Section VIII of the Center's Bulletin 40-1A describes the ILS requirements for preparation and conduct of the contractor-conducted maintenance and operator courses which are held at the beginning of the Interim Support Period.

Training course preparation must include analysis of such factors as the: organization; scope; content; and levels of training ot be conducted. How can these factors be best used with the combination of contractor technical services and technical data to qualify the maintenance and operator personnel, and to provide the military using agency with a life-cycle retraining capability?

Within Bulletin 40-1A, the Personnel Planning MEAR Exhibit and Section VIII define the framework and requirements for contractor-conducted training. It is an ordered, consistent, and predictable process of defining support personnel requirements and then meeting these requirements through the preparation and conduct of an effective maintenance and operator training program.

VI. BENEFITS OF CONTRACTOR-CONDUCTED TRAINING WITHIN ILS

ILS has benefits for the military services acquiring the device, and the contractor, as well as the Center itself. Through improved planning, analysis and management techniques, each activity is able to work with the other more effectively.

Early definition of training device support personnel requirements allow more effective development and conduct of support personnel training.

In turn, the effectiveness of contractor-conducted maintenance and operator training is measured by how well such training helps the military training agencies holding the device to accomplish their training mission.

Qualified maintenance and operator personnel can contribute directly to training device availability and utilization throughout its life-cycle.

We look forward to working with you in achieving the potential of ILS on contractor-conducted training programs, as well as all of the elements of ILS, in the future.

PERFORMANCE FEEDBACK IN THE DESIGN OF TRAINING SYSTEMS

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INTRODUCTION

In considering performance feedback in the design of training devices, it may be helpful to define the word "training." Essentially it is the modification of human behavior, in terms of increased proficiency in accomplishing a given task. If motivation is not considered, we might state this more simply as "learning." This observation serves to introduce the basic theme

of this paper, namely, that better training systems can be achieved by the systematic incorporation of the principles of learning in their design. Of these principles, one of the most important deals with performance feedback to the trainee or what is often termed "knowledge of results."

Considered here is performance feedback which may be applied to training in general and has special relevance to computer-based training devices. Specifically, we will discuss the incorporation of provisions for automatic collection, analysis, and presentation of trainee performance data. (Present trainers often do have some such provisions, but a more extensive use of feedback is desirable.)

Performance feedback can be defined as any information which indicates to a trainee the relationship between his actual performance and a desired level of performance. Note that to provide this feedback there must be provision to measure performance, the desired level of performance must be specified and there must be some means for presenting to the trainee a comparison between the two. There is also a less obvious but very real need to control or manage *the timing and manner in which the performance feedback is given.*

The increasing use of digital computers in training devices provides many opportunities to automate the application of performance feedback principles. It is our belief that, in general, these principles can be applied most effectively when they are designed into the hardware and software of training devices. Furthermore, when the principles are explicitly applied and are used under controlled conditions, their use can be evaluated more directly and effectively.

Automated scoring is one possible way in which direct feedback may be provided to trainees. Automated scoring can also provide a basis for achieving more effective training in several other ways. As examples, automated scoring can help to unburden instructors by providing better initial diagnoses of student training requirements; also, it can enable better monitoring and control over the training process and thereby result in a more effective expenditure of training time. Detailed feedback on student performance can also provide a data base that will aid curriculum designers in systematically improving training courses and material. Similarly, such objective information on training performance can assist operational commanders in assessing the proficiency and training needs of their forces. It could also lead to the development of fleet standards for training.

What follows is a discussion of: 1) principles of performance feedback; 2) use of performance feedback in present trainers; 3) requirements imposed on trainer design in order to incorporate performance feedback; and 4) training research needs.

THE IMPORTANCE OF PERFORMANCE FEEDBACK IN TRAINING

Skilled performance generally involves coordinated sequences of stimuli and responses. In operational situations a person's actions typically lead to several classes of feedback.

Figure 141, taken from Fitts, Bahrick, Briggs and Noble (1959) is a schematic representation of the various feedback loops which may be involved in skilled performance. These loops include: 1) feedback from the sensors within the operator's own body; 2) feedback from the equipment and other personnel with whom he is directly interacting; and 3) feedback from the more remote environment which he may be affecting. Many of these loops are directly relevant to the design of training devices. For example, the trainee's internal feedback is an important consideration in the specification of motion cue requirements in flight trainers. This example also illustrates the close interrelation which may exist between training feedback processes and key questions regarding fidelity of stimulation. However, one of the most important

characteristics of modern trainers is that augmented feedback can be provided. This is feedback which is in addition to that normally available in the operational situation.

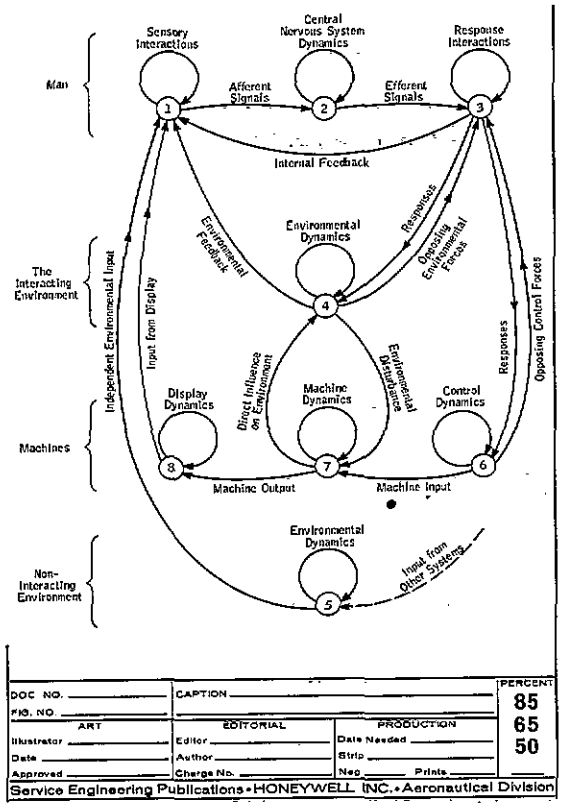

Figure 141. Diagram of Information Flow Network in Skilled Performance (After Fitts et al, 1959)

There are at least four functions which performance feedback may provide in a training situation. These are to:

- Provide information to a trainee regarding the adequacy of his responses
- Motivate the trainee by showing his progress toward a performance objective
- Reinforce desired trainee responses and eliminate undesired responses
- Direct the trainee toward his next response or objective

Research and practical experience have firmly established that performance feedback is the single most important variable in the learning of skilled behaviors. Therefore, explicit attention should be given during trainer design to the incorporation and management of the relevant feedback loops.

Several general principles regarding the use of performance feedback have been developed. These include the following:

- During early stages of learning, frequent reinforcement of a desired response to a specified stimulus is required to ensure that the stimulus will have a high probability of eliciting the response in the future. However, after the response is established, the most reliable and stable response patterns are maintained by the use of intermittent feedback.

- The effectiveness of feedback decreases with its delay.
- Within limits, the greater the specificity of feedback the more rapid the learning.
- The learning process can be enhanced by using augmented feedback.
- Prompting (a somewhat different mechanism from feedback) during early stages of training greatly aids learning.
- Repetition of reinforced responses (acceptable ones) is generally required to develop appropriate generalization and discrimination.

There are many variables involved in the application of these principles. The complicating variables include such things as:

- The type of task
- The level or stage of learning
- Trainee motivation
- The schedule and frequency of feedback
- The form and method used to provide feedback

An excellent review of the relevant experimental literature regarding many of these variables has been provided by Ina Bilodeau (1966) and by Glaser (1962).

Unfortunately, our present level of understanding of the effects of these variables is not precise. Consequently, their application in any given training situation is still a matter of some judgment and, often, of ad hoc experimentation. Nevertheless, we can profitably apply our present knowledge in many cases.

PERFORMANCE FEEDBACK IN EXISTING TRAINING DEVICES

It is probably fair to say that sufficient attention has not been given in the design of present training devices relative to the management of performance feedback. Typically, the devices provide a simulation of relevant displays and controls, a means for generating training exercises and a fairly limited scoring capability. Detailed performance assessment and feedback have generally been the responsibility of the trainer staff or, in too many cases, the trainees themselves.

Performance feedback as presently utilized in trainers frequently suffers one or more of the following shortcomings:

- It may be relatively gross due to a lack of detailed performance measures. This prevents the trainee from appreciating fully small changes in his responses which lead to improved performance.
- It is often imprecise due to the lack of clearly defined performance objectives. This interferes with the trainee's comprehension and motivation. The trainee must know not only what he is doing, but also what he should be doing.
- It is generally delayed. This tends to degrade the effectiveness of the learning situation.
- It is sometimes erroneous. This may happen when a score is miscalculated or a performance failure is attributed to a wrong cause.

If the primary source of detailed performance feedback is an instructor, the feedback may vary in completeness and efficiency of presentation and may have some degree of bias. These deficiencies are typical of any situation in which subjective evaluation is required. In many cases, instructors are overburdened by their tasks of operating the trainer, observing and recording trainee behaviors, and providing performance feedback in real time. Innovations to automate performance scoring and feedback can minimize routine tasks and thus produce a

more effective use of the instructor's time. The precise scoring data coupled with instructor free time (during which he may refine training) should produce a superior product.

Figure 142 provides an example of a problem in performance evaluation. The proficiency of a number of operational crews in employing one of the Navy's major weapons systems was tested in a team trainer on a set of standardized problems. The bar chart indicates the time to launch a weapon following target detection. The middle bar indicates the maximum performance time allowed by a Navy standard. The top bar shows the best single-trial performance on each problem, averaged across problems. Note that it is well under the Navy standard. This indicates that acceptable performance can be achieved on the problems used. The lowest bar shows average performance for all teams on all problems. It greatly exceeds the Navy's criterion. This, of course, indicates a critical need for training. The scale on the bottom shows how the instructors who ran the tests evaluated the training requirements of the same teams. Instructors reported their subjective evaluation to the trainees. This example illustrates the discrepancy which may exist between objectively measured performance and subjective feedback provided to trainees.

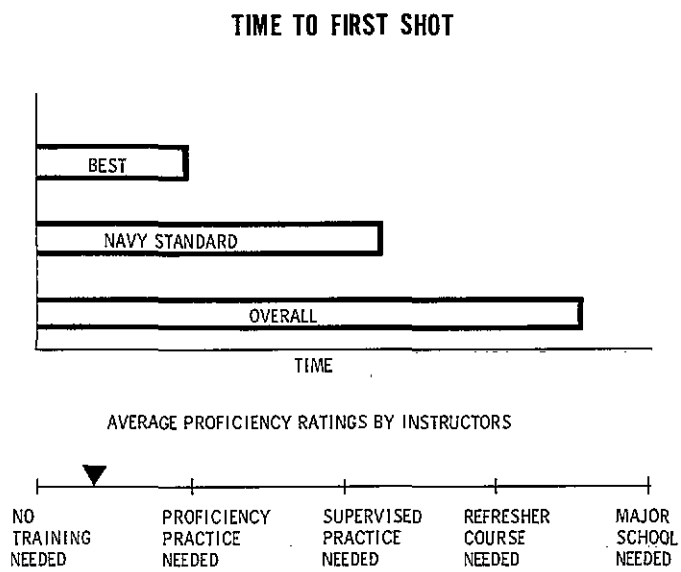

Figure 142. Objective versus Subjective Performance Evaluation

PERFORMANCE FEEDBACK DESIGN REQUIREMENTS

Better and more timely knowledge-of-results to trainees can probably best be accomplished through a "training systems" approach to the design of training devices. Trainer hardware could then be coordinated with trainer software in order to achieve training objectives. The required software includes not only computer programs to operate the simulated equipment and to generate synthetic inputs but also includes such items as course curricula and the programs and materials needed for evaluating trainee proficiency. The methodology for a training systems design process has not yet fully been developed. There are, however, some guidelines for the

major steps which must be accomplished. Kaufman, Corrigan, and Nunnelly (1966) have described one general approach to accomplishing this process. Eckstrand (1967) has also discussed a systems approach to training program definition. Several principal steps of these approaches are directly related to performance feedback provisions and are given in the following paragraphs.

DEFINE TRAINING OBJECTIVES

A key first step is the difinition of training objectives in explicit performance terms. These objectives provide specific goals for training program and device designers.

When training objectives are defined in performance terms there is a concrete basis for achieving concurrence about the objectives among operating forces, curriculum planners, device designers and fleet training groups. Furthermore, it becomes easier to detect and eliminate unnecessary or obsolete requirements.

Since training is basically a process of modifying behaviors, training goals are most appropriately expressed in behavioral terms. These statements also can provide relevant goals to motivate trainee learning.

DEFINE TRAINING CONTENT AND MEDIA

A second major requirement is the systematic definition of training content and media. This begins with consideration of the characteristics of the incoming students and the training objectives. Decisions regarding the general strategy of training and the role of training devices must be made.

The role of any device should be defined in relation to some larger scheme of training. Otherwise the trainer may be required to function in an inappropriate and inefficient manner, as when trainee deficiencies require that a team trainer provide individual operator training. There also should be a detailed definition of the manner in which the device is to function from a training standpoint. For example:

- The training course content and feedback should be matched to the trainee's stage of learning
- The functions of the instructor need to be explicitly planned
- Decisions regarding fidelity of simulation should reflect the nature and criticality of operator tasks as well as trainee acceptance and motivation
- A trainer utilization guide should be developed to help fleet and instructor personnel make the most effective use of the device

DEVELOP PERFORMANCE CRITERIA AND MEASURES RELATIVE TO SOME STRATEGY OF TRAINING

A third key requirement is the development of specific performance criteria and measures. These are derived from the training objectives. They are, however, more detailed and should be correlated with the parallel development of course content and methods.

Performance criteria should be content-referenced, not norm-referenced. In other words, they should be based upon levels of proficiency required by the fleet and not upon typical performances found in some sample of operators. Although it is often difficult to obtain agreed-

upon standards of performance, this is a necessary step. Fortunately, modern training devices have sufficient flexibility for modification should changes be required.

The specification of suitable performance measures is usually one of the training expert's most difficult problems. In some cases there are conflicting requirements, as in the case of speed versus accuracy in weapons delivery. In other cases no clear basis for evaluating performance elements is available, as is often typical of decision making tasks. In still other situations the behavior may be so complex and interrelated that only gross scores can be taken. Finally, at different stages of learning different measures may be most appropriate or significant as indicators of learning.

PROVIDE PERFORMANCE SCORING FACILITIES

Computer-based training devices are especially suitable for incorporating means for recording, reducing and analyzing data. Suitable provisions for displaying feedback information to students are also required. In addition, the computer can be used to control the nature and frequency with which feedback is given.

Some examples which illustrate possible applications of automated scoring in training devices are:

- In training sonar operators to track targets accurately and smoothly, augmented feedback in the form of a computer-controlled cursor could be used to indicate when the operator's cursor was being improperly positioned.
- In training electronic countermeasures operators to detect and respond to surface-to-surface missile signals, computer-controlled sequencing of displays and response feedback could be used to train operators to quickly discriminate threatening from non-threatening signals.
- In teaching electronics technicians proper switch sequences on test equipment, computer-controlled prompting could be provided through illumination of small indicator lamps located under the switches. The degree of prompting would be dependent on the level of training of the technician.
- In training tactical decision making, computer-generated displays could be used to critique performance by providing a plan-view record of each attack, showing actual versus desired track, points where erroneous actions were taken, important decision factors, etc.
- In training multi-man teams, automated performance recording and feedback could help to pinpoint specific errors, leading to more effective correction and better acceptance of it by team members.
- In training situations, better use might be made of instructor skills if the instructor were provided with automated performance monitoring facilities. He might be provided, for example, with a display which would graph the overall progress of each of a number of trainees. Alternative displays could provide more detailed data on each individual trainee. The instructor could then direct his attention to the specific difficulty of the student in greatest need of assistance.

A number of these examples are related to concepts developed for various forms of computer-aided instruction. Performance feedback has a central role in many of these concepts and is fundamental to the development of computer-based learning, adaptive training and self-instructional systems.

RESEARCH REQUIREMENTS

Although we have emphasized the application of known principles of learning there are still major gaps in our knowledge regarding practical techniques ofr performance feedback. The principal research needs that we see are related to training methodology for training devices.

A basic need is for a methodology for incorporating performance feedback into the design of training devices on a systematic basis. Innovations need to be validated and evaluated from a cost-benefit standpoint. Other research needs include:

- The definition of learning phases for various tasks and their relevance to performance feedback management
- The determination of effective instructional strategies, especially for the application of adaptive training
- Establishment of the role of trainee individual differences in relation to performance feedback factors
- The specification of the most effective measures and modes of presentation for performance feedback

CONCLUSIONS

In summary, potential benefits of automated scoring and feedback include:

- More effective and rapid learning
- Reduction of instructor workloads, and increase in student-instructor ratios
- Reduction in the adverse effects of instructor turnover
- Real-time evaluation of trainee progress and modification of training (adaptive training)
- More accurate and complete performance data permitting better use of trainers for proficiency testing
- Suitability of trainers as a vehicle for development of tactics
- Capability for greater student control over training (self-instruction)

It is our belief that the more extensive use of automated scoring and performance feedback could significantly improve the effectiveness of training devices. This might be best accomplished by single-source procurement of both training hardware and software. Also an effective stimulus for increasing the application of learning principles to training devices might be to include specification of trainee terminal proficiency as part of device procurement specifications. This is not an easy task but the potential benefits warrant efforts in this direction.

REFERENCES

1. BILODEAU, I. McD., Information Feedback. In E. A. Bilodeau (Ed.), Acquisition of skill, New York: Academic Press, 1966.
2. ECKSTRAND, G., Current status of the technology of training. In Uhlaner, J. E. (Ed.), Psychological Research in National Defense Today, U. S. Army Behavioral Science Research Laboratory, 1964.
3. FITTS, P. M., BAHRICK, H. P., BRIGGS, G. E. and NOBLE, M. E., Skilled Performance. Final Rep., Project 686, Ohio State University Res. Found., 1959.

4. GLASER, R. (Ed.), Training Research and Education. Pittsburgh: University of Pittsburgh Press, 1962.
5. KAUFMAN, R. A., CORRIGAN, R. E., and NUNNELLY, C. L., The instructional approach to education. Human Factors, 1966, 8, 157-162.

VERIFICATION OF MAINTENANCE DRAWINGS BY SAMPLING TECHNIQUES

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We seem to have a mutual problem, Gentlemen, which I wish to bring to your attention today. What is this problem? It is the technical accuracy of Engineering Drawings and, in particular, Category H Maintenance Drawings. In some recent checks by NAVTRADEVCEN, it turned out that their accuracy is not what the Government expected it to be. In one case, 25% of the grawings were wrong. Why? Well, the immediate answer is that the contractors did a poor job on their drawings. But what's the real reason behind that obviously shallow explanation. Why did they do a poor job? - After much thought, the fundamental cause of the whole problem appears to rest with the Government. First, our specification covering engineering drawings, MIL-D-1000, is inadequate. MIL-D-1000, paragraph 4.6, reads as follows:

> "4.6 Proving drawings against the hardware. Where hardware has been developed or produced by the contractor, drawings shall be "proved" against the corresponding hardware." Now here's the rub! "Use of the drawings in producing, inspecting, and testing satisfactory hardware shall be considered as satisfactory evidence that this requirement is met."

This says, in effect, Gentlemen, that if the hardware passes performance tests, the technical information on all drawings is considered acceptable. This is poor logic and the weak link in the chain! All engineering drawings are not totally used to get the final hardware out the door. As an example, if a printed circuit card is manufactured, passes quality control tests, and doesn't fail until after acceptance, who has verified the schematic diagram for that assembly against the finalized hardware? No one! Additionally, and more realistically, during assembly, systems test, and final checkout, frequent revisions are made to complex electronic equipments to achieve acceptable performance characteristics. The adequacy of the Feed-Back Loop in the drawing control system is also assumed by paragraph 4.6. To carry this kind of utopian of assumption approach to its extreme; it was assumed by the government that the contractor could satisfactorily manufacture the equipment or he wouldn't have been awarded the contract. Therefore, why should the government test to see if the hardware is acceptable? Why not just accept what he provides? Ridiculous? Well, this is the present situation for engineering drawings! A test procedure is required here to determine the technical accuracy in drawings, but no adequate procedure has been formulated to date for contractor or government use, other than 100% inspections of the drawings against the hardware.