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THE EVALUATION OF ASW TEAM PERFORMANCE BY MEASUREMENT OF OPERATOR ACTIVITIES

The Effect of Coaching on Team Performance in ASW Attack Teacher Exercises

Fourth Partial Report

Prepared for

Department of the Navy
Office of Naval Research

Bureau of Naval Personnel
Contract No. Nonr-351(02)

DUNLAP AND ASSOCIATES, INC.

New York, N. Y. Stamford, Conn.

Technical Report DA 30-4

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SUMMARY

The goal of the over-all research program has been the measurement of operator performance in the ASW weapon system. The ability to make these measurements is of practical importance as well as of theoretical interest. Three previous partial reports have been published covering the work in the program. These reports describe the development and validation of a set of ASW activity scales for the evaluation of operator activities in the ASW attack team.

The question arose as to the possibility of using these scales as an aid in coaching of team members during ASW attack exercises. It was felt that coaching in this manner would bring about an improvement in ASW team performance.

It was noted early in the research program that coaching played an important part in the performance of the ASW team. It is an important activity of several officers in the team. A theoretical discussion of coaching in the Second Partial Report pointed out a series of specifications for coaching of operators. The use of the activity scales by enlisted coaches furnishes a methodology for satisfying these specifications.

Procedure

Regular dual-ship attack teacher exercises were conducted for ships' teams. The ships were divided into two groups, one group being coached in their activities, the other carrying out standard procedures without coaching. Experimental conditions were carefully controlled so as to maintain similar conditions for the groups. Ratings were made of operator activities for both groups and the attack error was measured to serve in the evaluation of team performance.

Results

It was found that the two groups of ships' teams were approximately equal in attack performance during the equating trials. After exposure to the experimental conditions, the coached group showed significant improvement as compared to the control group. This improvement was indicated in several ways:

1. The coached group improved 11 yards in mean attack error, whereas the control group decreased in performance by 11 yards.

2. The coached group made a significantly higher proportion of lethal attacks than the control group. Although the coached group was 9% superior to the control group during the equating trials, it showed a 17% advantage during the experimental sessions.

3. The ratings of individual operators showed a consistent improvement for the coached teams whereas the control group ratings seemed to fluctuate randomly.

The results of the study were found to be statistically significant at a fairly high level of confidence. However, a repetition of the experiment is warranted before broader generalizations may be made from the findings. Such a study is included in the planning for future investigations.

Future Research Plans

A repetition of the present study is planned for the purpose of confirming the obtained results. This study will once again be confined to the evaluation of depth charge exercises. It is suggested that several other related problems be included in the formulation of future plans. These proposed areas of investigation are:

1. The effects of coaching on team performance in simulated hedgehog attacks.

2. The effectiveness of coaching by stand-by members of the ASW team.

3. The residual effects of coaching on team performance.

4. The transfer of training from attack teacher to sea exercises.

The results of these investigations should have considerable practical implications and contribute valuable information to the formulation of ASW training procedures.

INTRODUCTION

Background

The major goal of the present research program is the measurement of operator performance in the ASW weapon system. The ability to make these measurements is of practical importance as well as of theoretical interest. If a quantitative measure can be made at the various operator stations in a weapon system, it is possible to assign minimum acceptable levels of performance for the satisfactory employment of a specific weapon. As measurement techniques are developed and tested, it will be possible to study available weapon systems in this manner. In time, the demands placed on an operator can be stated either in terms of a specific weapon or of any weapon that may be used on his ship.

The previous reports of the work of the research program have been concerned with the rationale of the study (First Partial Report), a sea test of the procedure (Second Partial Report), and a study of team performance in attack teacher exercises (Third Partial Report). Appendix D presents abstracts of these reports.

Present Problem

During the analysis of the data for the Third Partial Report, some of the results were of particular interest to training activities. The activity scales used for measuring performance could be used to predict attack effectiveness. In addition, the research team raised a question concerning the use of the activity scales to improve team performance. The question was finally stated as a hypothesis to be tested under controlled conditions:

"Can the activity scales be used to improve ASW team performance by coaching the team members during the practice attack?"

Included in this hypothesis are subsidiary problems which should be investigated at a later date. Among these are the time lapse between coaching and a change in performance, the elimination of Class B attacks, the residual effects of coaching, the transfer of training from attack teacher exercises to sea exercises, etc. Class B attacks in this and other Newport studies are defined as attack errors of 210 yards or more. The precise value of 210 yards is a result of the projection scale in the attack teacher and the measurement of error to the nearest tenth of an inch. (This value is a reasonable approximation of the SurASDevDet limit, "exceeding 200 yards.") The value for Class B attacks will change slightly as different attack teachers and projection scales are used.

These problems are not covered in the present study. Major emphasis has been given to the investigation of the effect of coaching on attack effectiveness and the relative frequency of lethal attacks (i.e., attacks with an attack error of 50 yards or less). Positive results in reducing the attack error and increasing the proportion of lethal attacks indicate the need for study of related problems.

Coaching Activities

The importance of coaching members of the ASW team was apparent early in the research program. During the development of the activity scales,[1] emphasis was placed on the coaching activities of the several officers in the team. The commanding officer devoted a major portion of his time to advising the Evaluator and ASW Officer. In turn, these officers coached their subordinates. However, none of the activity scales measuring coaching activities could be used to predict attack effectiveness.

[1] CAMPBELL, J. W., DORNY, L. R. & CHANNELL, R. C. The evaluation of ASW team performance by measurement of operator activities. First Partial Report, ONR Contract Nonr-351(02), Technical Report DA 30-1, 1 May 1952, CONFIDENTIAL.

Additional experience with the ASW team during sea and attack teacher exercises led to the development of an operational definition of coaching.[1] It became apparent that coaching activities were not being performed adequately for several reasons. Perhaps the most important reason was the amount of attention an officer had to devote to his primary activities during the attack--the conning of the ship, weapon selection, attack decisions, and the like. There were also the problems of knowing when coaching was required, the aspects of an operator's performance that required coaching and the fact that the directions given by officer personnel are often more likely to be in general terms rather than in the form of specific instructions. It would seem that a solution to these problems could be found by delegating coaching responsibilities to enlisted men whose primary duty would be to fulfill the role of a coach.

The Second Partial Report includes a theoretical discussion of four general specifications for coaching an operator:

1. The supervisor must be able to recognize the overt behavior typical of an adequate performance.

2. Immediate recognition of inadequate performance is necessary.

3. Coaching should be in the form of specific instructions.

4. The elements of job performance most closely related to attack success should be given priority in coaching.

The following steps show how the rater could satisfy each of these coaching specifications by observing and coaching operator performance with the aid of activity scales:

---

[1] CAMPBELL, J. W., TOLCOTT, M. A., MUCHMORE, S. C., KELLNER, A. D. & CHANNELL, R. C. The evaluation of ASW team performance by measurement of operator activities. Second Partial Report, ONR Contract Nonr-351(02), Technical Report DA 30-2, 1 July 1952, CONFIDENTIAL.

1. The observer is aware of the overt behavior of the operator at all stages of the attack.

2. The steps of the activity scale describe operator performance in varying degrees of "goodness."

3. The observer could tell the operator what he should do to improve his performance since the scales are in behavioral terms.

4. The coaching can be limited to those activities that serve to predict the attack error.

The present study was designed to test the effectiveness of coaching (measured by reduction of mean attack error) when the activity scales are used as coaching aids.

CHAPTER I

PROCEDURE

As in previous studies conducted at Newport, certain modifications of the attack teacher equipment and training procedures were made to insure the collection of data under experimentally controlled conditions. However, the practicality and adaptability of the procedure were kept in mind. If Navy personnel are to make use of the methods developed in the course of this research, it is necessary to design procedures which are practical and readily adaptable by personnel of the fleet.

Selection and Training of Coaches

In designing the experimental procedure for the present study it was decided that coaching activities within the ASW team could be delegated to enlisted men of the fleet. The three coaches in this study were chosen by the research team from a group of 12 enlisted men selected at random from the fleet by ComDesLant. The coaches consisted of two rated sonarmen and a rated radarman. The coaches had no previous specific training or experience in coaching activities, and had approximately the same background with respect to education and Naval experience. These men should be typical of other enlisted men in the fleet who might be called upon to perform such activities in future applications of this procedure.

The coaches were given instructions in standard coaching procedures, and were instructed in the use of the scales as coaching aids by members of the research team. The course of instructions covered a one-day period, and could readily be adapted for use by the fleet.

Experimental Design

The sample for this study consisted of 10 ships of the DD type selected at random by the Operations Officer of DesFlot Six. It was necessary to divide the ships into two groups since the goal of the present

study was to determine the effects of coaching as a method of reducing the mean attack error: an experimental group subjected to coaching and a control or practice group with no coaching. Each ship was assigned to the attack teacher for a two-day cycle. The first half-day of each cycle consisted of regular practice runs (P_o) for ships in both the experimental and control groups.

This provided a reference for their typical performance and gave the ships of both groups an opportunity to coordinate their activities and to reach a relatively stable level of performance. During the remainder of the two-day cycle, the experimental group was coached during exercises, and the control group conducted standard practice attacks without coaching. The experimental plan is shown in Table I.[1]

Table I

Experimental plan

	Cycle			
	First day		Second day	
	A. M.	P. M.	A. M.	P. M.
Experimental group (Coached)	P_o	C_1	C_2	C_3
Control group (Practice)	P_o	P_1	P_2	P_3

P = Practice attacks
C = Coached attacks

Experimental controls were used throughout the exercises to insure both the experimental and control ships operating under identical conditions insofar as possible. Throughout all cycles the ships conducted

[1] The number of coaching and practice sessions selected for a cycle was arbitrary since prior to this study it was not possible to determine the number of sessions required before coaching would be effective.

standard two-ship coordinated exercises using their regularly assigned GQ teams. A continuous target course, consisting of five standard runs combined randomly, was used for all exercises. This assured the same target maneuvers for all ships. The time intervals between changes in course and speed were controlled by the target helmsman using a stop watch. The ships were alternated on the basis of their initial performance between the coached and practice side of the attack teacher at the end of their first practice session (P_o). This permitted the equating of the experimental and control groups.

Range and bearing information for the CIC spaces was obtained from a grid pattern projected on the plotting screen. In previous attack teacher work it was found that this method would furnish more frequent and accurate information to CIC as well as relieve the behind screen plotters of the extra burden of making direct measurements from the screen. In this way a possible source of experimental error was eliminated. A discussion of this projection system is presented in Appendix A.

All ships of the coached group were assigned to one side of the attack teacher for all cycles. This was necessary since a Course-to-Steer Indicator, which is installed on only one side of the attack teacher at Newport, is of importance in the evaluation and coaching of the helmsman.

The coaches for the experimental trials were assigned to one side of the attack teacher. The two sonarmen were assigned to the Bridge and Sonar compartments; the radarman to CIC. The stations and activities coached are shown in Figure 1.

Inasmuch as the present study was also designed to evaluate team performance using measurements of the attack error and the activity rating scales, operator activities of both the coached and practice exercises were rated by Navy personnel with the scales developed and used in previous studies.[1, 2] The raters, one for each compartment, were selected and

[1] CAMPBELL, J. W., DORNY, L. C. & CHANNELL, R. C. The evaluation of ASW team performance by measurement of operator activities. First Partial Report, ONR Contract Nonr-351(02), Technical Report DA 30-2, 1 July 1952, CONFIDENTIAL.

[2] MUCHMORE, S. C., KELLNER, A. D., KOPONEN, A. & CHANNELL, R. C. The evaluation of ASW team performance by measurement of operator activities. Third Partial Report, ONR Contract Nonr-351(02), Technical Report DA 30-3, 1 November 1952, CONFIDENTIAL.

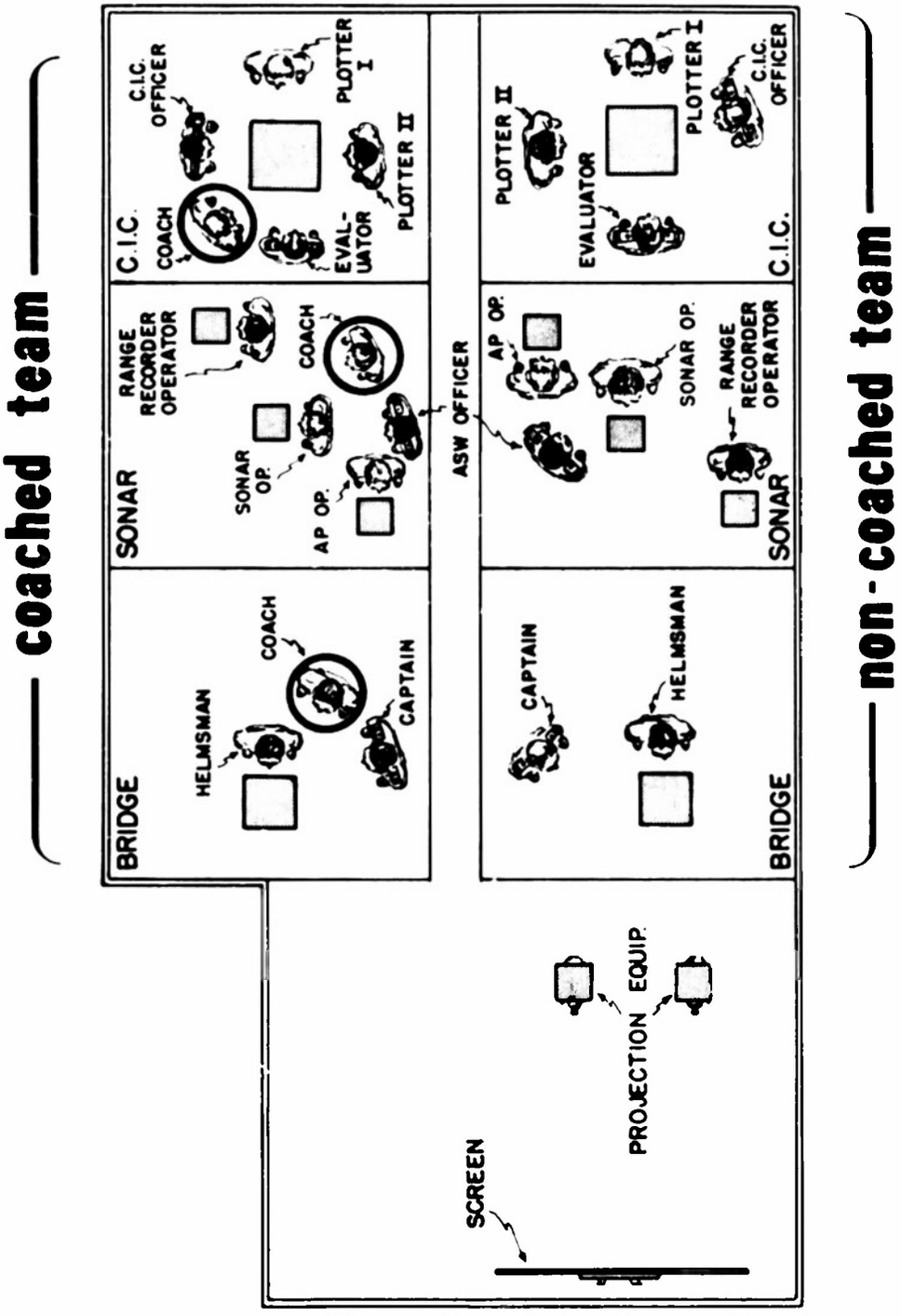

Figure 1. Coached and non-coached operators in the attack teacher.

and trained by the research team. The operators whose activities were rated included: [1]

Bridge	- Helmsman
Sonar Control	- ASW Officer, QHB Operator, Range Recorder Operator
CIC	- Evaluator, CIC Officer, Plotter I and II

The raters alternated between the coached and practice ships with each new cycle. This provided a control so that no one rater would rate the activities of the coached group for the entire study.

The practice sessions consisted of approximately 40 minute exercises during which three or four attacks could be observed for each ship. As in previous studies, target and ship information were plotted on DRT paper placed on the back of the projection screen. This provided a permanent plot from which more accurate measurements of the attack error could be made.

The attack error was measured after each exercise by members of the research team. Measurements were made from the center of the weapon pattern to the center of the target position after allowing sinking time for the depth charge. All measurements were made to the nearest tenth of an inch.

[1] A complete list of the activities observed is shown in Appendix B.

CHAPTER II

RESULTS

The results of the study of coaching on ASW team effectiveness are presented in this chapter. In general, the findings indicate an improvement in performance for those teams which are coached in their activities. This improvement is significant when compared to the performance of a control group which carried out standard attack teacher runs without coaching except that normally done within the team. The results are presented without any extensive discussion of significance and other statistical concepts involved. A more technical discussion is presented in Appendix C.

Sample

A total of 356 attacks were observed at Newport (Table II). It was necessary to exclude certain runs in the final analysis of the data because

Table II

Breakdown of attacks observed at Newport

Runs excluded from analysis	
Incomplete cycles	90
Class B attacks	13
Casualties in system	11
Total	114
Runs analyzed	
Control group	128
Experimental group	114
Total	242

of the methods used in analyzing the data and the nature of the experimental design. Runs during which equipment casualties occurred, Class B attacks (i.e., those with attack errors of more than 210 yards), and runs from incomplete exercise cycles in which a ship did not complete two full days of exercises were excluded. The last requirement was imposed in the selection of the final sample since in comparing the control with the experimental group it was necessary for ships of both groups to have completed the full cycle of runs. The final sample for analysis contained 242 runs: 128 for the control group and 114 for the experimental group.

Equating of Experimental Groups

The manner in which the ships were divided into an experimental group and a control group was described in the preceding chapter. The assignment of ships was made in such a way as to equate the groups on the basis of initial performance. By using this procedure it was possible to work with two groups which were approximately equal before introduction of the experimental conditions. Actually, the groups differed by only 5 yards in mean attack error for the equating sessions.

Figure 2 presents an ogive showing the cumulative percentage of attack errors for each group during the equating sessions. An ogive is a cumulative frequency curve; at any point on the curve it is possible to determine the proportion of observations that are as good as, or better than, a given value. Thus, in the present curve, we can determine the relative frequency of attacks that fall within a given radial attack error. For example, the control group has 22% of its attacks within 50 yards of the target and 70% within 100 yards. When the performance of two groups is displayed, the vertical distance between the two curves is the important measure and provides a ready comparison of the groups.

In preparing curves of this type, it is desirable to "smooth" the fluctuations in observed values, assuming that such fluctuations are due to chance. Therefore, there will not be complete agreement between values taken from the figures and comparable values reported in the text. The text will use the actual values observed in the experimental study.

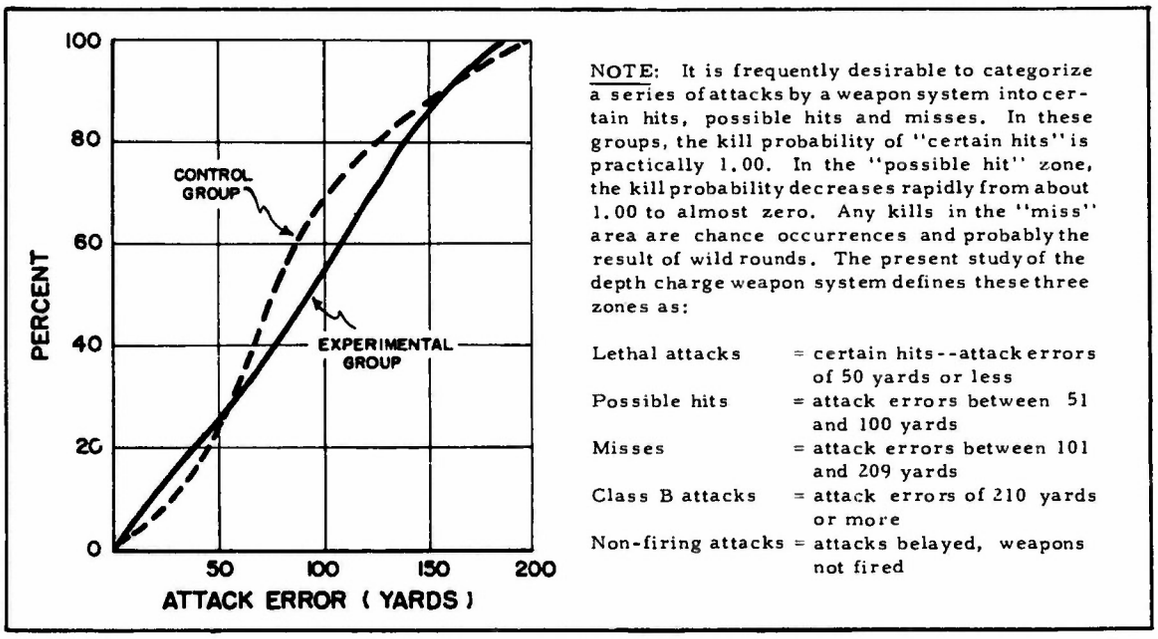

Figure 2. Cumulative percentages of attack errors during equating sessions for experimental and control groups (smoothed curves).

In Figure 2 it may be noted that there are only minor differences between the groups. The experimental group has a somewhat higher percentage of attacks within the 50 yard range while the control group has a higher percentage of attacks within the 100 yard range. The crossing-over of the two curves indicates the over-all equality of the groups in ASW attack proficiency as measured by the attack error.

Relative Attack Performance of Ships

It has already been shown (Figure 2) that there were no real differences in the original performance of the two groups of ships. If these ships are arranged in the order of their mean attack errors, it is possible to study their relative effectiveness in attack teacher exercises. (Such comparisons are routine in many training situations.) A similar

ranking of the ships was made at the end of the experimental period to provide an index of the relative performance of the coached and control ships (Table III).

Table III

Ranking of ships in order of mean attack error

Equating session			Experimental period		
Ship	Practice or coached	Attack error (yds)	Ship	Practice or coached	Attack error (yds)
A	Practice	60	B	Coached	63
B	Coached	75	D	Coached	82
E	Practice	80	F	Coached	84
F	Coached	86	A	Practice	85
D	Coached	107	E	Practice	88
C	Practice	115	C	Practice	106

An examination of the relative ranks of the ships in the equating sessions indicates no differences between the coached and the practice ships. However, there are consistent differences after the experimental period: all of the coached ships are better than any of the practice ships. The individual performances are also consistent. Each of the coached ships does better in the experimental period, but only one of the practice ships shows an improvement.

Effects of Coaching on Operator Performance

Any change in ASW team performance which might be brought about by coaching must first be reflected in an improvement in individual performance. In this case such performance was measured by ratings made

with the activity scales. It was found that these ratings improved consistently for the experimental group. The ratings for the control group showed no consistent trend. It will be noted later that the fluctuations for the control group parallel the session-to-session changes in mean attack error. Figure 3 points out the session-to-session change in ratings for the coached and control groups.

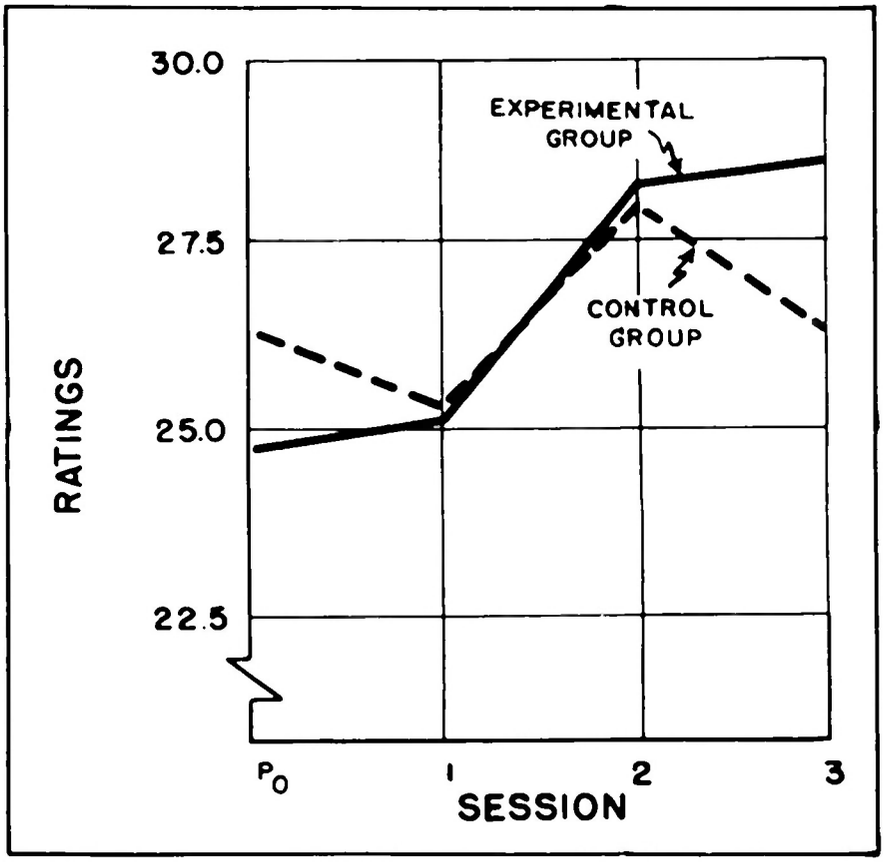

Figure 3. Mean activity ratings, as measured by activity scales, for equating and experimental exercises.

Team Performance During Experimental Sessions

The change in individual performance which is indicated in the ratings of operator activities is also observable in team performance as measured by the attack error. Cumulative percentage curves for the experimental sessions are shown in Figure 4.

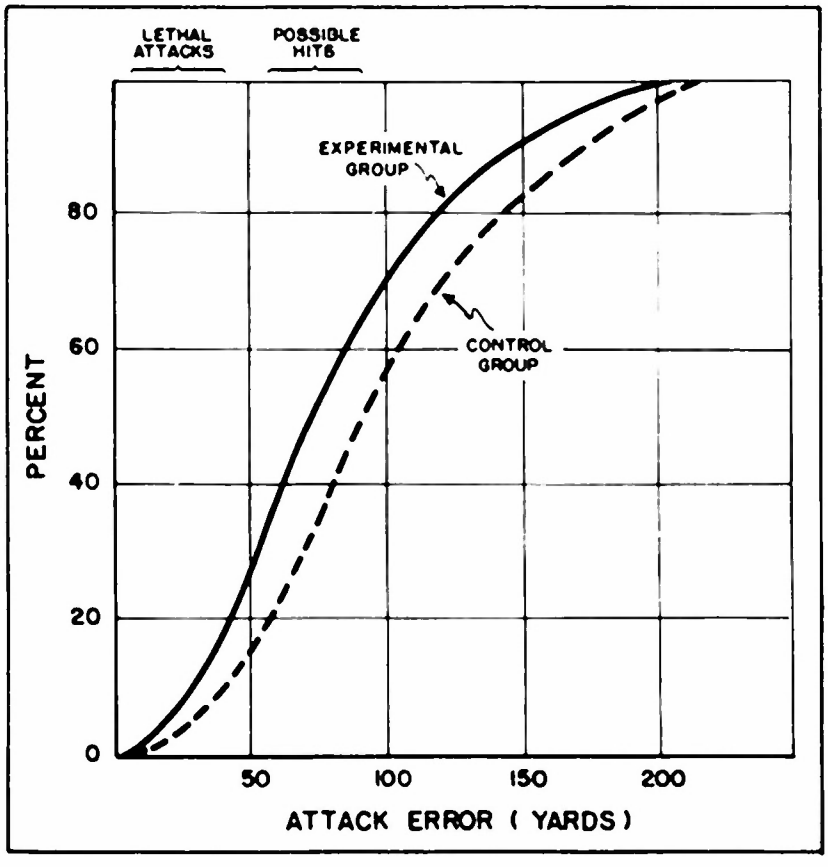

Figure 4. Cumulative percentages of attack errors during experimental sessions for experimental and control groups (smoothed curves).

The improvement of the coached group is apparent in comparing these curves with the curves obtained from the equating sessions (Figure 1). Where the two groups were essentially the same in performance during the equating sessions, the coached group shows much better performance during the experimental sessions.

Lethal Attacks

The distribution of attacks for the coached group was found to have shifted toward the lower end of the attack error scale. This shift is apparent in the increase in proportion of lethal and "possible hit" attacks. Although the proportion of good attacks tended to decrease for the control group during the experimental period, the ships which were coached during their attacks actually increased their proportion of good attacks. These changes in proportions are shown graphically in Figure 5.

The control and experimental groups differed somewhat in percent of lethal attacks during the equating runs (9%). This difference is not statistically significant.[1] However, the difference in proportion of lethal attacks during the experimental sessions was significant at the 1% level of confidence. The coached group changed from 28% to 35% in proportion of lethal attacks. During the same sessions, the group which used standard attack procedures without coaching went from 19% to 17% in proportion of lethal attacks.

In terms of possible hits, the control group was 16% superior at the outset. During the experimental sessions this difference was reduced to make the groups approximately equal. The proportion of misses increased for the control group while the experimental group reduced their proportion of misses by 13%.

[1] This difference cannot be considered as a real difference since in repeated experiments of this nature a difference this large would occur by chance too frequently. We can thus assume that no real differences exist. When the significance levels (1% level, 5% level) are noted in this report these figures are the probabilities that such differences could be attributed to chance.

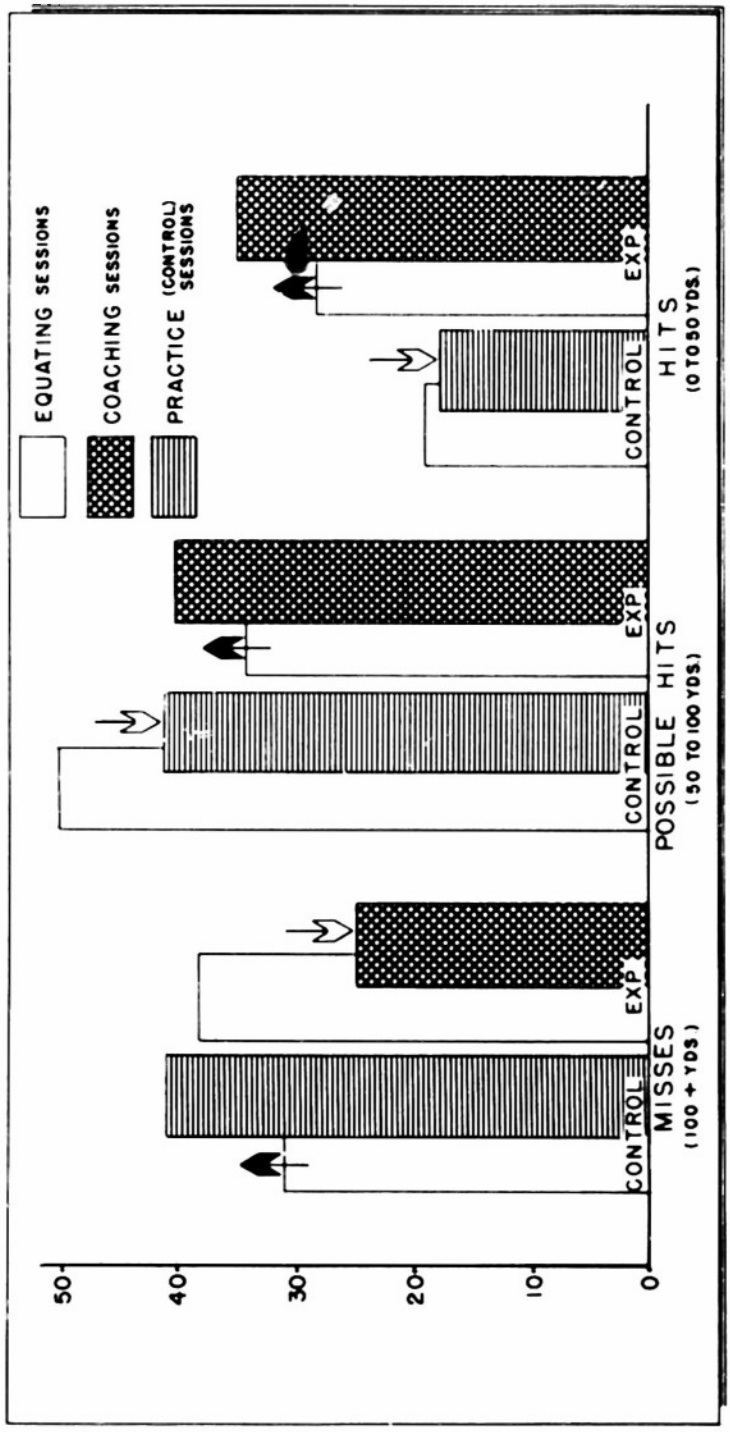

Figure 5. Changes in proportions of good and poor attacks from equating session to experimental session.

Comparison of Attack Error Means

The mean attack errors for the two groups are compared in Table IV, first during the equating trials and again for the experimental sessions.

Table IV

Mean performance of

experimental and control groups

	Mean Performance (in yards)		
	Initial runs	Experimental runs	Change
Control group	81	92	+ 11
Experimental group	86	75	- 11

The groups differed by 5 yards in mean performance during the equating trials. This difference is not significant. On the other hand, the difference between the groups during the experimental sessions was 17 yards. This difference is large enough to be expected to occur by chance, or sampling fluctuation, less than 1 time in 100 (significant at the 1% level of confidence).

Fluctuations in Performance of Control and Experimental Groups

The change in performance noted from the equating to the experimental sessions is also of interest. The coached group improved 11 yards while at the same time the control group went down in performance to the extent of 11 yards.

The improvement of the experimental group is presumably a result of the coaching. However, the reason for the decline in performance for the control group is not immediately obvious. Plotting the session-to-session attack error means for the control and experimental groups shows a general improvement for the coached group with a slight fall-off in the final session. The performance of the control group appears to fluctuate more or less at random (Figure 6).

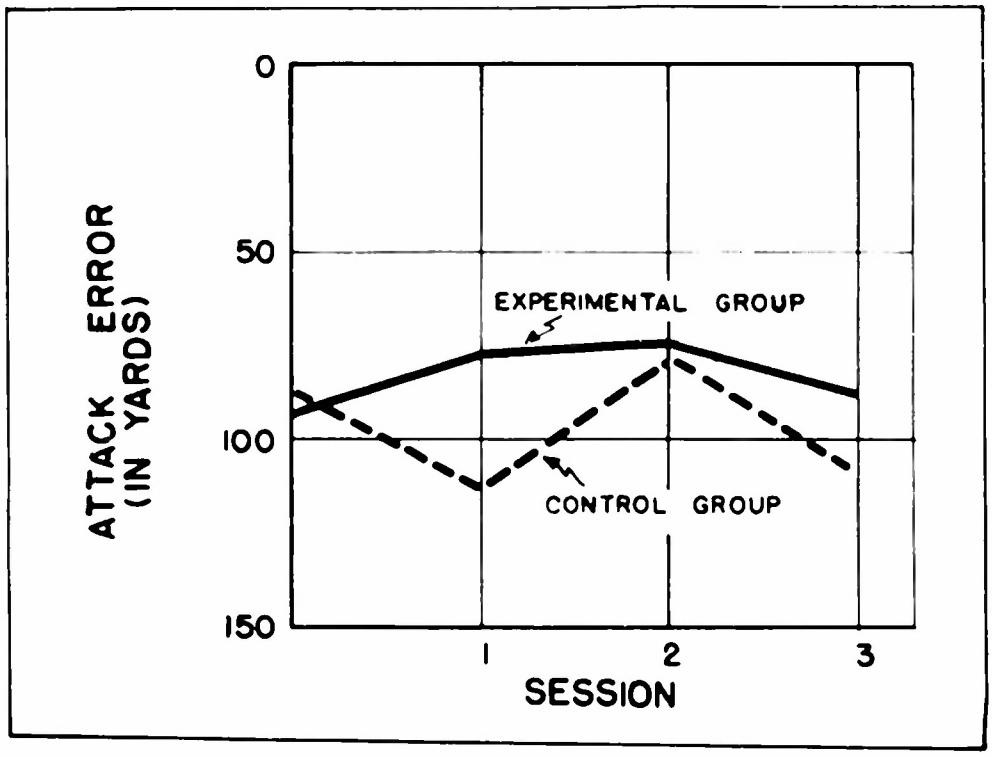

Figure 6. Mean attack error for experimental and control groups.

It is possible that the fall-off in performance for the control group during the afternoon sessions is an indication of a diurnal cycle of team performance. Such factors as fatigue or boredom may be at work to bring about a decrease in performance during these sessions. It will

be possible to investigate this fluctuation in future attack teacher studies to determine whether it is a typical diurnal fluctuation or merely a chance occurrence. Analysis of the data with this objective in mind can be made without any change in proposed experimental design. Further study of ASW attack effectiveness should be made before any conclusions are drawn regarding the observed fluctuation.

Validity of Activity Scales

It was mentioned earlier that the ratings of the control group paralleled the attack error means from session-to-session (Figures 3 and 6). This agreement might be considered an indication of the relationship between the ratings and the attack error. Calculation of a correlation coefficient for these variables has shown a significant relationship to exist.

Validations of the activity scales in the previous studies (Third Partial Report) have shown that the attack error could be predicted with a fair degree of accuracy by the use of the scales in combination. It was further reported that a satisfactory prediction could be made by simply adding all the ratings to get a total measure of team performance. The correlation coefficient obtained in this manner was almost as high as the multiple R obtained using more complicated beta weights.

A similar procedure was followed with the ratings obtained in this study using the same predictors as previously. A correlation of .34 was obtained. The previous study resulted in a validity estimate of $r = .42$ based on a sample of 81 observations. The present estimate, $r = .34$ ($n = 128$) does not differ appreciably from this original value. In fact, a test of the difference[1] indicates that we would expect such discrepencies about half the time simply as a result of sampling errors. Thus, the rating scales continue to show a significant positive relationship with the attack error criterion.

The ratings obtained in this study, as in the previous Newport study, were made by enlisted Naval personnel. The scales were used by these

[1] Using the conventional formula for testing the significance of differences between correlations results in a critical ratio of .67.

men after a brief orientation period with only a minimum amount of supervision by research personnel. Therefore, the obtained results are comparable to what might be expected from application in the fleet.

Future Research Plans

The results of this study indicate that, in general, an improvement in team performance in the attack teacher can be expected when operators of the ASW team are coached. To fully evaluate the effectiveness of coaching on depth charge exercises a study of this nature should be repeated. If comparable results are obtained, we may then say with considerable confidence that team effectiveness can be improved by coaching the individual operators.

The present experiment also suggests several related problems which should be considered in the formulation of plans for future study of the ASW attack system. An extension of this present study to include other weapons in the ASW system would provide information of value to the Navy in the formulation of training procedures for anti-submarine warfare. For example, it would be desirable to study the effects of coaching on simulated hedgehog attacks. The findings in the present study suggest that coaching will materially improve the effectiveness of a weapon system. If a similar improvement can be brought about by coaching in the more advanced weapon systems, a significant improvement will be effected in over-all ASW proficiency. To study the effects of coaching on weapon systems other than the depth charge the same procedure and experimental design can be used as employed in the present study.

Also, if the results of the present study can be confirmed by the repeat study, then it would be desirable to consider the use of stand-by members of the ASW team as coaches. Within-team coaching, where stand-by members of ASW team perform coaching duties, provides more efficient utilization of existing personnel since coaching personnel would not have to be drawn from outside the team. The results of such a study would be a valuable extension to the present work if changes in team performance could be effected by using team operators as coaches during their relief periods.

Another problem closely related to the present investigation is the study of the residual effects of coaching on team performance. The results of the present study have raised several interesting questions regarding this point. For example, how much training should be given teams in the attack teacher to maximize learning and maintain proficiency? An experimental study of this problem should give valuable information with respect to the spacing of attack teacher training sessions and the frequency with which re-training should be given. These studies, supplemented by additional research, could supply answers to the question of when a ship is ready to engage in sea exercises. To make the most efficient use of live submarine time at sea, the ASW team should have attained an adequate level of performance. The attack teacher can be a valuable aid in preparing the ASW team for sea exercises. This is especially true in the case of dual-ship attacks in which communication between the ships plays an important role.

Future plans for research should also include a study of the degree of transfer of training from attack teacher to sea exercises. Previous experimental studies in the attack teacher have furnished a methodology for evaluating team performance in shore training. The attack error criterion is considerably less reliable at sea. However, using the visual estimates, with the refinements which will have been implemented at the time, an estimation of the relationship of attack teacher performance to sea performance can be made. A study of this nature should lead to more effective utilization of shore-based training facilities.

APPENDIX A

Obtaining Ranges and Bearings of Assist Ship in the Dual Attack Teacher

The procedure for utilization of the dual QFA attack teacher in ASW training involves obtaining the ranges and bearings of the other ship. This information is required to enable the CIC of each ship to maintain a plot of the other ship. The procedure currently in use requires the use of two men behind the screen whose job it is to use a measuring arm similar to the Universal Drafting Arm except that it is designed to be used on a vertical surface. The instrument is provided with a pointer which, when allowed to swing freely as the arm is placed on a line between the ships, indicates the true bearing from one ship to the other. The arm is scaled so that ranges may be read from it. The information so obtained is transmitted through a talker to the CIC's.

It was found that the use of the above system did not furnish accurate nor frequent enough information to the ship CIC's. In order to control the experimental conditions to the greatest extent, an alternative system was implemented, one in which extraneous sources of error could be minimized. The substitute system involved the use of a 35 mm projector which was used to project a polar grid on the screen. A talker was stationed at the projector to read and transmit the ranges and bearings to the CIC's.

By use of a filter on the projector it was possible to project the grid in red. Projecting the image in red provided two advantages: 1) the short wave length of the red light did not interfere with the photo-electric mechanism of the attack teacher projection equipment, and 2) the diffused red light which showed through the screen did not affect the dark adaptation of the plotters.

For convenience in operation, the polar grid projector was placed on top of the pill projector mount and was easily trained on the appropriate ship by manipulating the horizontal and vertical controls on the mount. The operator was provided with a set of sound-powered phones which were hooked into the 21 JS circuit. The operator's job in obtaining ranges and bearings and transmitting them to the CIC's involved the following steps:

1. Turn on projector.

2. Manipulate control knobs so as to train grid projection on ship.

3. Read range and bearing to assist ship into SP phones.

4. Turn off projector.

This procedure took about 5 seconds to complete. Ranges and bearings were usually sent at the rate of 2 per minute and frequently faster. A degree of accuracy which was well within the required limits was obtained. In general, the use of the new system provided the following advantages:

1. More frequent and more accurate information was furnished to the CIC's of both ships.

2. Plotters behind the projection screen were free to plot the ships and submarine without the additional burden of obtaining ranges and bearings. Thus, more satisfactory plots were obtained.

3. One communication link was eliminated by having the talker read the range and bearing directly off the screen into the SP phones.

The implementation of this system in the QFA attack teacher exercises involved only minor changes in over-all operating procedures. However, throughout the exercises, the use of the slide projector served to keep the flow of range and bearing information on a more than adequate level. The projector was removed upon completion of the experiment, but it was indicated by operating personnel that the system would, if possible, become part of the standard operating procedure in the QFA installation.

APPENDIX B

Operator Activities Observed in the Attack Teacher

SONAR CONTROL

ASW Officer

1. Coaching of operators
2. Information control of (UB Plot and) sonar

QHB (Stack) Operator[1]

1. Search procedure
2. Tracking targets

Range Recorder Operator

1. Range information
2. Range rate

CIC

Evaluator

Coaching of CIC team

CIC Officer

Communication with assisting ship

Plotters

1. Completeness of plot
2. Neatness of plot

BRIDGE

Helmsman

Course at time of fire

[1]Searchlight type sonar equipment was employed at the Newport attack teacher. This scaie was adapted for use with this equipment.

APPENDIX C

Statistical Significance of Results

The technical reader, who may be concerned with research on problems similar to those covered in this report, may be interested in a more detailed presentation of the results of the statistical analysis. Other readers, interested in the operational or training implications of the results, usually have little interest in such information. This appendix is therefore prepared for the technical reader and presupposes a working knowledge of statistical methods, information which most readers have had no occasion to use since their undergraduate days. All of the information presented here has been covered in Chapter II--Results.

The crucial comparison to be made in examining the data gathered in this study is the difference attributable to the experimental treatment, i.e., coaching. As a preliminary to this, it must be demonstrated that any original differences between the groups are probably chance determined. Variance analysis provides a method for making this test.

In making this analysis, the variance was divided into that portion accruing from the groups to which ships were assigned (experimental or control), the mean performance of the individual ships, and the intra-ship variability of performance (see Table V).

Table V

Analysis of variance for P_o sessions

Source	SS	df	MS	F
Between conditions	5	1	5.0	-- (4.04, 7.19)*
Between ships	193	5	38.6	1.80(2.41, 3.42)*
Within ships	1029	48	21.4	
TOTAL	1227	54		

*Required F ratio for the 5% and 1% levels of confidence

This analysis indicates that the variance in attack error performance observed during the equating session was caused by the intra-ship

variability. Thus, we are able to conclude that there were no essential differences between the two groups of ships at the beginning of the study.

The results of the testing of the difference in proportion of lethal attacks during the equating trials are shown in Table VI.

Table VI

Difference between proportions of lethal attacks during P_o sessions

	Number	Lethal	Non-lethal
Experimental group	29	28%	72%
Control group	27	19%	81%

Obtained difference = 9%

σ $prop_1$ - $prop_2$ = 11.2

$t = \frac{9}{11.2} = .80$ (not significant)

While there was a difference of 9% in proportion of lethal attacks between the two groups during the P_o sessions, this difference may be attributed to chance alone. With samples of this size the possibilities of obtaining a difference of this magnitude, when no real difference exists between the two populations, are too great to accept this as significant.

Performance During Experimental Trials

The analysis of variance for performance of the groups during experimental sessions was computed in the same manner as that for the equating session (see Table VII).

It may be noted that the difference between the two groups after coaching is significant at the 1% level of confidence. In other words, the obtained difference between the coached group and the practice could be obtained by chance alone (sampling fluctuation) less than 1

time in 100. Thus, it may be concluded that, in this sample, the coached ships were brought to a performance level which differs significantly from that of the practice ships.

Table VII

Analysis of variance for experimental sessions

Source	SS	df	MS	F
Between conditions	152	1	152.0	7.07(3.90, 6.79)*
Between ships	349	5	69.8	3.25(2.27, 3.12)*
Within ships	3863	180	21.5	
TOTAL	4364	186		

*Required F ratio for the 5% and 1% levels of confidence

In analyzing the differences between the groups in proportion of lethal attacks, the following results were obtained.

Table VIII
Difference between proportions of lethal attacks during experimental sessions

	Number	Lethal	Non-lethal
Experimental group	103	35%	65%
Control group	85	17%	83%

Obtained difference = 18%

σ $prop_1$ - $prop_2$ = 6.3

$$t = \frac{18}{6.3} = 2.86 \text{ (Significant at .01 level)}$$

APPENDIX D

Abstracts of First, Second and Third Partial Reports

ABSTRACT OF THE FIRST PARTIAL REPORT

The Evaluation of ASW Team Performance by Measurement of Operator Activities

Rationale

Team activities exist at three levels: activities performed by the individual operator, the complex of closely related activities going on in a space such as CIC or Sonar Control, and finally the integration of the functions of the various spaces into the performance of the ship. Each practice attack can be considered as a separate work sample with a measurable output, the attack criterion measure.

The various activities of an individual operator, after quantification of the task, can be combined in a regression equation to predict the attack criterion. In conventional statistical terminology, this relationship is represented as:

$$W_{a1} P_{a1} + W_{a2} P_{a2} \ldots\ldots W_{an} P_{an} + C = E_a$$

$$W_{b1} P_{b1} + W_{b2} P_{b2} \ldots\ldots W_{bn} P_{bn} + C = E_b$$

where

W_{an} = Regression weight of activity n for operator a

P_{an} = Performance level of activity n for operator a

E_a = Predicted criterion score using activities of operator a

Since the activities of various operators are interrelated in that the basic input data, sonar range and bearing, are "processed" by the various members of the team, it is desirable to use the performance of the operators to predict, as well as possible, the performance of the ship attack team. It is shown that this can be done with the equation:

$$W'_a P'_a + W'_b P'_b + W'_c P'_c \ldots\ldots W'_n P'_n + C = \overline{E}$$

where

W'_a = Regression weight for predictor activities of operator a

P'_a = Mean performance level on predictor activities of operator a

$\overline{E}$ = Predicted criterion score using activities of all operators

Activity Ratings

The problems involved in the use of units peculiar to the various activities are complex and excessively time-consuming. Applied psychological research has made extensive use of rating scales since the first World War, with positive results in the evaluation of personnel efficiency.

Rating scales were developed with the following requirements fulfilled:

1. Scales were in job behavior terms.

2. All major activities of an individual that had a logical relationship to the success or failure of the attack were covered.

3. All scales were five step scales, with the middle step descriptive of "4.0" performance.

4. Almost identical activities (e.g., talkers in various locations) were covered by the same scale.

Criterion Measurement

Several criterion measures of the effectiveness of team performance were investigated. These included the attack error, bearing error, location error, range error, and duration of lost contact.

There are, of course, many criteria which can be used to measure the over-all effectiveness of an ASW team. Among these would be sonar location error, prediction error, kill probability, attack error, etc. However, the criterion to be used in the early phases of the program willbe the attack error. A technique for measuring the attack error with shipboard equipment is described. The major limitations to this technique are:

1. Short duration of the air bubble on the surface.

2. Difficulty in locating the bubble in sea states greater than 1 or under certain glare conditions.

3. Frequently, unfavorable viewing angles (relative bearing of 160 to 200) occur due to standard maneuver plans.

4. Excessive ranges to the bubble due to slow rising rate of bubble (approximately two feet per second).

Attack Teacher vs. Sea Exercises

The attack teacher, as with most synthetic training devices, is a convenient means for training large numbers of operators. Sea exercises, while far more costly and time-consuming, are more nearly like combat anti-submarine operations.

Research considerations indicate the use of sea exercises, although the criterion measurement at sea may seriously limit the results. The attack teacher, while facilitating the measurement of attack errors, is deficient in simulation of sea exercises, communication facilities and integration of CIC and the Bridge as parts of the attack team.

A series of attack teacher exercises have been observed at the Fleet Sonar School (San Diego, California), and certain conclusions are drawn from the data.

1. Enlisted students are not adequate subjects because of the influence of the instructor on the attack error under present training doctrine.

2. Non-firing attacks must be excluded from the data, although data can be gathered as to causation of these failures.

3. Two-ship coordinated attacks provide a better training problem for CIC than do single-ship exercises.

Analysis of Sea Exercise Data

The general plans for collection and analysis of data on sea exercises are described. The plans for the intensive study of the various activity rating scales to improve the prediction are also covered.

Future Work

The preliminary plans for future data collection, including the sea exercises covered in the present report, are described. These include attack teacher studies, systems research, and various small experimental studies to test hypotheses developed by the research team.

Implications for Future Research

Potential uses of the present methodology, after demonstrating its validity, are presented for consideration. Among the more obvious uses are criteria in personnel research on selection and training.

ABSTRACT OF THE SECOND PARTIAL REPORT

Operator Activities in Relation to Sea ASW Exercises

ASW Training

Current ASW training exercises were observed both ashore and at sea. Some of the major differences between sea and shore-based training are presented with emphasis on the relative value of these two modes of training.

Shore-based training: It has been demonstrated that knowledge of results of a performed task facilitates the learning process. Knowledge of results of attack effectiveness is almost immediately available to crew members during shore-based training. The instructor reviews the performance of the team and provides a critique. However, motivation is not as high as during sea exercises due to the lack of competition and realism in the synthetic problems.

Sea exercises: Typical sea exercises do not provide a review of team performance and precise data on target course and attack effectiveness are not usually available to the crew. When the knowledge of results of the attack are communicated to the crew, the accuracy of the information is open to question because of the guesswork involved in the estimates of the attack error. Motivation is high because of the realistic and challenging nature of the problem.

The sea exercises used for experimental purposes were observed at Guantanamo Bay. A total of 356 attacks were observed of which 117 attacks were used to obtain preliminary information that would serve as a basis for eliminating certain activity rating scales. This provided a total of 239 attacks which were used to obtain rating data on the selected activity scales. From this group of 239 attacks, 139 attacks were rejected for various reasons. The final sample for analysis consisted of 100 attacks, an attrition of about 58%.

General Quarters Job Descriptions

The activity rating scales had been developed after a survey of the available material on ASW training, including a study of the training activities of the Fleet Training Center, Norfolk. Observations of the ASW team during sea exercises at Guantanamo Bay provided data on the activity ratings and job duties of the specific members. These data also provided information of value in determining some of the causes of non-firing attacks and differences in operating procedures. Some of the outstanding factors which affect operating procedures include attitudes and training of Commanding Officers, capabilities of personnel, training stations at which procedures were learned, equipment arrangement and type of exercise.

Attack Error As A Measure of Attack Effectiveness

The development of an adequate criterion measure of team performance has been one of the major problems in this phase of the research program. The criteria which have been investigated include location error, bearing error, duration of lost contact, probability of kill, and the attack error. Research personnel have been working on the development of a satisfactory attack error measurement device for a number of years, but a practical (and inexpensive) method is still not available. During the experimental phase of the present research program, several measures of the effectiveness and limitations of team performance were investigated. These are discussed along with suggestions for new or improved measures. Because of the lack of a more precise measure, visual estimates of the attack error are used in this present study as the criterion measure.

Results of Sea Observations

An analysis of the results of this study indicates that there is general agreement between the research findings and the results of a logical evaluation of the important activities of the ASW system. The immediate usefulness and application of these findings is, however, limited because of the lack of a more precise criterion measure. The relationship between the present criterion estimate and the critical activities of the ASW team indicates that the rating technique is a potentially valuable

method for measuring operator and team performance and thus the methodology used in this study may be profitably applied to other research problems on team performance.

Related Research Problems

During the field trips the research team observed variations in attack procedures which suggest several training research problems. From an investigation of these areas it may be possible to determine those procedures which will provide better and more effective team performance. A study of ASW activities also revealed that it would be profitable to conduct a human engineering analysis of the arrangement of existing ASW equipment. This is particularly important since it is felt that working conditions within ASW spaces could be improved by making relatively minor modifications of equipment arrangement while ships are undergoing a periodic overhaul. A discussion of some of these human engineering recommendations are presented in this report.

Future Research Studies

Future plans for the research program include further studies of attack teacher exercises and additional sea observations. The plans call for further investigation of the validity and reliability of the activity scales and the experimental testing of various hypotheses.

ABSTRACT OF THE THIRD PARTIAL REPORT

Operator Activities in Attack Teacher ASW Exercises

ASW Training

Incidental to the research, the report includes observations of the attack teacher training methods. Motivation should be increased by critiques, orientation lectures and the use of more realistic and complex target courses. The present emphasis in training appears to be placed on learning by repetition. However, instruction and coaching to be effective should point out poor performance as well as adequate performance as soon as it occurs. The criticisms should be specific and where possible the operators should have immediate knowledge of results. Coordination within teams and between ships is necessary for the development of effective ASW team performance.

Procedure

Regular dual-ship attack teacher exercises were conducted for ships' teams. The target course of the teams consisted of standard runs combining both full and limited evasive target maneuvers. The activities of the ASW Officer, QHB Operator, Range Recorder Operator, Evaluator, CIC Officer, Plotters and Helmsman were rated during the trials by Navy personnel familiar with the activities. Permanent plots were recorded for each trial and the attack error was measured and later corrected to account for target evasion after loss of contact.

Results

1. The data of 81 attacks were used in tabulating the results. Class B, single-ship and attacks without sufficient data were excluded from the analysis.

2. Measures of the attack error criterion were adjusted to allow for random turns of the target after loss of contact.

3. An analysis of the data indicated a homogeneous group of ships' teams which justifies combining them in various ways for purposes of investigation.

4. An evaluation of target aspect showed that there was no significant difference in attack error depending on the target angle (bow, stern or beam aspects) during the final stage of attack.

5. The QHB Operator's and the ASW Officer's composite rating scales correlated most highly with the attack error criterion.

6. Correlations between the criterion and the rating scores were higher in the attack teacher than the correlations obtained in sea exercises which may be due to the more reliable measure of attack error in the attack teacher.

7. The correlations between the criterion and the rating scores tended to maintain the same positions of rank according to magnitude in both the sea exercises and in the attack teacher.

8. Team members who performed well in one activity tended to perform well in others.

9. Individual team members who performed well were usually members of teams in which others performed well.

10. When all of the ratings were combined and correlated with the attack error criterion, the relationship compared favorably with those usually found in rating techniques.

11. Ships' teams rated high on the activity rating scales have a larger percentage of lethal attacks than ships' teams rated low.

12. A small improvement in the average attack error can result in a relatively large increase in the percentage of lethal attacks.

Future Research Plans

A program for attaining maximum use of the attack teacher as a training device should improve ASW efficiency because the results indicate transfer of training between the attack teacher and sea exercises. Since the rating scales show a consistent relationship to the success of ASW attacks, the scales can be used as a guide in the coaching of operators.

The future research will involve an experimental study of coaching as a means of improving team performance.

Additional research will include an investigation of the error recorder being developed by SurASDevDet to ascertain its value in ASW training. The error recorder makes possible the analysis of errors arising at the QHB and the Range Recorder.