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Military Training Research in the Engineering of Training Programs for Technical Personnel

by

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Prefatory Note

This paper was presented at the 1961 Annual Convention of the American Psychological Association in New York City in a Symposium titled: "The Implications of Military Training Research for Industry." Research reported in the paper was performed at the Human Resources Research Office in Division No. 1 (System Operations), formerly the Training Methods Division.

Because of the continuing relevance of the subject matter of the paper, it is being issued as part of the HumRRO Professional Paper series. This series was initiated in order to provide permanent record of specialized aspects of HumRRO work, and deposit in the scientific and technical information storage and retrieval systems of the Department of Defense and the Federal Clearinghouse.

MILITARY TRAINING RESEARCH IN THE ENGINEERING OF TRAINING PROGRAMS FOR TECHNICAL PERSONNEL

Arthur J. Hoehn

THE PROBLEM

That this is a period of rapid technological change is evident. Military man-machine systems are characterized by the increasing employment of complex equipments, particularly electronic gear. There are radars for sensing, automatic systems for data processing, electronic checkout devices for maintenance, and so forth. These developments parallel the flood of technological innovations in industry where numerous production systems are completely or largely automated.

The changes in military and industrial systems are creating new problems of manpower and training. For as these systems change, the functions performed by men are shifting toward greater concentration in maintenance and supply activities, communication functions, and control and decision-making. Such shifts are bringing decreased emphasis on manual and motor skills and greater demands in perceptual and intellectual capabilities such as those required in the checking, repairing, monitoring, and control of machines.

The growing problems in manpower and training stem in part from the sheer *rate of change*. Even in technical jobs, men cannot be trained once and for all. *It is necessary to train and retrain as man-machine systems are altered and the associated jobs assume new patterns.*

But mere rate of change is not the only source of difficulty. *The functions allocated to men in new military and production systems are such that the demand for high aptitude, highly trained personnel is outrunning the supply.* At the same time, the requirement for unskilled and semi-skilled personnel is declining and difficulties are encountered in finding suitable employment for them.

These problems in manpower and training are common to industry and the military. What can be done about them? Are there means of offsetting the increases in training costs that result from the need to continually retrain? Are there ways to better utilize lower aptitude personnel, enable them to learn and perform more of the work in new systems, and thus relieve the shortage of scarce, highly skilled technicians.

SOLUTIONS INDICATED BY MILITARY TRAINING RESEARCH

Recent military training research has yielded concepts and techniques which, if implemented, would go a long way toward solution of these problems. The directions of the advances in training technology include:

(1) Improved methods for describing required human performance outputs and for deriving training content.
(2) Better design of informational job aids.
(3) New techniques and devices for guiding the learning processes.

Defining Performance Outputs and Deriving Training Content

The system concept

A major source of inefficiency in training has been fuzzy definitions of the objectives. In military training research, an antidote to this is found in the concept of the man-machine system and in the concept of training as the means of developing the human component of man-machine systems. Proceeding from these concepts, the goals of any particular training program can be defined in terms of specific human performance capabilities essential to efficient operation of a particular system. Then training can be geared directly to the development of these capabilities.

Task and skill analyses

Starting with a particular job position within a man-machine system, a first step toward design of an efficient training program is clear specification of what a man in that job postion must be able to do. The more precisely these human performance specifications can be defined, the easier it is to develop efficient programs of instruction.

With recent military systems, efforts have been made to generate, as a more or less integral part of the man-machine system design process, task and skill analyses suited to the purposes of the training program designer. Providing adequate descriptions of procedural tasks consisting of fixed performance sequences has been a relatively simple matter. With these tasks we are able to identify in detail the relevant cues and the responses to be made to them. The analysis and description of *complex continuous control tasks* and decision-making tasks present more difficult problems. Progress in defining complex psychomotor tasks for training purposes awaits the development of better models for describing such performance—models stated in terms that can be related to the conditions which govern acquisition and retention of such skills.

Some complex decision-making processes will also yield only slowly to analyses of a type that will help the training program designer—for example, the decision-making tasks of the battlefield commander or those of the business executive. *However, the kinds of decisions required of the typical machine operator or maintenance man* are generally not so complex as to defy detailed analysis.

As an example of what can be done, the analysis Mayer (1) made of SAGE system operator tasks is illuminating. The information generated by her techniques "(a) describes all pertinent conditions that may occur, (b) states what problem the operator should attempt to solve under each condition, (c) states the information he should consider as pertinent to each problem, (d) tells how he should evaluate that information, (e) names the solution he ought to select in each case, and (f) describes how he ought to carry that solution into effect. The information was organized into a series of binary decisions, each answer leading to a further question or direction until solution is reached."

Mayer was not content to accept the view of on-the-job supervisors that ". . . interpretation 'know-how' and speed cannot be taught but can be acquired only on the job through an undefinable, information-organizing process conducted by the trainee." She built and evaluated training programs on the basis of her detailed task analyses or schedules and found that the processes of acquiring performance capability could be greatly facilitated by organizing practice around them.

Military training research has found this time and time again—job processes generally believed to be quite mysterious and learnable only through "experience" turn out to be amenable to detailed analyses which make it possible to train men faster and at lower cost.

Deriving training content

Typical task and skill analyses identify only the external cues to which the man must respond and the observable responses which he must make. In most jobs, conducting training purely in terms of practice on all the specific cue-response situations is highly uneconomical or even impossible. Concepts, principles, and procedural rules are taught to mediate desired responses to the job-relevant cues. This is the situation, for example, in training of electronics repairmen. That a valid case can be made here for teaching principles and rules is clear. Unfortunately, there has been no objective basis for determining what principles and rules the man needs to know, and, as a result, there has been a *tendency to load training programs with an amount of highly abstract theoretical content far beyond any demonstrable requirements of the job*. When this is done, the effect is to lengthen training time and raise training expenditures beyond what is needed, and to use very high aptitude personnel where those of lower aptitude would suffice.

Recent studies have shown that in *training equipment repairmen, the abstract theoretical content can be sharply reduced without any adverse effects on performance*. In HumRRO's Work Unit FORECAST, Shriver (2) and other researchers developed a training program for radar repairmen that largely eliminated the treatment of theory. This training program reduced training time by 60%, yet end-of-course repair skill of trainees was equivalent to that reached through the much longer conventional program.

Such studies as these indicate a need to reexamine current assumptions regarding the informational and conceptual requirements of technical jobs. The possible savings that could result, both in manpower and in training costs, appear to be immense.

Improved Design and Use of Informational Job Aids

Another means of reducing training costs being explored in military training research is improved design and use of informational job aids. Such aids as checklists, job sheets, symptom-cause charts, diagrams, and data tables have long been used to guide or facilitate performance. However, until recently little systematic effort was made to more fully exploit informational job aids in order to reduce training requirements.

Studies in military as well as industrial settings have shown that the potential gains here are very great and are largely untapped. An illustration of these potential gains is found in a recent application of an audio-visual job aid providing visual guidance by means of slides and audio-instructions through magnetic tape (3). In one application, it was utilized to train and to support the job performance of personnel assembling electronic circuits. The worker views colored slides depicting each step and follows verbal instructions synchronized with the slides and fed through earphones. It was reported that this procedure reduced the requirement for formal training by as much as 75%, increased production by as much as 50%, and at the same time reduced defect rates by as much as 55%.

Another example of what can be done through job aids is found in the work of Rogers (4) on the design of improved handbook materials for electronics technicians. The special instructions and diagrams he developed greatly reduce the decision-making demands of the troubleshooting process. In a study conducted at Fort Bliss, he found that introduction of the new manuals (even without any alteration in the training program) resulted in approximately a 15% increase in troubleshooting success, along with a 50% increase in performance rate.

Particularly dramatic results have been obtained when the design of *informational job aids* has been integrated with the design of *training*. Weiss and Wulff (5) recently developed a short, on-site training program for teaching SAGE system maintenance technicians how to troubleshoot a complex data processing equipment. Starting with a careful definition of the desired performance capabilities, they built an integrated set of job aids and self-instructional training materials. A field evaluation showed that the 10-hour, self-instructional training program resulted in striking improvement in troubleshooting capabilities. The technicians participating in the field evaluation had received lengthy conventional training and had had two years of experience on the equipment. Seven matched pairs were formed and one member of each pair took the brief special training program. Typical performance of personnel who received the self-instructional training was *seven successes out of eight* troubleshooting problems, as compared with a typical performance level of only *one success out of eight* problems for those who did not receive the program.

It is, of course, difficult here to separate the contribution of the job aids from that of other important features of the program. But we should not miss the important point. Here, a training program was designed to teach men to perform tasks often viewed as highly complex. By application of a carefully conceived training design methodology including careful determination of what the men should learn, on the one hand, and what they should have available to them on the job in the form of informational supports, on the other, marked gains in performance levels were achieved with a very short period of training.

New Techniques and Devices for Guiding the Learning Process

Although training for many jobs can be greatly simplified by better definition of performance requirements, by more careful derivation of training content, and by exploitation of informational job aids, few jobs are such that training can be bypassed completely. How can the necessary learning be effected at minimum cost? What can we do that will enable us to employ more of the so-called "slower learners," "marginal personnel," or "lower-aptitude" men? These are questions to which military training research has devoted a great deal of attention.

Teaching Machines

Perhaps the most promising recent developments in the area of training techniques and devices center around the work on automated teaching devices and methods of developing the associated programs of training materials. Judicious applications of "teaching machines" or self-instructional training programs should have these effects:

(1) Enable closer adherence to procedures that have been found to facilitate learning in laboratory settings.
(2) Make it possible to individualize the pace and perhaps even the content of instruction, thus enabling success by many who would fail under conventional group-oriented instructional methods.
(3) Foster better use of, or (under specialized conditions) elimination of the requirement for, highly trained instructors.

That carefully programed, autoinstructional materials can pay big dividends in technical training is already apparent, although reports have been made on only a few relevant studies conducted in *training* contexts, as contrasted with *educational* contexts. Crowder and Zacherts' first pilot study, conducted at Keesler AFB, demonstrated that electronics fundamentals could be taught by an autoinstructional device at least as well as by conventional methods (6). Rocklyn's work in HumRRO's Work Unit CONTACT (7) shows that a limited language capability can be developed efficiently through an automated, instructor-free program. Weiss and Wulff's self-instructional program for on-site training in troubleshooting upgraded performance sharply with very short training time (5). Other applications are being made with good effect in military as well as in industrial training situations.

Despite the great promise of teaching machines or autoinstructional materials and devices, some problems in their application to training are apparent. These stem largely from the fact that research has not yet produced a fully adequate basis for decisions on the selection of machines and programs and on methods of employing them in training organizations. As a consequence, training officials are confused by the great variety of machines and the many variations among programs; they currently find an inadequate basis for deciding what to automate, and what kinds of programs and machines will best fit their requirements, how much it will cost, and how they will have to adjust their administrative practices.

Vigorous research attacks are being made on these problems—much of military training research on teaching machines concerns problems of programing, the desirable functional characteristics of self-instructional devices and materials, efficient means of allocating training functions among trainee, instructor, and machines or devices, and management problems associated with the introduction of teaching machines. Through such research we may expect further rapid increases in our ability to capitalize on the potential advantages of teaching machines.

Functional Context

Military training research on effective methods of programing is not, of course, confined to work organized around the design and use of autoinstructional materials and devices. One of the more important recent studies bears on methods of organizing training programs where the objectives are technical skills. It has been a common practice in technical training to start out with a large block of conceptual content (e.g., electronics fundamentals for electronics repairmen) and then in separate blocks of instruction later in the course to provide equipment-specific information and job practice. There is *evidence in recent military training research that important gains can be made by organizing the presentation of conceptual content around job-related tasks.* I refer in particular to a study conducted by Brown and other HumRRO personnel at the U.S. Army Signal School at Fort Monmouth, N.J. (**8**).

In this study comparison was made between a conventional course and a new course in which trainees were presented with a graded series of job-related tasks, each of which required, for successful performance, that the trainee increase his knowledge of certain theoretical principles or that he acquire new skills. Thus the abstract concepts, principles, and procedural rules were integrated with realistic practice and taught in a "functional context" rather than as an isolated block of instruction. Performance as well as written tests given at the end of the course strongly favored the "functional context" method. This approach to the structuring of training programs has great promise, not only as a means of facilitating learning but also as a brake on the tendency to teach conceptual content that is not necessary to job performance.

Other Developments

Time limitations permit me to do little more than mention two other areas in which there is considerable activity and from which major advances in the efficiency of training can be expected:

First: Research on the use of simulation for training of crews or teams and for training in command decision-making. Examples of research in these areas are studies on the use of gaming techniques for training men in command decision-making, on the use of simulated battlefields for training tank crews, and on the design and use of simulated air defense centers for training air defense personnel.

Second: The development of better methods of evaluating training programs in terms of the performance capabilities of the graduates. Techniques are being developed to make it feasible to evaluate a greater number of training programs in terms of the readiness of the graduates to meet the human performance requirements of a man-machine system, rather than in terms of amount of information acquired. At the same time, progress is being made in the development of techniques for identifying weaknesses in the human components of operational man-machine systems and for feeding this information back to those who design the training programs so they can make the necessary "fixes."

Military training research has shown that we do have practical methods and guidelines, the application of which can yield sizable reductions in training requirements, greater efficiency in training, and improved utilization of personnel. Greater efforts should be made to more effectively implement recent advances in training technology including improved methods of deriving training content, better design and use of informational job aids, and new techniques and devices for organizing training and for guiding the learning process. Even though training program design remains more art than science, and even though there is a clear need for intensified research to enable us to replace crude guidelines with validated practical rules, vigorous application of concepts and techniques already at our command can do much to simplify the training and manpower problems created by the ever-increasing pace of technological change.

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[1]Trademark Hughes Aircraft Company.

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13. ABSTRACT

Rapid technological change makes it necessary to train and retrain personnel as man-machine systems and associated jobs are altered. Because of the continuing rise in required skill levels, the demand for high aptitude, highly trained manpower outruns the supply while it is hard to use lower aptitude men. Recent advances in training technology should, if implemented, help to solve training and manpower problems. Major directions indicated by military research in this area include (1) improved methods for describing required human performance outputs and for deriving training content, (2) better design of informational job aids, and (3) new techniques and devices for guiding the learning process.

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