felt that this sample was reasonably representative of the sonar operator community, with the majority of subjects (364) from the surface community.

Table 1. Sonar Operator Characteristics

VARIABLE	Submarine Service	Surface	Total
N	174	364	538
M age	27.4	27.0	27.1
M years experience	6.6	6.3	6.4
M months at sea	42.5	36.6	37.9
ST 3(E-4)	6	79	85
ST 2(E-5)	81	95	176
ST 1(E-6)	74	137	211
STC(E-7)	12	42	54
STCS(E-8)	1	3	4
STCM(E-9)	0	3	3
OTHER*	0	5	5

*= Operators designated for sonar E-3 and below.

Instruments

The Sonar Operator Questionnaire (SOQ) was developed for the purpose of this study. The questionnaire consisted of demographics, 25 Likert scale items for rating the relative importance of job issues (see Table 2), and 10 open-ended questions dealing with job stressors, problems, and characteristics of good operators and supervisors (see Tables 3 and 4). The questionnaire had high face and content validity, because most items were gathered from interviews with sonar operators. Piloting was used to refine and reduce items, ensuring readability and coherence of the questionnaire. Adequate internal consistency was reflected in the similarity of responses to like questions. Retest consistency, based on a random subsample of 50 operators (25 submarine, 25 surface), indicated > 95% agreement for the 25 Likert questions.

Procedure

Questionnaires were distributed to 580 submarine (STS) and surface (STG) sonar operators in San Diego. Questionnaire dissemination and collection was carried out by senior enlisted assigned to FLEASWTRACENPAC. The proportion of returned surveys was 93%. Surveys were collected over a four month period. A test-retest of 50 subjects was conducted with a 6 week interval.

All instructions for the survey were included in the handout to participants. They were asked by a staff instructor to read and voluntarily sign the research consent form, then read and complete the survey. Subjects were able to do this without assistance in 15 to 20 minutes. Questions were omitted by subjects on occasion, but most surveys were returned completed.

Results

Characteristics of the subject sample are shown in Table 1. Although there are more than twice as many STG as STS operators, the groups are comparable in age, years of experience, and time at sea. The distribution of subjects across rate is somewhat different for the two groups, with proportionately greater representation of ST3, STC, and STCM rates among surface operators. However, this distribution is representative of the number of individuals found within each rate throughout the navy.

The bulk of questionnaire data is summarized in Table 2. Responses to 25 questions are averaged for each group and the total sample. These means are listed in order from high to low score, or most to least "important" items. Mean scores are similar between groups (STS, STG) on most items. Only three items produced modest disparity in group results. Ratings of the importance of "school training" and "sea state" were rated higher by STG operators. STS operators rated more highly "the availability of refreshments."

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Items	STS M	SD	STG M	SD	TOTAL M	SD
Ability to stay alert	4.61	.62	4.56	.63	4.58	.63
Integrate Aud &Vis Info	4.4	.66	4.26	.78	4.33	.75
Motivation perform best	4.01	.68	4.03	.78	4.33	.75
Fatigue	4.10	.75	4.04	.85	4.06	.82
Work/rest cycle	4.02	.75	3.99	.79	4.00	.78
Type/quality of equipmt.	4.01	.91	3.98	.85	3.99	.87
At sea experience	4.13	.77	3.90	.95	3.98	.90
Ship's location and situation	3.83	.99	3.92	.94	3.89	.95
Positive attitude	3.79	.85	3.91	.82	3.87	.83
Getting along coworkers	3.74	.86	3.63	.93	3.67	.91
Personal life situation (health, family, money)	3.58	1.00	3.65	1.06	3.63	1.05
Ability see weak signals	3.52	.82	3.65	.88	3.61	.86
Follow procedures	3.63	.91	3.53	.88	3.56	.90
Ability hear weak signals	3.54	.86	3.45	.99	3.48	.95
School Training	3.24	.95	3.60	.97	3.48	.98
Number of operators on watch	3.50	.82	3.41	.78	3.44	.79
Length of time at sea	3.54	.87	3.32	1.06	3.39	1.01
Absence of noise	3.33	.87	3.40	.87	3.37	.87
Getting along with super.	3.45	.92	3.28	.96	3.34	.95
Develop own techniques	3.15	1.01	3.32	1.10	3.26	1.07
Knowing ship speed	3.27	1.08	3.24	1.03	3.25	1.04
Knowing ship's course	3.19	1.14	3.28	1.04	3.25	1.08
Sea state	2.97	1.60	3.36	1.02	3.24	1.25
Comfortable chair	3.16	1.05	3.07	.98	3.10	1.00
Refreshments available	3.27	1.01	2.82	1.09	2.97	1.08

* Likert scale responses: 5 = Of critical importance, 4 = Very important, 3 = Important, 2 = Of some importance, 1 = Not important.

More important than group comparisons are the total sample mean scores which indicate what operators consider to be most important. As can be readily noted, three of the top five scored items deal with "attention, fatigue, and work/rest cycle." On the other hand, items related to working conditions such as "comfortable chair" and "availability of refreshments" were the lowest scored items.

Tables 3 and 4 summarize operator responses to open-ended questions. Table 3 summarizes the responses of each group for two questions: 1) What are the top five most important characteristics of a good sonar operator?; and 2) What are the top five stressors which affect your performance while at sea? Due to the large number of potential responses, only 100 subjects from each group were randomly selected for this analysis. Their responses were tabulated in terms of total nominations. For question #1, the results indicate a wide variety of responses with little agreement as to a "top" characteristic of a good sonar operator. The most nominated characteristic involved the operator's "attention and alertness." This supports the earlier results from the 25 scaled questions indicating the importance of attention and alertness for successful sonar operation. Of considerable importance to a large number of operators was a) attitude and willingness to learn; b) knowledge of rate, publications, and procedures; c) aptitude and ability to think and make decisions; d) equipment knowledge and skill; e) integration of information and classification ability; f) teamwork; and g) initiative/assertiveness. Most other characteristics were mentioned by fewer than 20% of the operators.

Interesting group differences were found which indicate that more STS operators place importance on innate characteristics such as attention and aptitude, whereas STG operators place more importance comparatively on knowledge and training, factors that need to be acquired (see discussion).

There was more homogeneity of responses on question 2, with 64% of subjects nominating "fatigue" as a significant stressor (30% mentioned it as the most critical stressor). Almost half the subjects listed supervisory incompetence/problems as a stressor. Also, personal issues (home, family, financial problems) surfaced as a significant stressor. STS operators were particularly sensitive to the type of mission they were on and knowledge about

potential threats. STG operators were more inclined to view time at sea as a stressor.

Table 3. Ranked Responses to Open-Ended Questions of 100 STS and 100 STG Operators.

Question/Responses	Total Nominations	
#1		
Most important characteristic of a good sonar operator.	STS	STG
Attention/alertness	52	41
Attitude/motivation/willing to learn	41	44
Knowledge of rate, pubs, procedures	41	48
IQ, aptitude, decision making	40	22
Equipment knowledge/skill	36	42
Classification ability & signal integration	35	35
Teamwork	27	20
Initiative/assertive	21	25
Experience	16	13
Professionalism/dedication	18	14
Handle stress	15	13
Communication	9	15
Flexibility	11	8
Training	11	16
Common Sense	9	16
#2 Stressors	STS	STG
Fatigue	65	63
Supervisory complaints	45	45
Personal (home) issues	42	46
Mission/plan	54	23
Threats/contacts	24	9
Workload complaints	31	33
Ship and work conditions (smoke, food, noise...)	33	35
Crew attitude and competence	34	29
Equipment problems	22	13
Time at sea	21	31

* Subjects were asked to rank five responses in order of significance (1=most significant). Each time a response was nominated it was counted; number of first nominations are also reported.

Table 4 reports the tabulated responses on three open-ended questions: 3) What are the desirable qualities of a "good" sonar supervisor?; 4) What else needs to be included in training?; and 5) What most detracts from your attention to sonar performance? Again, there was a wide variety of responses that were similar between groups. Operators said a good supervisor is knowledgeable, a leader, calm under stress, able to communicate and make decisions, knows the equipment, and can function on a team. The operators reported that training needs to be more realistic and involve at-sea experiences on actual equipment. They also suggested that they receive more training in tactics and teamwork. Operators reported numerous issues that detracted from performance. Interestingly, first among the detractors was poor supervision and/or leadership, followed by lack of sleep, various drills and collateral duties, working conditions (i.e., noise, smoke, poor food, etc.), and visitors in sonar.

Correlational analyses were conducted on the 25 Likert scale items along with age, years of experience, rate, and operator group. Age, rate, and group did not correlate significantly with any of the rating items. Length of experience correlated significantly (r = .23; p < .05) with positive attitude toward the job. Intercorrelations among the rating items showed no surprises. The highest correlations were between hearing and vision abilities (.62), ship speed and ship course (.63), fatigue and work/rest cycle (.56), positive attitude and motivation (.51), getting along with supervisors and coworkers (.48), and refreshments and a comfortable chair (.39). These and other significant correlations (p < .05) reflect logical relationships among these variables. Such results provide evidence as to the study's internal validity.

There were some interesting differences between group responses on these questions. STS operators more often said a good supervisor has operational knowledge and is calm under stress. STG operators said a good supervisor can make decisions

and work well on a team. Both groups wanted more realistic training with STS respondents desiring sea experience and STG respondents desiring training on real equipment. STG operators also expressed the need for more general knowledge in their training. The groups differed in several responses on performance detraction. STS operators more often noted lack of sleep, drills and poor work conditions as detractors, whereas STG operators were more likely to nominate field days, collateral duties, and lack of training as factors detracting from performance.

Table 4
Responses to Open-Ended Questions of 100 STS and 100 STG Operators.

Responses   Total Nominations

#3 Desirable qualities of a "good" sonar supervisor

	STS	STG
Knowledge of tactics	33	38
Knowledge of ship, equipment, rate	37	30
Leadership	30	25
Calm under stress	30	21
Communication ability	27	23
Decision making ability	20	29
Equipment experience	20	25
Teamworker	15	26
Motivated	17	15
Responsible	10	9
Flexible	6	6

#4 What needs to be included in training?

	STS	STG
Realism	16	15
Sea experience	15	10
Tactics	13	12
Teamwork	11	13
Real equipment	3	15
Knowledge(physics, math...)	3	15
Cross training	11	5

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Table 4 (Cont)
Responses to Open-Ended Questions of 100 STS and 100 STG Operators.

#5 What most detracts from performance?

	STS	STG
Poor supervision/leadership	36	43
Lack of sleep	34	23
Drills	39	6
Field days	3	31
Collateral duties	2	23
Poor working conditions	31	17
Visitors in sonar	17	22
Lack of training	9	20
Equipment failure	7	11
Poor attitude	6	7
Personal problems	4	8
Boredom	11	6
Skylarking	4	4

Discussion

The purpose of this survey study was to document the collective perceptions of sonar operators on the important aspects of their job, as well as their views on job stressors, distractions, and training. A secondary concern was to document and speculate on likely differences in these perceptions between STS and STG operators. Both Likert scale and open-ended question formats were employed, and the data from each format were generally consistent. Since no recent investigation of this kind had been done, we opted to conduct a large survey study which would encompass a representative sample of sonar operators.

A review of the descriptive data indicates that the sonar population was well sampled, and that STS and STG groups were comparable on essential variables (i.e., age, experience, rate, and time at sea). Another methodological concern was instrument reliability. Both internal consistency (consistent responses to similar questions) and retest stability (consistent responses over time) were good, suggesting that the survey was a reliable instrument. Since the questions were developed from interviews and

piloting with operators the instrument was considered to be content valid. This type of a study relies upon the respondents being thorough and honest and there was no reason to think that operators were not truthful. In fact, we were struck by the thoroughness and frankness of their responses.

The findings are reasonably straightforward. On the ratings of what is important in sonar, there are several results worth noting. First, of the top five rated items, three had to do with fatigue, work/rest cycle, and staying alert. Obviously, the need to be physically and mentally fresh (vigilant) seems to be a critical aspect of the job. Second, as Kobus and Lewandowski (1990) reported in their modality preference study, operators rated highly the ability to integrate auditory and visual information. This finding was corroborated on another question as well. When asked to check whether they rely on auditory or visual information to make critical decisions, more than half of the respondents indicated in writing that "both," rather than a single modality, are critical for target classification. Third, there was a cluster of items rated highly that had to do with personal characteristics. These included motivation to perform your best, positive attitude toward the job, getting along with others, and personal life situations. Items regarding work environment (i.e., chair, refreshments, smoking, noise) were rated among the least important items. These data suggest that it is more important to an operator to be well-rested, capable, motivated, and someone who likes his work and co-workers, than to have optimal work conditions, equipment, and calm seas.

Results from the open-ended questions revealed confirmation of the important characteristics stated above. Again, attention and alertness were mentioned most often. On the flip side, "fatigue" was reported to be the number one stressor. The theme is consistent throughout the survey. Operators feel the need to be well-rested, mentally sharp and alert, yet must operate under conditions of long watches, sleeplessness, boredom, and at times, high workload. The

strength and repetitiveness of these data seem to call for some changes in the work life (work/rest cycle) of sonar operators.

Another finding evident in both questions of Table 3 is the importance of attitude, both individually and of the entire crew. Many of the comments on attitude included a "willingness to learn" given that sonar systems are constantly changing. Interestingly, "abilities" such as general IQ or aptitude, auditory/visual classification, and decision making were viewed as important, whereas "training" was not frequently mentioned as important, nor was it rated as that important. It is as if the "within person" factors (e.g., aptitude, motivation, perception, decision making, interpersonal skill, etc.) are viewed as more important than "learned" (training) or "environmental" (work and ship conditions) factors. Although not mentioned by the majority of operators, teamwork is seen as important by a significant minority (Question 3, 21%; Question 4, 12%). On a similar theme, interpersonal issues are raised as significant stressors (44%). Perhaps selection and training procedures need to include team training and interpersonal relations to better prepare operators for this aspect of the job.

Despite the fact that both groups of operators had similar perceptions on many of the questions, there were some interesting differences between the groups. These differences reflect the nature of the work demands and attitudes of each group of operators. For example, one difference between the groups was on indicating the important characteristics of a good sonarman. STS operators viewed personal attributes (i.e., attention ability, IQ, teamwork) as more important than STGs, who rated extrapersonal factors (i.e., procedural knowledge, training) as more important. Perhaps STS operators rely more on intrinsic abilities, whereas the STG operators rely on quality of training and acquired job information. One reason for these differences may be that selection for STS operators involves more of an emphasis on certain intrinsic characteristics.

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Other questions revealed important differences between the two groups regarding perceived stress and job detractions. STS operators are more concerned about the mission they were on, the threats they incur, the number of drills, and the desire for a supervisor who is calm under stress. STG operators were less concerned about these issues, yet more reactive to time at sea and collateral duties. These results may be explained by the different work environments involved. Submariners work on nuclear-powered ships, have many more drills on safety issues and live on a craft that is in greater jeopardy. This seems to affect their work/rest cycle, daily tension levels, and preoccupations with the mission. Surface operators, on the other hand, are less concerned about drills and the daily stresses related to threats and environmental safety, while being more concerned about the long term routinization of collateral duties and time at sea.

These interpretations of group differences are speculative based upon knowledge of sonar operation on the two types of platforms and missions. It seems logical that there would be some different perceptions and concerns within these two groups of operators given their varied training and operational roles which foster different "operational subcultures". Future research may more directly address the comparisons of their daily job tasks, activities dictated by the different environments, and the "subcultures" in which these operators function.

The results of this questionnaire serve as a starting point for the type of information that the operator may be able to provide regarding operational issues. These results, although specifically related to sonar, suggest a more general lesson regarding all forces. That is, the end user should be studied and consulted so as to improve selection, training, operational performance, systems development, and job satisfaction. This information feedback loop is essential to future man-machine developments and performance enhancement.

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