ENHANCED KNOWLEDGE OF RESULTS: INDIVIDUAL AND TEAM APPROACHES

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ABSTRACT

The effectiveness of training programs depends fundamentally upon the availability of knowledge of results (KOR) concerning trainees' performance and how the KOR is used in instruction. This paper describes examples of individual and team training applications of enhanced KOR. The individual training system, called the Automated Performance Assessment and Readiness Training System (APARTS), generates KOR on carrier landing performance that is used by instructors to integrate training in operational aircraft with practice in a flight simulator. APARTS is currently being implemented at all Air Wings and Fleet Replacement Squadrons. The team training example, the Surface Anti-submarine Warfare (ASW) Training System, incorporates a variety of KOR data and presentation techniques to address problems unique to team training. Procurement of a prototype version of this major system is underway at the Naval Training Systems Center, and "follow-on" systems are planned for the near future. Requirements for individual and team training are compared.

INTRODUCTION

The origin of the concept of feedback can be found in engineering, specifically in the branch of engineering known as control theory [1]. In its original sense, "a system is said to contain a feedback loop when the output of that system interacts with its input in such a way as to modify the subsequent activity of the system as it continues to generate an output" [1,p.16]. The feedback loop allows comparison of the actual and the desired outputs of a system which, in turn, supplies information needed to adjust system activities to reduce discrepancy between these outputs. Feedback has been used in an extended sense by psychologists and educators to refer to the knowledge of results (KOR) necessary to reduce the discrepancy between actual and desired task performance [2,3,4]. It is this extended use of feedback or KOR that is the topic of this paper.

Sixty years ago, Thorndike [5] showed that without performance feedback or KOR, practice not only does not make perfect, but practice does not even improve performance. This was true even with extensive practice (hundreds of trials) and a relatively simple task (drawing three-inch lines). Later research defined types of KOR that are best for learning.

In spite of the research and general acknowledgment that KOR is critical for efficient learning, trainers have been designed and used more to support practice (trainees perform tasks in an operational-like environment), than to give KOR and other instruction on the behaviors that comprise the task. Trainees receive instruction on specific skills to the extent that instructors have the enthusiasm, expertise and time to improvise performance measures and related instructional actions. Trainees also teach themselves, but this instruction is incidental and often is not optimal. In such cases where KOR is not provided, trainees are treated much like the subjects who never learned to draw three-inch lines in the Thorndike study, and similar results are to be expected.

Functions of KOR

KOR serves several functions which can enhance training effectiveness. Operant psychologists maintain that KOR serves as a reinforcing stimulus and have used KOR to shape behavior and maintain its strength [6,7,8]. Others explain the reinforcing effects of KOR as due to the information that it offers in locating errors and providing information so the learner can correct the errors [9,10,11]. Still other explanations assign a motivational component to KOR. Removal of KOR has been shown to increase a person's annoyance, boredom, and carelessness [12]. When MacPherson, Dees and Grindley [13] replicated Thorndike's drawing experiment, telling subjects that the next set of trials would be made without KOR, they found that subjects' scores on the current set dropped immediately. Since performance deteriorated where KOR was still present, the effect was attributed to decrements in motivation from anticipating the loss of KOR [4]. Another function of KOR is to serve as guidance for the trainee and to restrict his or her number of alternative responses. Without KOR, "people may come to learn the errors which they commit, and tend to repeat them. Later, these erroneous responses will have to be `unlearned'" [4,p.37]. KOR also has been shown to enhance subjects' perceived task competence [14] and to increase the correlation between the subjects' perceived competence and their actual task performance [15].

The remainder of this paper discusses two complex, real-world applications of KOR in its motivational, guidance, and informational roles. In one application, using the Automated Performance Assessment and Readiness Training System (APARTS), *instructors and trainees* receive KOR from performance on carrier landings in operational aircraft. The KOR guides future training in the aircraft and in a simulator. The second example applies similar KOR principles to team members during training for surface anti-submarine warfare (ASW) operations.

THE USE OF KOR IN INDIVIDUAL PERFORMANCE TRAINING

Carrier Landing Training: A Task Description

One of the most difficult tasks encountered by a Naval aviator is landing a high-performance jet aircraft on the deck of an aircraft carrier. The demands of this task are exacerbated during bad weather or during night landings. In general, carrier qualification (CQ) training proceeds in three stages. The sequence begins in a relatively high-fidelity simulator-based training system, like the Night Carrier Landing Trainer (NCLT), proceeds to the aircraft during Field Carrier Landing Practice (FCLP), and ends with landing the *aircraft on the carrier (CQ). Although* this sequence is designed to promote step-by-step landing skill acquisition, often each stage is performed in isolation from the others. For example, the trainee may not practice those tasks in the simulator that showed the worst performance during aircraft trials.

In a report on A-7 aircraft training effectiveness, the author [16] concluded that the effectiveness of CQ training could be improved if FCLP performance could be coordinated with individualized remedial instruction with the NCLT. When such individualized remedial instruction was included in CQ training, the number of replacement pilots who failed to qualify during their first CQ attempt was reduced. A drawback of this remedial program was that it utilized a manual system to identify FCLP performance deficiencies. An automated system was recommended to facilitate the accumulation, analysis, and presentation of FCLP data.

The Automated Performance Assessment and Readiness Training System (APARTS)

APARTS was developed to help the Landing Signal Officer (LSO) derive and use FCLP data for remedial KOR. Figure 1 pictorially represents the LSO's operational situation. The LSO observes *and records performance of aviator* trainees and then enters these data into APARTS. APARTS then analyzes and displays the data for subsequent use. Several prototype APARTS units have been

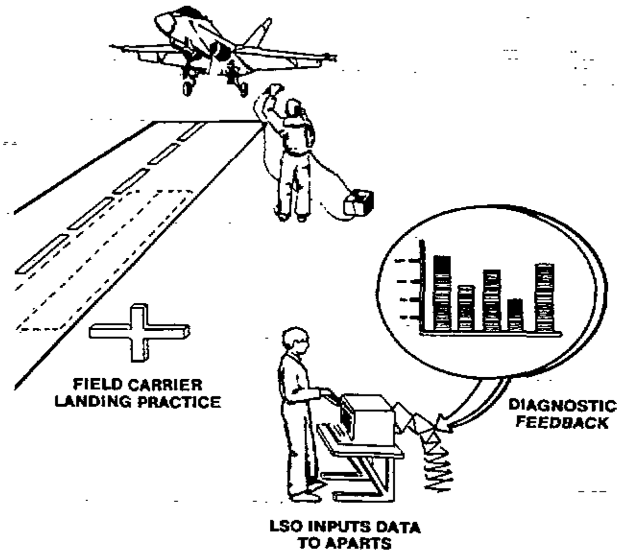


Figure 1.
Pictorial Representation of APARTS

used at west coast Fleet Replacement Squadrons and have proven very effective. APARTS presents a large body of performance data in forms that are easily understandable by the LSO and trainee. Preliminary data indicate that the use of APARTS to integrate FCLP performance with remedial practice on the NCLT reduces the number of recycles necessary for aviators to pass CQ. The APARTS application incorporates several principles of learning: (1) meaningful organization of information; (2) problem analysis; (3) immediate knowledge of results; (4) individualized instruction; and (5) remedial instruction.

System Description. APARTS currently operates on a Hewlett-Packard Series 9800 desktop computer, but can be readily modified to operate on virtually any micro-computer. APARTS software consists of two independent, but interactive, programs: the Editor and the Performance Review. Each program contains numerous subprogram modules. This modular design provides system flexibility because existing modules may be easily updated and new modules added to extend system capabilities.

Briefly, the Editor Program provides capabilities to add, change, list, process and store FCLP performance data. The Performance Review Program provides ready access to summaries of large quantities of these FCLP data. The program selects and retrieves the data, *analyzes FCLP performance problems and* develops performance tables and graphs. Additional information on these programs may be found elsewhere [17].

APARTS Outputs. The outputs of the APARTS system consist of a number of graphic displays of FCLP data. Figure 2 shows a sample FCLP grade sheet, which is the raw FCLP performance data recorded by LSOs. At instructional sites where APARTS has not been implemented, these FCLP grade sheets are the only record of trainee performance in the aircraft. Without APARTS, the LSO has no efficient method for using these data for feedback to the trainee aviator. APARTS stores and statistically analyzes the raw data entered into the system, and produces tabular and graphic displays of the analyses.

Several different tables and graphs may be obtained from the system. For example, an FCLP trend analysis is a table with each row showing LSO comments for a single landing approach and each column representing a category of landing technique errors. Average LSO grades are also calculated and displayed at the bottom of this table. The FCLP Trend Analysis provides a meaningful organization of the data for further analysis.

The graphic outputs of the system consist of the following:

(1) The General Landing Problem Type (Figure 3) is a histogram showing a summary of general landing problems over 12 approaches.

DATE		LSO
A/C 234		PILOT Recycle IM
1	B→	HAW BAR
2	B→	HCDAW DECIC BAR
3	WO	SRDIM HFNDIC-AR
4	B→	HAW •
5	(OK)	SRDIM (H) CDIC-AR
6	B→	2DECSIM (H) BIC-AR
7	—	2NEPX HIM NOIC (H) BAR
8	OK	(DECIM) (BAR) (NOTL)
9	B→	DECIM 2SIC BAR
10	(OK)	HX-IM (TMPIC) (LR)
11		
12		
PTS		
PASS:		GRADE
	DAY:	NIGHT:

Figure 2. APARTS input: FCLP Grade Sheet

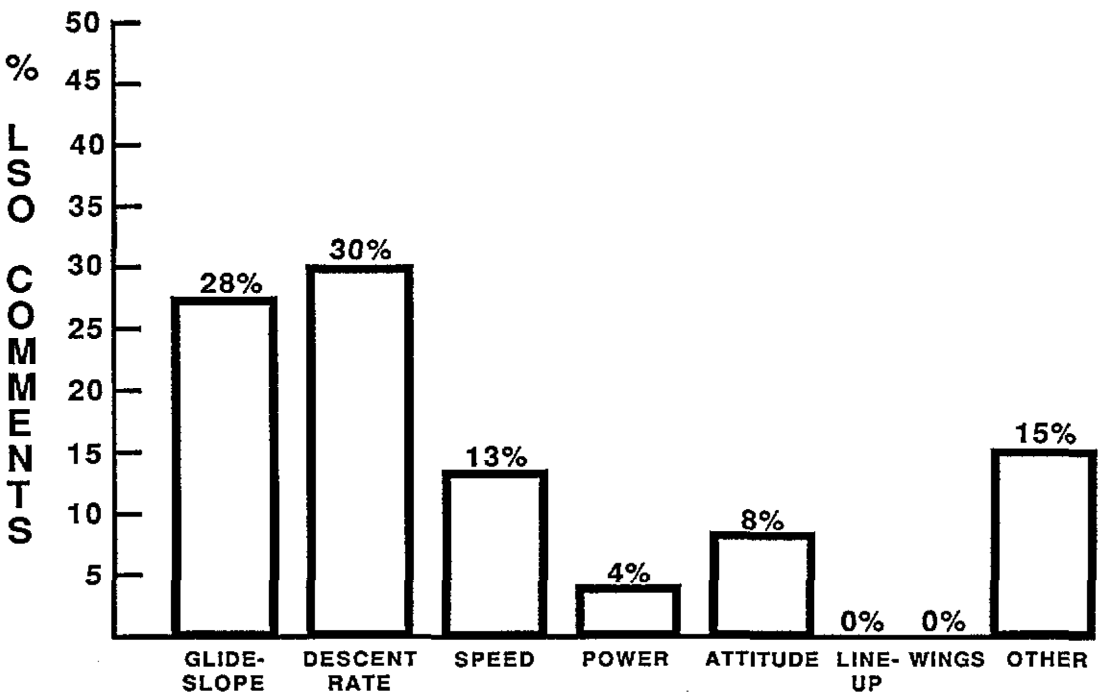


Figure 3. APARTS output: General Landing Problem Type

(2) The Specific Landing Problem Type (Figure 4) shows specific information on the four most frequent landing technique problems.

(3) The Problem Location from Touchdown graph (Figure 5) shows where, in relation to distance from touchdown, the landing technique problems occurred.

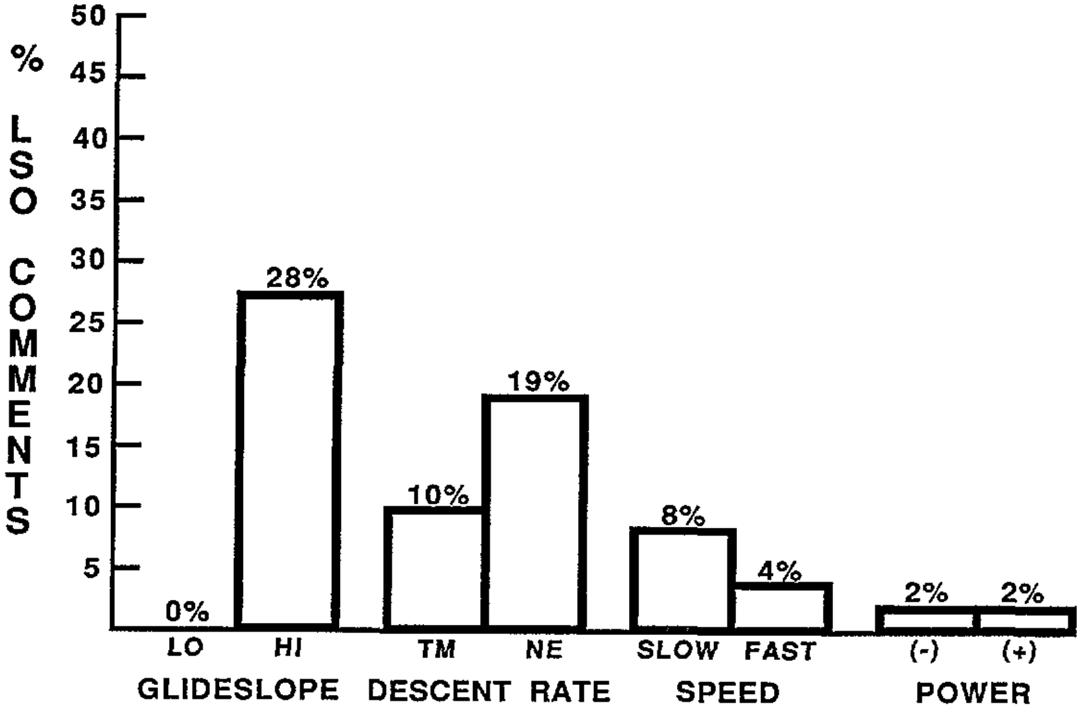


Figure 4. APARTS output: Specific Landing Problem Type

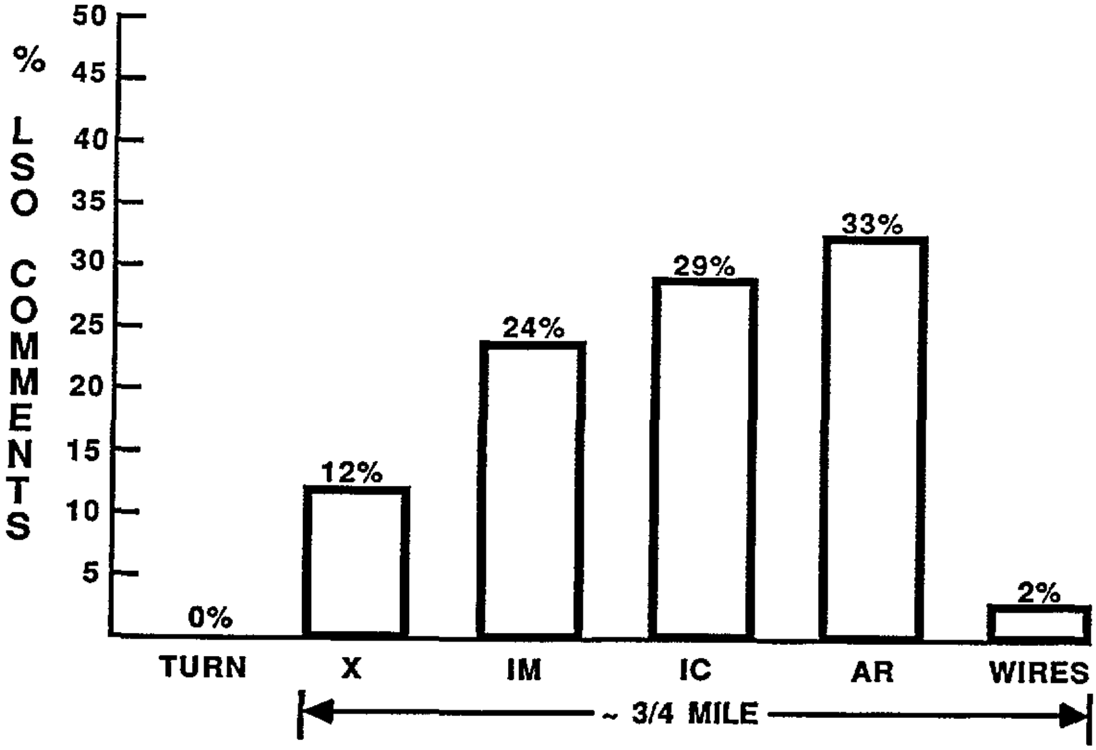
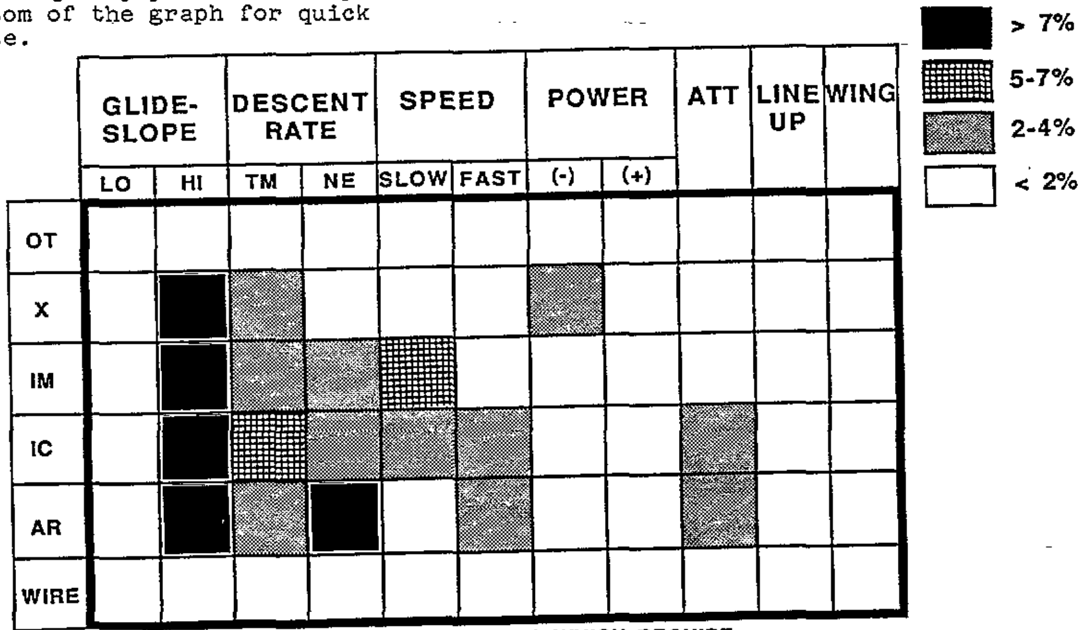


Figure 5. APARTS output: Problem Location from Touchdown

(4) The Landing Problem Profile (Figure 6) is a topographical chart designed to reflect both type and location of landing problems in one display. This graph displays the magnitude as well as the frequency of landing technique problems. The three highest frequency problems are printed at the bottom of the graph for quick reference.

(5) The FCLP Performance Summary (Figure 7) displays average grades plotted for day and night FCLP periods, the total number of passes, and inclusive dates for both day and night FCLP performance. This graph portrays the trainee's learning acquisition curve over the course of FCLP training.



HERE ARE THE THREE MAIN PROBLEMS WHICH REQUIRE CORRECTIONS:

1. HIGH GLIDESLOP AT THE RAMP	11.8%
2. NOT ENOUGH RATE OF DESCENT AT THE RAMP	11.8%
3. HIGH GLIDESLOPE IN THE MIDDLE	10.8%

Figure 6. APARTS output: Landing Problem Profile

	DAY	NIGHT
AVG	2.7	2.4
PASSES	53	109

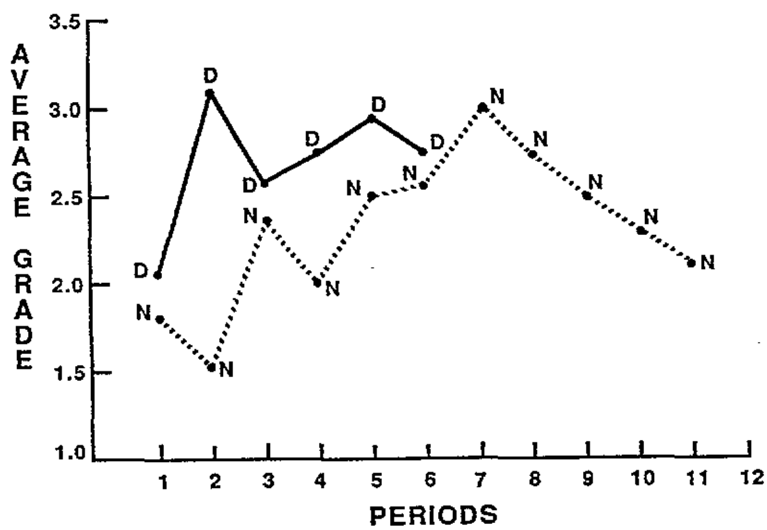


Figure 7. APARTS output: FCLP Performance Summary

Each of the above graphs may also be generated to show the accumulated grades of several trainees or classes of trainees. Individual trainee scores may also be related to class norms to quickly show the LSO instructor how each trainee relates to other trainees in a single class or across classes. The average scores of different classes can also be compared.

Use of APARTS Data. The LSO uses the tabular and graphic data produced by APARTS to provide detailed KOR to guide remedial training for individual trainees. Based on this KOR, the trainee focuses practice in the training device on those aspects of the task that are deficient. Practice time in the device is thus used most effectively. This individualized remedial training has been found to reduce recycle training in student pilots as well as to improve CQ performance [16].

In addition to information to remediate performance, APARTS gives an ongoing record of landing problems for all trainees that can be used to modify programs of instruction. For example, if APARTS displays show that aviator trainees generally have problems with a certain portion of their landing approach (e.g., in close to the ramp), the LSO can place more emphasis on that portion of instruction throughout the course.

Current APARTS Developments. APARTS has been field tested at several west coast Fleet Replacement Squadrons [18]. Based on positive results from these field tests, APARTS is currently being hosted on a standard computer system (Zenith 150) for economical implementation Navy-wide. Additional APARTS software is being developed so that the system can be used aboard the carrier to provide ongoing records of aviator and LSO performance. Efforts are currently underway to determine additional task areas where APARTS might enhance training effectiveness. The first task outside the Navy will be an application of APARTS for Army rotary wing training at the Army Aviation School, Fort Rucker, Alabama.

THE USE OF KOR IN TACTICAL TEAM TRAINING

Anti-Submarine Warfare (ASW)/Anti-Surface Warfare (ASUW)/Anti-Air Warfare (AAW) Training: A Task Description

The organizational structure for Naval combat consists of an integration of ships and support aircraft that defend against air, surface, and submarine threats in pursuit of their mission. Each ship and aircraft coordinates its own sensor and weapon operators, and serves as a component of the larger "Battle Group" to form complex interaction networks.

Training for Battle Group team members generally advances from simulation-based instruction on individual operator tasks, through simulation training for subteams and single-platform teams, to simulation for multiple platform teams. After initial simulator training, individuals are trained as a total Battle Group using operational equipment at sea interspersed with additional training in simulators on shore.

The Navy invests major resources in this training, much of which goes for teaching Groups how to work together to achieve common goals. For example, one training system designed for combined anti-submarine and anti-surface warfare alone trains many teams, totaling over 10,000 personnel annually [19,p.1-1]. It is estimated that two training systems currently under development at the NAVTRASYSCEN, the Surface ASW Training System and the Tactical Team Training Device, will cost hundreds of millions to develop and several million per year to operate [20]. The former system trains team ASW operators for CIC, sonar, bridge and LAMPS aircraft for single ships operations and for particular ship classes [21,p.2]. The latter system limits the training to personnel above the operator level, and extends the training to ASUW as well as ASW operations. It also trains for coordinations among, as well as within, ships and other platforms. Additional team training requirements and costs come from the need to train at a still higher (Battle Force) command level, to coordinate activities among battle groups. At lower command levels, separate team training is needed in job areas such as air-to-air combat, air-to-ground combat, strike warfare, over the horizon targeting, electronic warfare, casualty control, submarine diving maneuvers, Naval gunfire support, etc.

Training specialists criticize team training programs in and out of the Navy for offering little support for teaching team performance [e.g., 22]. Without support from the training program, instructors are forced to improvise team instruction, and team trainers commonly are used to teach individual skills. This can result in poor training for both individual and team skills.

The ubiquitous and critical nature of team performance and the high costs of associated training demand that team training programs be as efficient and effective as available technology will allow. RD and operational programs are placing greater emphasis on team behaviors and processes, in addition to overall team outcomes. Such programs can be found at United Airlines [23], the Nuclear Regulatory Commission [24], Seville Training Systems [25], the Navy

Personnel Research and Development Center [26], in the two earlier mentioned team trainers under development at the NAVTRASYSCEN, and in RD underway at the NAVTRASYSCEN [27]. These training programs also incorporate instructional aids and procedures (e.g., automated alerts, performance measurement, etc.) to help guide instruction toward team elements. Finally, system designers are beginning to use systematic approaches to develop instruction that is based on behavior-oriented team training objectives. Table 1 summarizes major system elements through which program designers are shaping these new technological trends.

Table 1.
Elements of Team Training Design

- Training Objectives (Generic and Specific)
- Performance Measures
- Data Collection Techniques
- Data Processing Techniques
- Data Display Techniques
- Trainee Briefings
- Performance Demonstrations
- Exercise Selection
- Exercise Development
- Exercise Control
- Performance Cueing and Coaching
- Diagnostic Feedback
- Remedial Instruction
- Operational Readiness/Qualification
- Instructor/Operator Training
- Instructor/Operator/Trainee Guides
- Instructor Alerts
- Instructor Workload
- User Acceptance
- Training Effectiveness Evaluation

Unique Problems in Team Training

Major deficiencies in team training programs can be traced to inadequate definitions of critical task elements that give bases for assessments of trainees' performance, and in turn other elements of instruction (display formats, feedback, remediation, etc.). In team training, critical task elements include overall team and subteam outcomes, as well as specific actions of individual team members. Lacking definitions of such elements of good team performance, good performance can not be demonstrated and reinforced and faulty team performance cannot be diagnosed to show who was in error and what specific interactions, behaviors, and knowledges need improvement. Team performance assessments often emphasize general team outcomes (e.g., "the ship was sunk because a submarine was not detected") and fail to trace the outcomes to the causes (i.e., specific subteam performance factors and ineffective interactions among team members).

Also, the value of diagnoses that are given in many team training programs is not known. The diagnoses are not validated to show that the information offered and the behaviors recommended for performance actually do result in the desired team outcomes.

Interactions among team members typically are more complex and dynamic (i.e., "emergent") than interactions between a person and equipment (as in individual skills performance). This creates special problems in defining the interactions and the associated critical task elements for team training. At the same time, it increases the importance of identifying task elements at the interpersonal level as part of the instructional design process. Not doing so only passes the problem to instructors and trainees, requiring them to improvise ways to identify interpersonal behaviors that need improvement.

Team training poses additional design problems attributable to the following:

- Speech (a typical type of team interaction) takes variable forms for the same content, making it difficult to asses, especially through automatic means.
- An individual's performance is often affected in unknown ways by the actions of other team members, so the contributions of individual team members are difficult to assess.
- It is difficult to give KOR to individual team members without disrupting training for other team members.
- Assessment of overall team performance is difficult because of problems associated with combining measures of individual team members' performance.
- True assessment and validation of military team performance often is not possible, since operational performance of many team tasks occurs only during battle.

The remainder of this paper briefly reviews design specifications and plans for applying the instructional principles to the Surface ASW Training System. Similar approaches are being developed for the Tactical Team Training Device. The design specifications and plans for these devices are products of many individuals from Government and private industry. We acknowledge these combined efforts and note that this paper expands upon prior descriptions in line with ongoing system design evolution.

Meaningful Display Formats

Table 2 and Figures 8-12 give examples of performance measures and display formats planned for the Surface ASW Training System. Additional details can be found in project documentation [28]. Table 2 shows an automatically recorded, chronological record of actual scenario events (e.g., friendly ship and threat submarine platform motion, sensor, and weapon events). Instructors use this Exercise Event History Listing to reconstruct the scenario (i.e., to show team outcomes) during post-exercise debriefing sessions. This record also includes cues for displaying more detailed descriptions of team, subteam, and individual performance. The "cues" are comments recorded by instructors or the training software during the exercise to guide subsequent KOR.

Table 2.
Exercise Event History Listing

PLATFORM DESIGNATIONS:
OS - Own Ship (FF-1053)
1 - Assist Ship (FF-1052)
2 - Victor SSN
3 - Own Ship LAMPS

TIME	PLATFORM	EVENT
00:00:00	OS	Initial course = 000°, speed = 10 kts
00:00:00	1	Initial course = 000°, speed = 10 kts
00:00:00	2	Initial course = 100°, speed = 10 kts, depth = 340 ft.
00:00:00	OS	SQS.26 mode = CZ/ODT, SQR-18, mode = SSV, SWS-35 mode = modes Search Aft
00:05:00	OS	SQS-26 detects platform 2, 353°, 34,600 yds.
00:06:00	OS	SQR-18 detects platform 2, 354°
00:11:00	OS	C/C 090°
00:12:00	1	C/C 355°, C/S 20 kts
00:18:00	2	C/C 060°, C/S 18 kts
00:24:00	OS	C/C 050°, C/S 14 kts
00:42:00	OS	SQR-17 detects platform 2, 210°, 2700 yds.
00:44:00	2	C/C 010°
00:50:30	OS	SQS-26 lost contact platform 2, 004°, 35,000 yds. SQR-18 lost contact platform 2, 005°, 35,000 yds.
00:51:00	3	MK 46 launched on platform 2, 021°, 460 yds.
00:51:45	OS	C/C 010°, C/S 20 kts.
00:53:30	3	MK 46 hits platform 2, battle damage = kill

When trainees complete the exercise, instructors obtain a printed record of the Exercise Event History Listing. Next, pictorial displays of scenario events automatically appear on the Geographic Plot (Figure 8) at points in the exercise that are identified (on the Exercise Event History Listing) for trainee KOR. Instructors describe the exercise situation and provide instructional KOR to trainees using the Exercise Event History Listing and displays of the Geographic Plot (CRT displays and hard copies are available for all displays).

The system supports the instructor in efforts to give diagnostic KOR by identifying, on the Exercise Event History Listing, the additional displays of group performance and individual behaviors that are relevant to the instruction at the points designated for instruction. For example, the Exercise Event History Listing could cue the instructor to access displays of signal-to-noise ratios for a given sonar versus a selected platform (Figure 9).

The system could also extend the diagnostics to show common errors made by groups and individuals during team operations. These diagnostics suggest ways to correct problems noted in the more global measures. Instructors assess performance errors by answering "yes" or "no" to questions (displayed by the training system) such as, "Once the target detection occurred, did the team utilize all available clues to perform?" Predefined questions may be modified and added to. Instructors monitor trainees' performance for these evaluations from communication circuits, direct conversations, and various performance data displays.

If a "no" answer is entered by an instructor, an associated "Common Error Analysis Display" (Figure 10) is made available to isolate the cause of the substandard performance to particular system/equipment, the type of action taken, and the nature of the error. Instructors use this display, along with keyed-in remarks, to achieve the most specific level of performance diagnostics.

Performance measurement systems have been criticized because they present large quantities of information that no one knows what to do with. One approach to this problem is to define, in the design process, how each display will be used for training. Another approach is to allow instructors to select the performance information that they desire before beginning the exercise. All selected information is recorded and then the instructors may select all or a portion to be displayed after the exercise is completed. The amount of information to be processed is made more manageable also by assigning primary responsibility for the various subteams and the overall team to different instructors. Instructor utilization guides and instructor training courses further assist the instructional process.

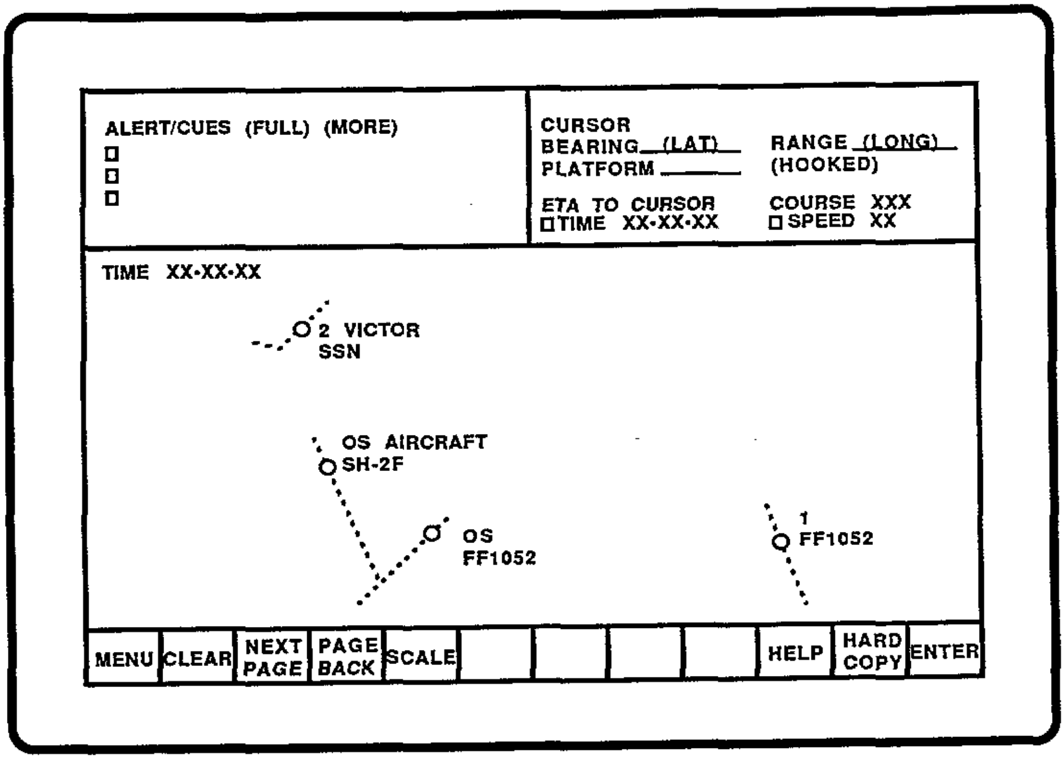


Figure 8. Geographic Plot

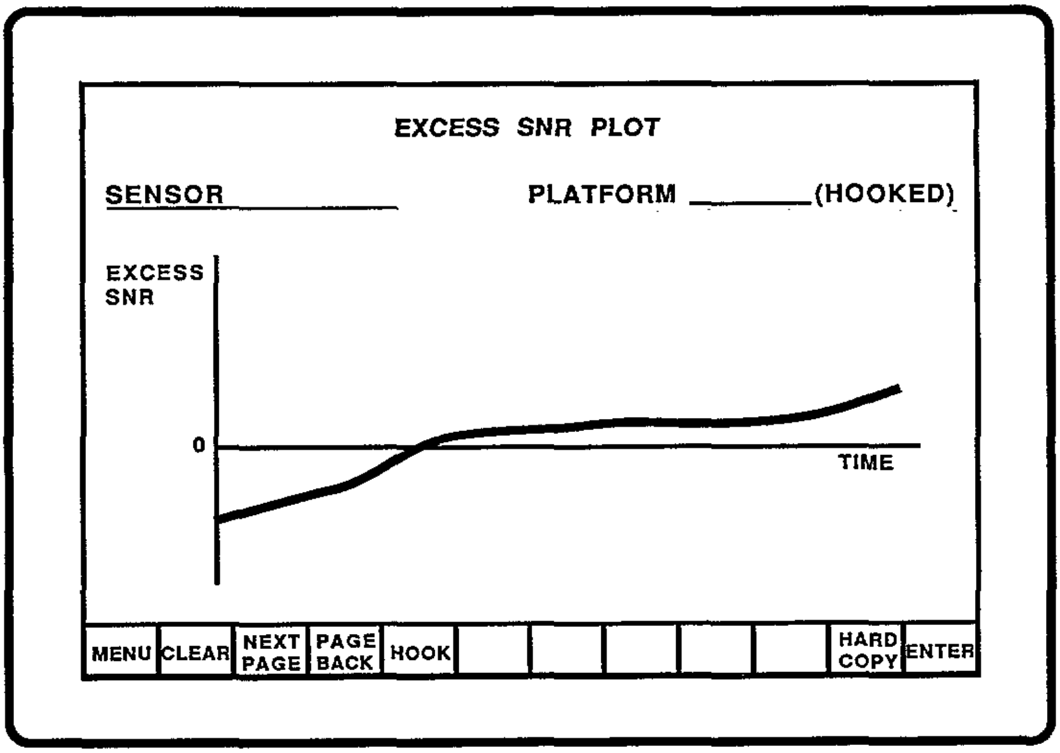


Figure 9. Excess Signal-to-Noise Ratio Plot

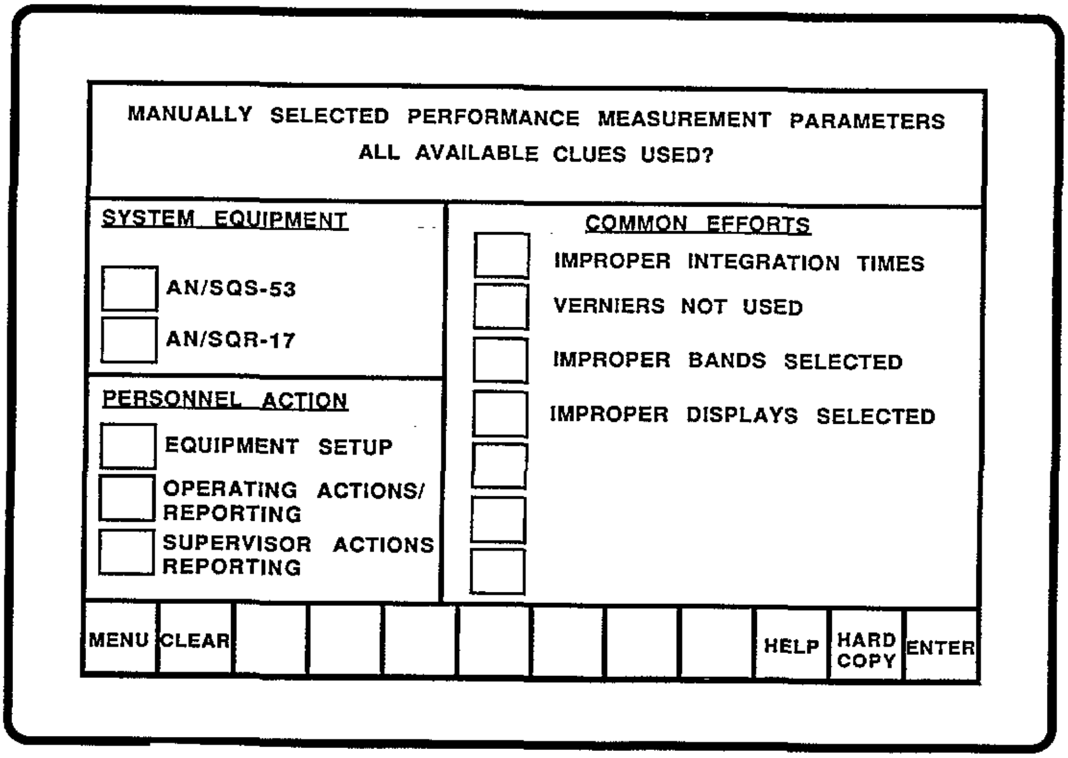


Figure 10. Common Error Analysis Display

Additional displays still may be needed to help integrate the performance information and derive instructional actions from it. Examples of such displays, shown in Figures 11 and 12, can summarize data for: (a) the entire Battle Group (e.g., for the Tactical Team Training Device); (b) platforms within the Battle Group; (c) subteams within platforms; (d) individuals within subteams; (e) separate mission phases; (f) the entire mission; (g) categories of training objectives (TOs; e.g., procedures, communications, etc.); and (h) individual TOs.

Using these displays, the instructor can trace the causes and effects of recorded team performance through the entire network of team interactions. For example, given information from the display shown in Figure 11 (taken from [27,p.252]), the instructor could: (a) note a performance deficiency in the "sonar total search phase score"; (b) check the effects of the noted deficiency on the performances of the associated platform and the entire Battle Group; and (c) trace the deficiency to a TO category and an individual within the sonar subteam. The operator then could use displays such as shown in Figure 12 to identify specific TOs associated with the area of deficiency and training exercises that teach those TOs. This process is intended to show the overall team impact of individual actions for all command levels and positions; and would identify the platforms, subteams, mission phases, performance categories, individual, TOs and exercises that need training emphasis. Using the Exercise Event History Listing (Table 2) and Geoplot (Figure 8), the operator can reconstruct the scenario to show trainees when and how the deficient performance occurred and with reference to subteam and individual performance displays (e.g., Figure 10), how the trainee can correct the deficiencies.

Summary and Recommendations

The use of KOR to enhance the effectiveness of training has been discussed, and examples of the use of data presentation techniques for individual (aviator) and team training have been presented. The techniques discussed in the paper apply to the training of any complex task. This is especially true when the task yields a variety of multivariate performance data. Training effectiveness can be enhanced if these data can be used for KOR by both instructors and students. The data presentation format should: (1) reflect all important elements of the task; (2) be presented in a meaningful and usable format (in most cases, graphic presentation is recommended); and (3) be produced by a suitable data processing system for data analysis and presentation.

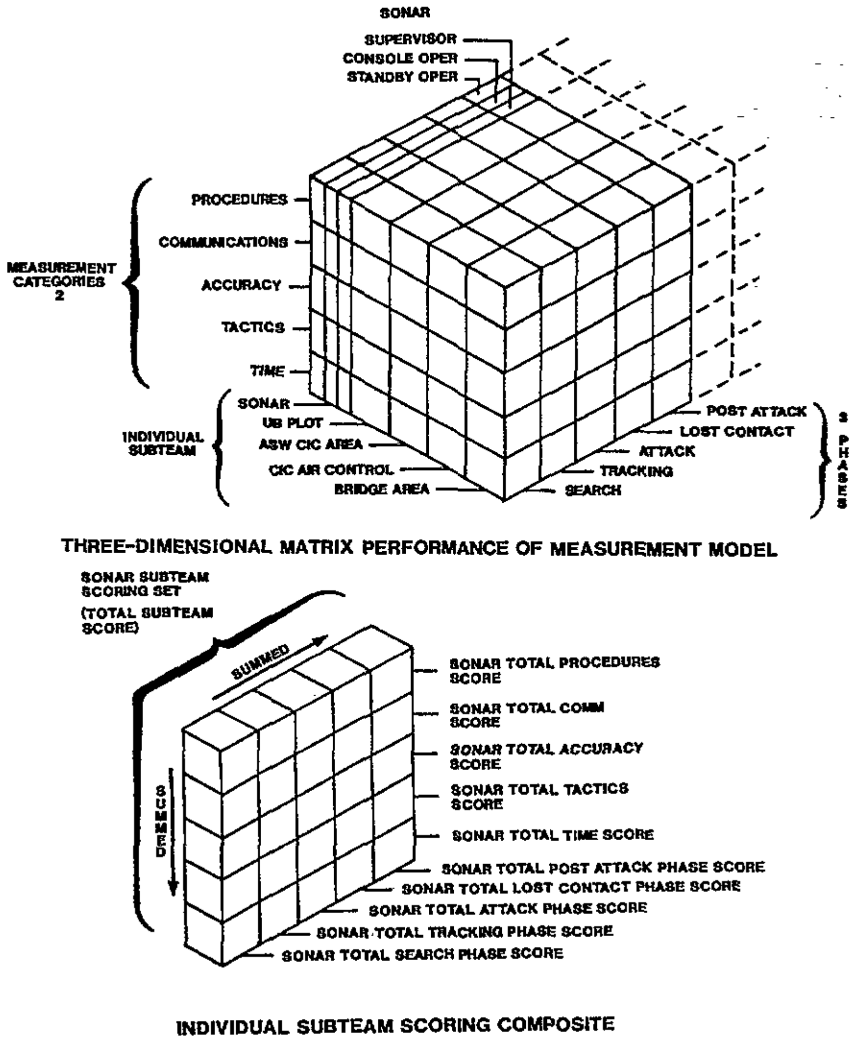


Figure 11. Sample Performance Summary Graphs

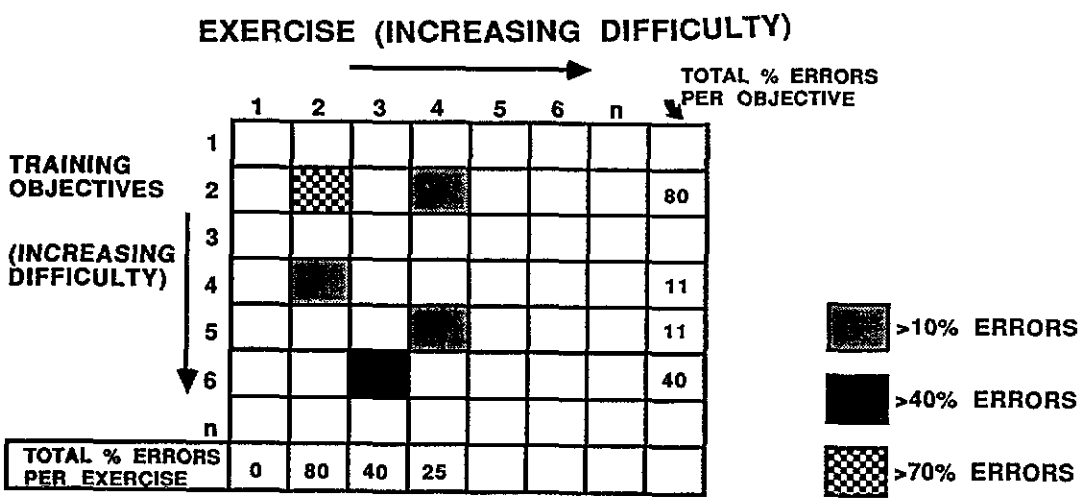


Figure 12. Sample Performance Summary Graph

Modern computer-based training devices have the potential to provide enhanced KOR. It is essential that training developers and training device designers utilize this potential to its fullest. To this end, the processing capacity of the computer included in the training device should be sufficient not only to collect performance data and control the simulation aspects of the training, but also to process the data to provide information in a form usable for KOR. The printer, included with the training device, should have graphics capabilities rather than merely print text. Finally, the software required to analyze and present KOR data should be developed in conjunction with other training device software and courseware.

Incorporating these features into computer-based training devices will allow programs of instruction to use enhanced KOR in all phases of training. We strongly recommend that these capabilities be included by training device designers and instructional developers in their plans for any new instructional system. These capabilities, aided by additional research and development to further define the principles of instructional KOR, will enhance our ability to produce effective training systems and improve readiness.

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