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ISSUES IN THE ISD PROCESS: THE NAVAIR/NAVTRAEQUIPCEN MODEL.(U)

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TECHNICAL REPORT: NAVTRAEQUIPCEN IH-309

ISSUES IN THE ISD PROCESS: THE NAVAIR/NAVTRAEQUIPCEN MODEL

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This report discusses a variety of questions concerning the applicability, methods and philosophy of the NAVAIR/NAVTRAEQUIPCEN model for large-scale Instructional Systems Development (ISD). The purpose of this report is to extend the ongoing evaluation of the model beyond the level of application-oriented problems to a more theoretical level of fundamental questions. The questions discussed are grouped into seven major areas of ISD; viz., (1) subject matter expert training and utilization; (2) determination of time-phased segmentation
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of the ISD process; (3) instructional media; (4) training device design and utilization; (5) instructor training and continuity; (6) task analysis, listings, validation, and selections; (7) behavioral objectives and hierarchies. Each question raised in the report is discussed within the context of the NAVAIR/NAVTRAEQUIPCEN model, and referenced to the appropriate section(s) and DID(s) of the model as it is stated in specification MIL-T-29053 entitled "Training Requirements for Aviation Weapon Systems."

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SECTION I

INTRODUCTION

PURPOSE

This report discusses a variety of questions concerning the applicability, methods, and philosophy of the NAVAIR/NAVTRAEQUIPCEN model for large-scale Instructional Systems Development (ISD). Although many of the questions raised in this report apply generally to other training system models currently in use throughout the armed services and industry, the intent here has been to address only those matters of concern that derive directly from the NAVAIR/NAVTRAEQUIPCEN model as it is presently formulated in the specification (MIL-T-29053) entitled "Training Requirements for Aviation Weapon Systems" (October 1977), and in the associated Data Item Descriptions (DIDs). Even though the scope of this report is limited to the NAVAIR/NAVTRAEQUIPCEN model, it should not be assumed that all areas open to valid and important inquiry have been exhausted; neither should the questions raised here be regarded as a definitive evaluation of the current NAVAIR/NAVTRAEQUIPCEN model.

The model has already undergone several revisions subject to knowledge gained from various applications of it to both existing and newly emerging weapon systems training programs. By continuing this evaluation process the applicability of the model can be refined and maintained in a dynamic state, and its responsiveness to the training needs in the Naval aviation community can be augmented.

The purpose of the present report is to extend the on-going evaluation of the NAVAIR/NAVTRAEQUIPCEN model beyond the level of specific application-oriented problems to a more theoretical level of fundamental questions. The questions discussed in this report were viewed as items offering major potential for fruitful consideration in the course of future development and application of the model.

HISTORY

Growth in the inherent complexity of airborne weapon systems over the last thirty-odd years has been paralleled by the emergence of an equally complex problem - the design of large-scale instructional systems. Until recently the Navy's response to this problem has been much the same as the other armed services and industry. The concept of systems analysis was embraced as an operating strategy and the principles of applied psychology and educational technology were transformed into proceduralized methodologies for training program development. The result was called the "Systems Approach to Training" (SAT).

The principles underlying SAT were sound, but the approach suffered a fundamental weakness. It lacked a management system capable of directing multiple applications of SAT, i.e., a general control process that would effect a uniform application of SAT across training programs developed for different weapon systems.

By the mid-1970s the Naval Training Equipment Center (NAVTRAEQUIPCEN), acting under the auspices of the Naval Air Systems Command (NAVAIRSYSCOM), had undertaken the task of constructing a generally applicable model for ISD. The ISD process was divided into five major phases of activity - analysis, design, development, implementation, and quality control. The activities to be carried out within each major phase were identified and further developed into logically coherent procedures that made explicit the key decision points, specific objectives, and end-products required at each stage in the process. The resulting standardization of the ISD process made possible effective management control throughout the successive stages of each developmental project, and it permitted cross-project comparisons essential to further refinement and generalization of the process.

The NAVAIR/NAVTRAEQUIPCEN model of the ISD process has been widely applied in the development of a variety of training programs throughout Naval aviation, and the model has undergone several revisions in response to feedback from these applications. As a management tool, the model has proved its value, but it continues to be evaluated as experience with it accumulates.

OVERVIEW

Seven major areas of ISD were considered to be of sufficient practical and theoretical interest to merit inquiry in terms of the NAVAIR/NAVTRAEQUIPCEN model. These areas are: (1) subject matter expert (SME) training and utilization; (2) determination of time-phased segmentation of the ISD process; (3) instructional media; (4) training device design and utilization; (5) instructor training and continuity; (6) task analysis, listings, validation, and selection; (7) behavioral objectives and hierarchies. Within each of these areas a number of subtopics were selected for discussion. The problematic nature of each subtopic is identified within the context of the NAVAIR/NAVTRAEQUIPCEN model, focused into the format of a question, and suggested approaches are offered that may be helpful in obtaining the desired answer to each question. Subtopics that relate to others in the text are appropriately cross-referenced. Each major area in this report is referenced to the applicable section(s) of the model (MIL-T-29053) as well as to the pertinent DID(s).

SECTION II

SUBJECT MATTER EXPERT TRAINING AND UTILIZATION

The questions raised here are referenced primarily to Data Item Description number UDI-H-25712 (Subject Matter Expert Training Materials), and to military specification number MIL-T-29053, Training Requirements for Aviation Weapon Systems, sections 3.1, 3.3, 3.7, 3.9, 3.10, 3.14, 3.17, 3.18, 3.20, and 3.21.

SURVEY OF SME PROBLEMS

Since the success of an ISD project depends so critically upon the proper functioning of SMEs, especially during the early stages, it would seem worthwhile to undertake a program aimed at determining the kinds of problems previously encountered in the use of SMEs. What have these problems been from the point of view of the contractor, on the one hand, and what have they been from the point of view of the SMEs? The data necessary to answer these questions could be obtained by means of questionnaires that would be sent to the contractors who have in the past worked with SMEs, as well as to the SMEs who have participated in ISD projects. Different forms of the questionnaire would need to be prepared for the SMEs and for the contractors. Some of the problems that could be identified by this means would be peculiar to the particular ISD program, but the thrust of this effort would be to abstract from the questionnaires from all programs any problems that they all had in common. For example, SME motivation, conflicts in personalities, communication, difficulties with certain areas or requirements in the specs, etc.

SME EXPERTISE IN ISD

The DID dealing with Subject Matter Expert Training Materials, number UDI-H-25712, stipulates that the contractor will prepare a systematically developed package for SME training. The stipulations laid out in the DID appear complete in that they cover all areas of the ISD process in which SMEs are involved. Essentially, the DID stipulates to the contractor what areas the contractor's training package for SMEs should include. However, the extensiveness of the SME training program must depend to some extent on the previous experience of SMEs with training programs in general, and ISD analyses in particular. It is probably safe to assume that entry level of SMEs with regard to ISD analyses are zero. Thus, the extensiveness of the contractor's SME training package will be governed by two things, the time alloted for the SME training, and the degree of ISD expertise that SMEs must achieve. It would seem reasonable to assume that, in any case, SME training would have to be brief. This would mean not only that SME training would have to be highly efficient, but also that the level of ISD expertise would have to be somewhat attenuated. Thus, it would be important that the contractor know the answer to the following question; what level of expertise must SMEs achieve in each of the areas of activity stipulated in the DID dealing with subject matter expert training materials? SME expertise level could be specified in terms of the following: (1) a task analysis and listing for SME activities in the ISD process; (2) an analysis and statement of the degree of conceptual comprehension of abstract ISD principles needed by SMEs; (3) an identification of areas of ISD activity which have proved in the past to be especially problematical for SMEs to learn.

TIME FLOW OF SME TRAINING AND UTILIZATION

While the DID concerning Subject Matter Expert Training Materials is quite complete regarding areas in which SMEs are to be trained, it says nothing regarding such matters as optimum procedures for obtaining the required SME performance in those areas, nor does it state the optimum number of SMEs required to achieve the objective laid out. For example, what is the most effective way to achieve a task listing? How many SMEs does a contractor need in order to carry out a task listing? Is there a critical number of SMEs which will be optimally effective for achieving each objective, a number above which communication and effectiveness will break down, and below which objective realization becomes impeded? Is it necessary that all SMEs be trained in, and/or be utilized in all phases of the ISD process calling for SMEs? Perhaps a division of SME responsibilities would be more efficient since this would not require that all SMEs be trained in all areas, and this might allow differently trained SMEs to work on different assignments simultaneously. Or, from a slightly different perspective, a small group of SMEs might be trained to carry out first-stage tasks, and then, at the point in time when this first group began work, training of the second group of SMEs on the part of the project for which they would be responsible could begin, and so on. This type of time-flow in SME training and utilization might not only be more efficient, but also it might avoid problems of SME turnover, etc. Of course, this raises another question, to what extent may each SME activity be trained independently? For example, must SMEs working on objective hierarchies also be trained in task listing? Division among certain areas of SME activity probably will not be possible. However, because of the potential gain by taking this approach, it would be highly desirable to determine what areas of SME activity may be trained independently.

QUALIFICATIONS AND PERSONALITY OF THE ISD EXPERT

Since the contractor's representative responsible for training SMEs and guiding them through the successive stages of the ISD process will probably be a psychologist with limited military experience, if not limited ISD experience, it would seem worthwhile to inquire into the matter of qualifications of the presumed ISD expert. Assuming that the contractor can be called upon to provide psychologists with sufficient ISD experience, there still remains the problem of the kind of relationship that this individual will be able to establish and maintain with the SMEs. It is probably not an overstatement to say that, to a large degree, success of the ISD project depends upon the kind of relationship that will exist between the psychologist and the SMEs. Thus, it would seem important to know what kind of relationship will be most effective and productive, and what personality characteristics the psychologist needs in order to maximize the probability of achieving this relationship? Essentially, the question is, what array of social behaviors will be optimal in establishing and maintaining an effective and productive relationship with military-trained subject matter experts? This question could probably be answered sufficiently well to enable a general specification to contractors which would be helpful to them as an aid in selecting their representative.

SECTION III

DETERMINATION OF TIME-PHASED SEGMENTATION OF THE ISD PROCESS

The questions raised in this section are referenced primarily to Data Item Description number UDI-H-25710 (Work Plan), and Data Item Description number UDI-H-25711 (Progress Report), and to the document entitled Training Requirements for Aviation Weapon Systems (MIL-T-29053).

ISD PROCESS SEGMENTATION

Time-phased segmentation of the ISD process offers many potential advantages to both the Navy and the contractor. Two of the more prominent advantages of time-phased segmentation are; (1) contracts could be awarded for segments of the ISD process rather than the whole thing, and (2) the proposed work plans and budgets of potential contractors could be prepared and evaluated more accurately with respect to projected time, manpower, cost, resources, etc. For example, it might be advantageous for the Navy to use different contractors on different segments of the ISD process. Due to differences in expertise, resources, etc., between contractors, one contractor might be better prepared to carry out a particular segment than another contractor. Also, for a variety of reasons, it might be necessary for the Navy to terminate a contract at the end of a particular segment and to have a different contractor continue the ISD project from that point forward. On the other hand, small contractors with considerable expertise in particular areas might be inclined to bid for contracts if their responsibility were limited to a particular and highly defined segment of activity. In order for any of this to be possible, the ISD process must be broken down into mutually exclusive, non-over-lapping segments that are time-phased. Thus, the question is: What portions of the ISD process can be broken down into self-contained segments of activity which have a defined starting point, specified objectives, products, manpower and resources requirements, and time rate of progress of completed ISD projects might provide the answer to this question.

SIMULTANEOUS COMPLETION OF DIFFERENT SEGMENTS OF THE ISD PROCESS

This question is really a subtopic of the foregoing question, but its potential importance would seem to warrant treating it separately. Should it be possible for the ISD process to be broken down into self-contained, independent segments that were properly time-phased with respect to one another, it might be possible to shorten the time to completion of the entire ISD project by having different segments completed simultaneously by different contractors. The question is: Which segments could be carried out simultaneously? Obviously, in order that any two segments be carried out simultaneously, the products of neither one could serve as prerequisites of the other. That is, there could be no substantial sequential dependencies between any two segments if they were to be carried out simultaneously. As a part of the study suggested in the above question, sequential dependencies between separate segments could be identified. If they should prove to be minor, a strategy probably could be developed to eliminate them. The objective would be to reduce to a minimum the number of sequentially dependent segments, thereby increasing the number of segments that could be completed simultaneously.

SECTION IV

INSTRUCTIONAL MEDIA

The questions raised in this section are referenced to Data Item Description number UDI-H-25718 (Media Selection Model), Data Item Description number UDI-H-25722 (Training Support Requirements Analysis) and Data Item Description number UDI-H-25719 (Media Selection Report), and to sections 3.9, 3.13, and 6.4 of Training Requirements for Aviation Weapon Systems (MIL-T-29053).

THE MEDIA SELECTION MODEL

The process of selecting instructional media that are optimally matched to behavioral objectives is as complex as it is critical to the success of an ISD project. The importance of media selection is reflected in both the DIDs and specifications where it is required of the contractor that an explicit media selection model be provided. An example of such a model and its use is provided in Section 6.4 of the specifications. The model serves as a mechanism for determining first, second, third, and fourth choices of media for each behavioral objective. The user begins by answering each of five questions about a specific behavioral objective. For each question the user must decide which of several coded answers is most applicable to the particular behavioral objective in question. The coded answers to these five questions can then be used to step through the decision matrix stipulated in the model. There are 44 terminal points in this decision matrix and each possible pathway through the matrix leads the user to one of these terminal points. Upon arriving at a terminal point, the user then turns to a table which enumerates the rank-ordered choices of media for each terminal point. Thus, the model stipulates a rational decision process for determining optimal media selection. However, the success of the model depends almost entirely upon the nature of the initial questions one must ask about each behavioral objective, and the theoretical significance of the kinds of distinctions made in the coded answers to each of these questions. The magnitude of importance of the outcome from this model is entirely too great to merely assume that the initial questions and distinctions characterizing the answers to these questions are in fact the best possible set of questions and distinctions. The basic question being raised here is both empirical and theoretical. With what degree of confidence can we assume that these five questions and the distinctions they offer as answers are either appropriate or sufficient? Even though the specifications and DIDs call upon the contractor to provide their own decision models for media selection, the importance of this subject would seem to warrant an independent study. Such a study should be carried out by someone expert in both learning theory and instructional media. Part of the study would be aimed at establishing a kind of catalog of currently available instructional media, the kinds of information display and presentation utilized by each medium, and the kinds of behavior such medium is most capable of training. Once the catalog was established, an experimental program could be undertaken with those media which were judged to be most appropriate within the military framework. The purpose of this experimental study would be to determine not only the limits of each medium, but the relevant behavioral dimensions most appropriate for use in a media selection model. A further outcome of this kind of inquiry might be a kind of matrix in which behavioral dimensions on the one hand would be related to media types on the other hand. At the conjunctions of behavioral dimensions and each media type numerical indexes representing relative cost-effectiveness of each media could be entered in tabular form. Other indexes, such as availability, could also be entered in this table. Lastly, it is implicit in this question that an attempt would be made to establish the validity of media types with respect to such performance variables as rate of acquisition, recall, discrimination, appropriateness of rule use, etc., and the long term reliability of criterion level performance. As part of this last objective, the researcher would attempt to identify the sources and kinds of incentives that could, or would, be associated with each media type.

NEW KINDS OF INSTRUCTIONAL MEDIA

Although great strides have been made in all aspects of instructional media over the past 25 years, we are still faced with the fact than an expertly prepared workbook will, for many kinds of instructional objectives, be nearly as effective as any other more costly instructional medium. With the exception of training in perceptual-motor skills, which may require sophisticated weapon systems trainers, it appears that the old-time programmed workbook falls short of its modern electronic equivalents only in the area of motivational incentives. And while motivational incentives certainly provide the juice that keeps the cognitive wheels oiled, as it were, one is nevertheless left with the impression after viewing a professionally prepared videotape presentation that the instructional value of the show would be considerably diminished had its viewer not been provided with a well-prepared workbook as a backup. Thus, it appears that we are still in the horse-and-buggy stage of instructional media. In the opinion of this writer, the fundamental question is: What is the most effective way to present information and require a response to it such that the result will be competent, enduring, and reliable utilization of that information? Optimally we would like to achieve training methods in which rapidity of acquisition would not trade against endurance of retention, regardless of the difficulty of the subject matter. The enormous amount of time required by humans to learn complex response sequences with heavy memory loading is an example of a primitive training methodology or a wrong approach to training. In this writer's opinion, it is the latter. In spite of all of the research which has been conducted on learning and training methodologies over the past 25 years, relatively little attention has been given to the question: What kind of functional unit does the human represent when he must operate within the context of a specified information-processing and action system? Without trying to answer this question here, it would seem evident that the human might be regarded as a decision-making and actuating device with exceptional perceptual capabilities, but with remarkably poor memory capacity. Such a concept may or may not be accurate. The point is, if we are to effectively train men to function as units in sophisticated information processing and action systems, then our concept of the role of humans operating in such systems should be an accurate one. Such a concept would guide both the design of the systems men must operate and the instructional methodology by means of which we train them. Ironically, probably through trial-and-error and the availability of micro-electronics, the more complex systems requiring human operators seem to have been designed with some such concept in mind, while the media selected for training men to operate such systems seem not to have been driven by any unified concept of man as an operational unit. The relatively greater effectiveness of weapon systems trainers probably stems from the fact that, unlike videotapes and workbooks, they require men to take action based on information stored elsewhere and presented in the proper sequence to them. And so we find that the success of the weapon systems trainer is not so much in its fidelity of simulation, but rather it derives from the manner in which it requires humans to utilize information and take appropriate action. Extending this concept to the usual squadron learning center with carousels and associated media library, one can readily conceive of a centralized system driven by a computer which would (1) provide visual and auditory displays to students in carousels, process their responses to inputs and provide feedback information, (2) provide random access to any segment of the program and highly individualized instruction, and (3) simulate in a very limited way the actual operational situation. In other words, a set of carousels in a learning center each of which would be a kind of mini-trainer with response consoles and visual and auditory displays driven independently by a centralized computer system. This is just one sort of possibility that the concept discussed above might lead to. The point of this question is that research needs to be done on the emerging functional role of man in complex operational systems as a means of identifying the behavioral dimensions necessary for the development of new kinds of instruction media. (See Section V (A New Training Device Concept).)

SECTION V

TRAINING DEVICE DESIGN AND UTILIZATION

The questions raised here relate to Data Item Description number UDI-H-25716, Data Item Description number UDI-H-25720, and to sections 3.5, 3.6, and 3.10.1.2 of the Document Training Requirements for Aviation Weapon Systems (MIL-T-29053).

TRAINER MODIFICATION

In the case of ISD for existing weapon systems, the specifications recommend an inventory of potential training resources including training devices which might be modifiable. The rationale for modifying an existing training device for use in a new training program is that the cost of such a modification will be less than the cost of a new training device. The modifications made are those required by the training objectives of the new ISD program. The operating principle that comes across in the specs might be stated as follows: Use training devices that are available if they can be modified to meet the new training objectives. Again, the driving force behind this emphasis appears to be cost savings. While cost savings will always appear to be a highly desirable goal, the emphasis in the specs on use of modifiable training devices appears to be too strong. The question is what sort of training device would be optimally designed if only the behavioral objectives to be trained were considered in the absence of the constraint imposed by the necessity to utilize, if possible, an already existing training device? More directly, how would an ideally designed training device compare with a modified training device? Presumably, the optimally designed device would result in a superior realization of the training objectives than the modified device. In fact, the best way to evaluate the modified training device would probably be to compare it with the optimally-designed device. This does not mean that the optimally-designed training device would actually have to be either built or designed, only that its characteristics be specified. The question, then, that is being raised here is: How does one (1) determine whether a training device can be modified in such a way as to realize the training objectives, and (2) what is the best way to determine the needed modification? It seems to be implicit in the specs that all one needs in order to answer these two questions is the behavioral objectives. While this is questionable, the specs do not recommend a procedure for answering these two questions. As a matter for further investigation, it is suggested here that a good procedure would be to deduce from those behavioral objectives that require training device utilization the ideal characteristics of the optimal training device. These optimal characteristics could then serve as a model by means of which existign training devices could be assessed for possible modification, and, if modification is judged to be feasible, the extent and direction of modification could be guided. It would thus seem to be worthwhile to develop procedures by means of which optimal characteristics of training devices, given certain behavioral objectives, could be generated. Research in this area could lead to the development of a set of procedures which could then be incorporated into the ISD specifications.

A NEW TRAINING DEVICE CONCEPT

It would appear that the chief restriction on utilization of training devices is the cost. Assuming that there is a nearly direct relationship between training device cost and the fidelity of simulation built into the device, it should be possible to reduce costs of training devices by reducing the fidelity of their simulation. This immediately raises the question: What degree of fidelity of simulation ought to be incorporated into training devices? The answer to this question would seem to depend almost totally on the training objectives for which the device is built. In the ISD specifications, training devices are used for "hands-on" objectives, and other media are specified for the remaining objectives. This restriction on the use of training devices appears to be the result of their very limited availability which, in turn, reflects the enormous cost of developing, producing, and operating a training device. Thus, we have a situation in which the utilization of training devices in training programs is controlled by their cost-availability rather than their potential for training. Thus, cost of training devices is a function of their fidelity of simulation, and the emphasis on simulation appears to be centered in the age-old assumption that training device effectiveness must be measured in terms of transfer of training. To be sure, if the fidelity of simulation in a trainer nearly matches that of the operational environment, then transfer of training is a meaningful criterion of training effectiveness. On the other hand, no one would argue that transfer of training was a meaningful criterion for evaluating the effectiveness of training carried out with workbooks or videotape displays. Effectiveness of training produced by the latter is measured in terms of performance criteria derived directly from the behavioral objectives being trained. In general, it may be said that it is the behavior that is trained that is tested, and it is the test performance which provides the basis for evaluation of the effectiveness of training. If fidelity of simulation in the training situation is high, then the behavior to be tested approximatees that required in the operational situation and the test performance may be taken as an indication of transfer of training. So, the real question is not whether transfer of training is high, but whether, after training of numerous individual behaviors, performance in the operational situation will be at criterion levels. This is not to say that high fidelity trainers are not important. Such devices probably are the best sort of interface between school-type training and the operational environment. The point here is simply that most training is not carried out under high fidelity conditions and, therefore, it should be possible to design and utilize low-fidelity, low-cost training devices which would have the potential of proving far superior to the traditional workbooks, videotapes, etc. Such devices might, for example, take the form of individualized consoles with computer-driven visual and auditory displays, response processing and feedback capacity, etc. Computer programs could be designed to optimize learning and retention of cognitive tasks with a high memory loading, strategy and problem solving tasks, even perceptual-motor tasks. A centralized computer could serve a number of consoles, yet preserve the individualized nature of instruction. This system would incorporate well-known principles of computer-aided-instruction and generalized trainers, and it would probably eliminate the need for the large variety of training media required by the more traditional approach to training. In addition, this kind of system should prove to be more plastic and modifiable, and probably would reduce the time required for training. This approach has the potential of greatly advancing modern training technology and might even prove to be less expensive in the long run. Research on the feasibility of such systems is strongly recommended. (See Section IV (New Kinds of Instructional Media.)

INTEGRATION OF TRAINING DEVICES INTO TRAINING PROGRAMS

The contribution that a training device makes to the effectiveness of a training program depends not only on the characteristics of the training device itself, but also on the manner in which it is incorporated into the training program. Regardless of the device's potential for training, if it is utilized inappropriately, its contribution to the training program will hardly justify its cost. Given a training device that has been designed to simulate the operational environment, what factors will determine how it is integrated into the training program? While the ISD specifications provide some guidance with respect to this question, there appears to be no procedure for determining the answer to such questions as: (1) is the training received on a training device more effective if that training occurs at certain key stages in the training program, and if so, how does an ISD contractor determine the optimal stages for training device use; (2) how does the ISD contractor establish what skills need to be trained prior to training device use in order that its effectiveness will be optimal; (3) how does the ISD contractor determine the kinds of skills (cognitive, decision-making, communication, perceptual-motor, etc.) may be most effectively trained by means of a training device rather than other media; and (4) how does the ISD contractor establish the relationship that may exist between the kinds of skills the training device is designed to train and the points in the training program at which the training device should be inserted? Furthermore, it would be important for the ISD contractor to know if there were any relationships between fidelity of simulation and the point in the training program when the training device should be introduced. The whole question of how and when the ISD contractor can optimally incorporate a training device into a training program needs to be investigated.

INPUTS TO TRAINING DEVICE DESIGN

Answers to the above questions should serve as important factors to be considered in the design of new training devices. Ideally, the specifications for the design of a training device would include a complete enumeration of its potential uses, including its potential for modification, the kinds of tasks it is designed to train, and the various points within the training program where its incorporation will be optimally effective.

SECTION VI

INSTRUCTOR TRAINING AND CONTINUITY

The questions raised in this section are referenced to Data Item Description number UDI-H-25728 (Training Device Instructor/Operator and Training Materials), Data Item Description number UDI-H-25727 (Instructor Training Course Materials), and to military specifications (MIL-T-29053) Training Requirements for Aviation Weapon Systems.

INSTRUCTOR QUALIFICATIONS

The ISD specifications appear to be lacking in any statements regarding instructor qualifications. Surely the instructor's past experience with the operational system and his previous instructional experience are important factors that will contribute to his success as an instructor in the ISD training program. Furthermore, the instructor's personality, ability to relate to students, his speaking ability, his educational background, and his motivation to be an instructor will all contribute to his success as an instructor. None of these factors are considered in the ISD specifications. This means, essentially, that there are no explicit instructor selection criteria. This, of course, reflects the general approach of the Navy to instruction. However, it would appear to be most worthwhile if a study could be performed which would demonstrate unequivocally the importance of selecting instructional personnel according to criteria appropriate for the job they are to perform.

INSTRUCTIONAL PERSONNEL FOR TRAINING DEVICES

The ISD specifications call for the development by the ISD contractor of training programs for both general instructional personnel and training device instructional personnel. While the pertinent sections of the specs and the DIDs appear fairly complete and well-formulated, there are a few points which would appear to need emphasizing. First, it would appear essential that instructors be fully acquainted with the rationale that has led to the specific manner in which a training device has been incorporated into the ISD program. That is, they should understand why the trainer is employed at certain points in the training program and not at other points, the general role of the trainer as it has been included in the program, and the objectives which use of the trainer is designed to accomplish. In other words, instructors should be able to see the use of the trainer as an integrated part of the whole program. Furthermore, it would seem important for all instructors, both those directly involved with training device operation and those involved in other aspects of training, to be familiar with the operational characteristics, the limitations, the features of the device that involve a high degree of simulation, and the kind of training exercises that will be carried out in the trainer. The point that is being made here is that each instructor, no matter what his specific responsibility may be, should have an overall view of the entire training program. This will help to prevent the program from becoming segmented into parts that do not dove-tail smoothly, and should better enable instructors to communicate to their students how their respective parts of the program integrate to form the whole. Perhaps some specifications along these lines could be developed.

INSTRUCTOR INCENTIVES

There is little doubt that the effectiveness of an instructor will, to a large degree, depend upon the instructor's motivation in that capacity. The Naval instructor system, however, would appear to offer relatively few incentives for its instructors. The Navy's large investment in its training programs, and the importance of the success of these programs in maintaining an operationally-ready personnel, would seem to argue for an instructor system that is both selective of and rewarding for those personnel who participate in it. In the present system instructors are only part-time, they do not appear to relish the duty, and they are not continued in it on a long-term basis. Likewise, personnel who are designated to become instructors are not selected on the basis of their potential expertise as instructors. Surely this is not a system that is designed to produce high-level instruction. Furthermore, it would appear to be wasteful of manpower resources due to its lack of continuity and the resulting need to train new instructors for every program, which prevents the accumulation of a reservoir of experience. This system would appear to be unnecessarily costly, inefficient, and generative of a lower level of instructional effectiveness than could otherwise be obtained for less cost. It is strongly recommended that a study be undertaken which would compare in detail the present instructor system with a more productive system. The study would seek to determine (1) what could be done to modify the existing system to make it more effective, (2) what transitional steps would be most direct and least disruptive in making the transition from the existing instruction system to a new instruction system, and (3) what incentives could be applied to instructor positions to make them more desirable (such things as advancement, prestige, awards and special recognition)?

SECTION VII

TASK ANALYSIS, LISTINGS, VALIDATION, AND SELECTION

The questions raised in this section are referenced primarily to Data Item Description number UDI-H-25713 (Task Listings), Data Item Description number UDI-H-25714 (Student Entry Level Report), Data Item Description number UDI-H-25714 (Task Selection Report), and to the military specification number MIL-T-29053, Training Requirements for Aviation Weapon System, sections 3.1, 3.2, 3.3, 3.4, and 6.2.

THE TASK STATEMENT

According to the specs, section 3.1, the three pieces of information to be contained in a task statement are (1) "the action specified," (2) "the conditions of performance," and (3) "the minimum acceptable performance standards." No further description or specification of task statements are provided in the specs. However, examples are provided in section 6.2 of the specs. A close study of the examples provided is somewhat less than satisfying. The statements are esoteric. Usually, no more than one word is used to denote the action. The conditions statements are brief to the point of being vague. And, the standards statements rarely contain anything approaching a specific criterion for performance, and are thus vague and probably useless. While this evaluation is harsh, it is intended to be constructive. Objective behavior descriptions are difficult and require practice under expert guidance. Since the approach taken in the specs is to define task statements by example, it would seem very worthwhile to have an independent contractor develop a set of ideal task statements to be included in section 6.2. These task statements could be preceded by a brief description of the behavioral setting and a detailed examination of one action sequence and its associated task statement. The objective of this would be to call to the reader's attention common epistemological and anthropomorphic problems that arise in making behavioral type statements. It would make clear to the reader that a task analysis is essentially a logical analysis of language. Specifically, it is suggested here that section 6.2 be revised such that it will illustrate for the contractor how to generate task statements, and will provide an ideal list of task statements for use as examples. This should help to improve the quality of task listings, and to bring about greater standardization from contractor to contractor. (See Section VIII (Behavioral Objectives and Hierarchies.)

ORGANIZATION OF TASK LISTINGS

According to the specs, a job or position is defined by its responsibility areas and these are further broken out into missions and phases and finally tasks. As illustrated in figure 2 of the specs, this type of organization provides the "overall structure of a task listing." This type of organization would seem to raise several problems. First, as defined in the specs, a "mission" is a specific group activity with definitive beginning and end points, and a specifiable resultant. But this tends to be confusing logically since "mission" is placed under "responsibility area" and therefore ought to be more narrowly defined. Responsibility areas pertain to individuals, according to the specs, but missions may pertain to groups. Hence, responsibility areas ought to be subsumed under missions. This becomes clear if it is considered that, in the case in a crew of one, a statement of missions would define comprehensively responsibility areas, and only in this case would missions fall under responsibility areas. Of course, in this case, this would be redundant organization. Second, as illustrated in the flow diagram in figure 1 in the specs, and as stated in sections 3.1.1.2 through 3.1.1.7, the format of the task listing structure is organized according to the relationships superordinate, ordinate, and subordinate. This type of organization would not appear to be workable at any level of the task listing structure. The fact that the specs require that missions be broken out into phases serves as a clear acknowledgement that the purely ordinal type organization would not hold for the mission levels of the task listing. However, within each phase, the enumeration of task statements is organized in a purely ordinal fashion by the task listing process stipulated in the specs. Thus, if temporal order can be taken into account in mission organization, why shouldn't it be taken into account in the task organization? Because the sequential order in which tasks often have to be performed may be as important as performance of the tasks themselves, it would appear that the sequential relationships among tasks should be preserved in the task listing. Furthermore, it would appear highly desirable to identify in the task listing any sequential dependencies that exist among the tasks performed by different operators. For example, the performance of a particular task by one operator may depend on the outcomes of the performance of another task by a different operator, and these two tasks may have to be performed in a tight time-frame. This type of coordinated performance of temporally dependent tasks by different operators may require specific training and should be indicated in the task listing. Perhaps, a solution to this problem would involve merely a division of the task listing process into two parts: (1) an ordinal hierarchy of task statements such as is now called for by the specs, and (2) a kind of flow diagram showing for each mission phase the sequential order of tasks for each operator position. This could be done in the following manner. A separate column would be assigned to each operator position. Tasks would b e coded with numbers corresponding to the task statements they represent. The coded tasks would then be listed in the appropriate column in sequential order for each position. Major time frames would be indicated by horizontal lines running across columns. This would permit the location of any tasks to be performed by any operator within the same time frame. Sequentially dependent tasks to be performed by different operator positions could be indicated simply by arrows between columns connecting the sequentially dependent tasks. Likewise, arrows could be used to indicate sequentially dependent tasks within columns and dashed lines could be used to indicate non-sequentially dependent tasks within columns. It would be necessary that all tasks appearing in this flow diagram be of the same ordinal position. It seems likely that they should all be subordinate tasks. It is likely that some subtasks would be repeated several times within the flow diagram for particular phase. Construction of such a flow diagram would focus attention on (1) those subtask sequences which must be trained as sequences for any particular operator position, (2) those subtask sequences that require coordinated action on the part of two or more operator positions and must, therefore, be trained as coordinated action sequences, and (3) the relative frequency of occurrence of subtasks within and across phases and thus help to avoid duplication in the training program and provide an objective means of determining the relative frequency of occurrence of subtasks. In light of the foregoing comments, it is suggested here than an independent study be initiated to reconsider the organizational framework of the task listing as it is currently stipulated in the specs. This study would also consider the merits of adding a time-flow type of listing such as that suggested above and develop a model which could be used to construct such a time-flow chart.

TASK SELECTION

After the task listing has been validated and updated, task are often classified according to training requirements. There are five categories of training requirements. These are: (1) "no training required," (2) "deferred training," (3) "full-scale training," (4) "review-only training," (5) "familiarization-only training." A task selection algorithm is offered in figure 6 of the specs as a suggested procedure for classifying tasks according to the five categories of training requirements. The algorithm is based on such factors as the percentage of students whose entry level behaviors are at criterion performance levels, the percentage of job holders that can be expected to perform the tasks, the frequency with which the tasks will be performed, the criticality of the tasks, the beneficence of the tasks, how soon after arriving on the job the tasks have to be performed, and the practicality of the on-the-job training. These criteria appear unnecessarily subjective and vague. For example, it is probably rare that entry level behaviors can be related in any specific, or quantitative way to the performance criteria of particular tasks. Thus, a "ballpark" guess would have to be made regarding entry level behavior. Likewise, judgments about the criticality and the beneficence of training certain tasks must also be subjective since neither of these two words is defined explicitly. Judgments about frequency of occurrence of task performance, the percentage of individuals who will be required to perform each task, whether performance of the tasks will be required to perform each task, whether performance of the tasks will be required immediately after assuming the job position, and whether the task training can be carried out on-the-job, all could be determined objectively, although the current specs do not require this. Frequency of task performance could be documented. In place of task criticality, two other criteria could be substituted, namely, essentialness and risk. Risk refers to the potentiality of hazard being contingent upon poor task performance, and it could be estimated in a reasonably objective way by using a rating scale. Essentialness refers to the necessity of including a task in the training program because it may be prerequisite to another task, or because of its sequential interdependence with other tasks, or because it occupies a key function in the completion of a mission. By taking these three dimensions of essentialness into account, fairly objective ratings of essentialness could be obtained. This should eliminate any need for the vague criterion of beneficence. In fact, it would probably be possible to develop an algorithm for determining degree-of-essentialness using the three dimensions mentioned above. A similar approach could be used in obtaining objective indices of the other criteria that enter into the task selection algorithm. A study directed at generating an objectively based task selection algorithm should be most worthwhile. Considering that the task selection algorithm acts as the filter which feeds into the subsequent stages of the ISD process, a well-formulated task selection procedure could serve as a check against improperly prepared task listings. (See Tasks Under Extraordinary Conditions and "Hands-on" Media and Tasks, this section.)

TASK VALIDATION

The specs require that the initial task listing be submitted to no less than respondents, none of whom will have been involved in the initial task listings in any way, and that these respondents be provided with the proper forms and necessary instruction to carry out the validation process. The criteria that the respondents will consider are essentially those that enter into the task selection algorithm described in Task Selection. Obviously, if these criteria were specified objectively, as argued in Task Selection, not only would it be easier for the respondent to validate the task listing more reliably, but evaluation and integration of the respondents' work would be easier. However, even if the criteria for use by respondents were completely objectified, there remains the question of how heavily their evaluations should be weighted since they would not have received any ISD training. Perhaps it would be worthwhile to give a small number of SMEs a brief and highly specificized introduction to ISD procedures and objectives so that they might better be able to perform the task listing validation in a meaningful manner. But how many SMEs should be included in this group? The specs call for no less than ten. Is this an optimal number? What kinds of problems are normally encountered in carrying out task listing validation? Do the specs need to be revised to reflect what has been learned from ISD projects in which task listing validations have already been carried out? Interviews or questionnaires with SMEs involved in task listing and validation, as well as contractors, should throw some light on these questions. The focus here would be to determine what general kinds of problems have been encountered in different projects, suggestions as to how those problems might have been avoided by a different set of specifications, and how the various problems were in fact resolved. From this sort of information, it should be possible to deduce what revisions need to be made to the specs.

TASKS UNDER EXTRAORDINARY CONDITIONS

Relating back to the suggestions about criteria made in Task Selection, a task to be performed under extraordinary conditions would be defined as one having (1) low frequency of occurrence, (2) a high risk rating, (3) a high essentialness rating, (4) hopefully will not be trained on the job, (5) might have to be performed at any time after assuming the job, (6) all personnel in that job should be prepared to perform it, and (7) it would probably exceed entry level behavior. Unless these kinds of criteria are present in the task selection algorithm, tasks to be performed under extraordinary conditions may not receive the proper classification in the training requirements. While this question might well be subsumed under Task Selection, an independent study of the kinds of tasks generated under extraordinary conditions, together with the kinds of training these tasks have received in the past, might reveal the kinds of criteria that will be most effective in selecting them. Other information which could be obtained from such a study might include the training methodology and media most effective for tasks to be performed under extraordinary conditions.

"HANDS-ON" MEDIA AND TASKS

According to the specs, preliminary "hands-on" media designation will be carried out after the task listing has been completed, including validation and selection. This would appear somewhat out of place. Relating back to Task Selection, perhaps one of the criteria which should be used in the task selection algorithm would be a "hands-on" criterion. This would probably have the effect of expanding the training requirements to six or seven categories rather than five. The two additional categories would be (1) operational training, and (2) simulated training. The implications of this sort of change in the specs may be worth considering. For one thing, it would mean that both the original group of SMEs and the group of SMEs acting as respondents during task validation would have played a key role in deciding which tasks could be optimally trained by simulation or by actual operational experience. For another thing, it might avoid elimination of those tasks which are, in and of themselves, relatively trivial but which become of some major importance in the operational or simulated environment. As a corollary of this, it may well be that some tasks might be initially designated for simulator training that might otherwise only obtain workbook training. In fact, the need for certain scaled-down simulator-type trainers might be identified in this way. Thus, this question relates to The New Training Device Concept, Section V, and to New Kinds of Instructional Media, Section IV, as well as to Task Selection in this section. Incidentally, both simulated training and operational training could be subsumed under the training requirements calling for full scale training. This category would then contain three subcategories, namely, standard media training, simulated media training, and operational training.

SECTION VIII

BEHAVIORAL OBJECTIVES AND HIERARCHIES

The questions raised here are referenced primarily to Data Item Description number UDI-H-25717 (Objectives Hierarchies), and to military specification number MIL-T-29053, Training Requirements for Aviation Weapon Systems, sections 3.7 and 6.3.

THE BEHAVIORAL OBJECTIVE STATEMENT

The criticisms and suggestions made under ISD Process Segmentation, Section III, regarding the task statements apply to some extent here. The objectives (task) hierarchies given as an example in section 6.3 could probably be improved. As was suggested in the case of the task listing given as an example in section 6.2, an ideal task hierarchy could be developed and substituted in section 6.3. It would probably be best if section 6.2 and section 6.3 could be developed together so that the reader of these specs could work his way from the task listing through all intervening steps to the task hierarchy. In fact, it would probably be most beneficial to the contractor if all intervening steps including decision algorithms, interactive procedures for developing complete task hierarchies, etc., could be included in the example. Extending this line of reasoning to include the entire ISD developmental process, it would seem worthwhile to develop an ideal example that would start with a task analysis on a scale-down and fictitious mini-operational system, and continue all the way through task listings, validation, and selection, to task hierarchies development, method and media selection, course syllabi development, training support requirements analysis, and lesson specification development. The resulting idealized example, then, would constitute a coherent set of materials illustrating the developmental phase of the ISD process in a direct and easily understandable way. The operational system used in the example would need to be highly fictitious to permit the developer of this example to create a system just complex enough to include only those components essential to illustrate the ISD developmental procedure. The fictitious mini-system should also have some "sex appeal," that is, it should have the potential of holding the reader's interest. It should be familiar, as opposed to esoteric, and perhaps even humorous. It should be kept in mind that the contractor undertaking an ISD project will prepare SME training materials, and that the contractor probably will use the example in the specs for this purpose. So the example provided in the specs should be prepared with an eye to all potential users of it. It has not been part of this question to suggest that the example be taken so far as to include the preparation of reports specified in the DIDs, although this might well be done. In any case, a carefully constructed idealized example of the ISD developmental phase would be a valuable addition to the specs, and it is recommended here than an independent study be undertaken to produce such an example.

OBJECTIVES SELECTION CRITERIA AND ALGORITHM

Analogous with the task selection algorithm, which serves as a filter to ensure the selection of significant tasks for training, the iterative process for ensuring that objectives hierarchies contain only instructionally significant objectives (sections 3.7.1.4, 3.7.1.6, 3.7.1.8, 3.7.1.9, 3.7.1.10, and

3.7.1.11) also serves as a kind of filter. However, in this case, there is no clear cut set of criteria. (1) In sections 3.7.1.4 and 3.7.1.5, the specs instruct the ISD expert to determine whether any decisions essential to the performance of a task have been omitted and to add these decision tasks to the components list. The ISD expert is provided with a list of five statements which presumably exhaust all possibilities for generating decisions. Assuming, as is done in decision theory, that an operator makes a decision each time he chooses between two or more alternatives, the five items given in the specs for generating all possible decisions appear to be inappropriate. (2) In section 3.7.1.6, the criterion that the ISD expert is instructed to use in determining whether memorization is a significant element of a task is simply whether an average trainee, whatever that is, would be unable to perform the task as a whole because he could not remember which components were to be performed, or the order of their performance. At best, this criterion is vague and requires an excessively subjective judgment on the part of the ISD expert. (3) In section 3.7.1.8, the ISD expert is instructed to determine whether there are too many subtasks. The four items provided for the ISD expert to use in determining this are confusing and ambiguous. For example, any subtask that is found to be a lower level component of another subtask on the list is supposed to be eliminated. No rationale for this is given, and it is not clear what the ISD expert should do if he judges the subtask to be critical in its particular position in both places on the list. The same objection would be raised with respect to the next point which stipulates that any subtask that repeats another subtask on the list be eliminated. And the next two items clearly require subjective judgments. One of these instructs the ISD expert to eliminate a task if it is not "necessary" to the accomplishment of the main task, in his judgment. The other of these items instructs the ISD expert to eliminate any subtask he judges to be "trivial." The two words "necessary" and "trivial" are not defined explicitly nor are any criteria given by means of which "necessary" or "trivial" may be determined. (4) In section 3.7.1.9, the ISD expert is instructed to narrow the list to the minimum set of subtasks necessary to perform the terminal objective. Again, the ISD expert is provided with four specific instructions to be used in narrowing the list. He is first instructed to eliminate any overlapping subtasks, although it is not made clear what is objectionable about overlapping subtasks. In some cases, overlapping subtasks might even be necessary. Secondly, the ISD expert is instructed to eliminate any task that is part of another subtask on the list. Why this must be regarded as necessarily objectionable is not at all clear. It might, in fact, be necessary that one subtask be part of another subtask in order to specify it completely. Thirdly, the ISD expert is instructed to make a judgment about which subtasks are not "essential" to performance of the superordinate tasks. The problem is, there is no explicit definition of what is meant by "essential," and thus no way to compare disagreeing opinions of essentialness offered by different SMEs. Fourthly, the ISD expert is instructed to group "trivial" subtasks into major logical categories and designate each category as a single subtask. What this means is anybody's guess. (5) In section 3.7.1.10, the ISD expert is given a formula for determining whether there are too few subtasks. The formula reads, "If, after having mastered all given subtasks, the trainee would be unable to perform the main task without more than a few simple instructions and some coordination practice, one or more subtasks have been omitted." This specification is accompanied by Figure 14 which shows an algorithm for hierarchy completion. The algorithm states that "mastery of all subtasks" plus "some minimal instructions and practice" equals "mastery of the major tasks." The problem with this is that neither "minimal instructions" nor "practice" are defined. As a general operating rule, it would seem that anything requiring "instructions" or "practice" should be included as a separate task objective for training and not left for the whimsical inspiration of some instructor farther on down the line. At any rate, if the algorithm for hierarchy completion is not found to be satisfied, the ISD expert is instructed to proceed to section 3.7.1.11 where he is instructed to expand the list of subtasks to the minimum necessary set, whatever that might be. Thus steps 3.7.1.4 through 3.7.1.11 form a kind of iterative process that is supposed to result in a "complete" objectives hierarchy. This iterative process is diagramed in the form of an algorithm in Figure 12.

All in all, it is clear what this process is supposed to accomplish, and there is little doubt that some such process is highly necessary. The question is: Will this process, as it is outlined in the specs, accomplish the necessary and desired goal of producing an objectives listing that is sufficiently complete to form the basis of the instructional program? It is hoped that the above criticisms will indicate that there is some doubt about the answer to this question. As in the case for the task selection process, this hierarchy selection process is also a critical stage in the development of an ISD program. It would seem to be sufficiently important to warrant an independent study designed to develop a set of explicit objectives selection criteria, and to design a functionally fine-edged objective selection algorithm.

ASSESSMENT OF DIFFICULTY OF BEHAVIORAL OBJECTIVES

Whereas, it is the goal of the task listing to state precisely what an operator must do in order to perform the requirements of his jbo, the purpose of the task components hierarchy is to provide an explicit statement of those things which a potential operator must be trained to do in order that he will be able to perform the operational tasks proficiently. It is implicit in this distinction that operational tasks and training tasks (behavioral objectives) are not necessarily identical. Even in the case of high-fidelity training device simulators, the task selected for training probably would not be exactly the same as the task required in the operational situation.

In the case of behavioral objectives to be achieved through training on workbooks, videotapes, etc., the question of simulation is not even appropriate. Much of this sort of training involves the learning of complex concepts, decision-making logics, and symbolic stimulus-response chains (rules) that serve as behavioral guides, etc. These tasks constitute the "knowledge" skills which an operator must carry with him to the operational environment.

Thus, at the task hierarchy stage of ISD development, the instructional design expert is faced with the question: Given the tasks specified in the task listing, what behaviors must be trained in order that those tasks will be performed proficiently under operational conditions? Answers to this question are given in the form of expanded task listings containing those component behaviors judged to be essential to wholetask performance.

The specs explicitly recognize two types of task components which often need to be added at the hierarchy stage, i.e., decisions (section 3.7.1.6). However, even in the case of these two components, the specs offer no objective procedure by means of which necessary additional task components may be identified (this point is treated in detail in Objectives Selection Criteria and Algorithm of this section). Nor would mnemonic rules and decision components appear to be the only classes of task components that would need to be added at this stage of ISD development. Thus, the question being raised here is: What pieces of information will enable the ISD expert to generate the additional task components needed to construct complete hierarchies of behavioral objectives?

One approach to answering this question would be to focus on the gap that exists between entry level behavior and criterion level behavior, and the kinds of hurdles the trainee must overcome in order to cross that gap. Here, we are concerned less with the precise identification of the hurdles (in most cases they probably could not be identified completely) than with the classes of difficulty that constitute the gap. There should be a finite set of difficulty factors which would comprehensively characterize the problematic components in any gap. By assessing the relative magnitude of each of these difficulty factors for a particular gap, it should then be possible to identify the kinds of components needed to bridge the gap. Of course, it would be necessary also to have some means of specifying the magnitude of the gap as well. Hence, the approach recommended for consideration here is based on an index of the gap magnitude and the relative magnitudes of each of a finite set of difficulty factors.

Such an approach would be based upon the requirement that, for each task selected for training, the following items be estimated: (1) recall difficulty level; (2) performance difficulty level; (3) discrimination difficulty level; (4) conceptual difficulty level; and (5) the ratio of criterion level to entry level performance. Let us consider each of these factors in some detail.

First, consider the ratio of criterion level to entry level performance. The purpose of this index would be to specify the magnitude of the gap. Several problems would be encountered with this determination. In the first place, entry-level evaluations of prospective trainees would be only in terms of general qualifications rather than specific task component performance. Thus, given a task to be trained, it is likely that the ISD expert and SMEs should have to estimate the entry-level performances which could be expected on that set of task components. They probably would have to base their estimates on the general entry level data available to them plus their own experience. The other part of this index, that is, the criterion level performance, already would be contained in the task listing (though perhaps not for all components in any given task hierarchy). With these two measurements in hand, the ISD expert would then calculate the magnitude of the difference between entry level and criterion level performance. Whether this were expressed as a simple ratio, or a difference, the purpose would be to arrive at some relatively objective estimate of the magnitude of the gap, i.e., how far the trainee must be moved by the training program in order to achieve criterion level performance.

The magnitude of the gap, however, would not be very meaningful in-and-of itself. Rather, it would have to be understood in terms of the overall difficulty of getting across the gap. For example, a very large gap may be found to exist between entry level and criterion level for a particular task (or task component), but, if the difficulty of achieving criterion performance were very low, relatively little training might be required. Conversely, a small gap associated with great difficulty might require extensive training. Hence, the magnitude of the gap would indicate only how far the trainee must be brought to achieve criterion level performance. It would not indicate the rate at which the trainee might achieve that performance level. The latter would be indicated by the four difficulty factors.

The magnitude of the four difficulty factors could be estimated by SMEs who might use a standard rating scale associated with an explicit definition of each factor. For example, in estimating the magnitude of the recall difficulty level for a particular task, SMEs might first ask themselves the following question: What information bits and bit sequences must the operator be able to recall (either verbally or functionally) in order to perform this task which has been selected for training? After having broken down the task into its recall components, the SMEs would assign to each component a number from the rating scale for recall difficulty. If, for example, the rating scale had five categories, the number five would be assigned to a component judged to be very difficult to recall, and so on for the other categories on the scale. Whatever else "great difficulty to recall" may mean to SMEs, they could be instructed by the ISD expert to base their estimate of recall difficulty on the number of rehearsal trials they think would be required for perfect recall. This instruction would define the upper end of the rating scale. The remaining categories on the scale could be defined in a similar manner. By systematically applying this scale to each task component, the degree of recall training required for each component would be specified (some procedure for averaging individual SME ratings would need to be worked out, of course). This procedure would not only identify task components that require recall training, but would indicate the degree of training required.

The next factor, performance difficulty level, would be estimated in much the same way using the same sort of rating scale. First, the SMEs would break the task down into its performance components, i.e., each group of overt actions into which the task may be subdivided. Note that not all task components requiring training would involve overt actions in the operational situation. After identification of task components involving overt actions, SMEs would estimate the performance difficulty of each. They could base their estimates of difficulty on the answer to the following question: How difficult is it to perform this task component in the operational environment even after it has been learned perfectly? This would define the upper end of the rating scale.

The idea here is to separate learning difficulty from performance difficulty. It should be pointed out that the recall task components identified above would also be considered under performance task components. The emphasis in estimating recall difficulty is on learning, but the same task components need to be evaluated from the point of view of performance difficulty as well. For example, if a task component requiring recall is found to be exceedingly difficult to perform in a simulated environment even after it has been learned perfectly elsewhere, the best course of action probably would be to provide a memory aid, or to automate this component by means of an on-board computer with associated display, thus substituting a computation component in place of the recall component. The same considerations would be especially evident for purely motor components. If the performance difficulties of motor components were excessively high, perhaps the device to be operated could be modified. Even if this were not a possibility, an important source of difficulty would have been identified and properly attributed to purely performance limitations rather than confusing them with learning difficulties.

The next difficulty factor, discrimination difficulty, refers to the relative ability of operators to distinguish among the informationally significant elements of perceptual displays. These perceptual elements may not be limited to any single sensory modality. They may include tactile displays which must be discriminated with the fingertips, motion or balance cues which must be discriminated by means of the senses of equilibrium, acoustic signals which must be differentiated by the auditory system, and visual cues necessary to read the various cockpit displays and to perform the visually-guided aircraft maneuvers. As before, the SMEs could use a rating scale as the basis for estimating discrimination difficulty. For each discrimination task component identified, SMEs would be instructed to ask themselves the following question: *How much* practice is necessary in order to achieve perfect discrimination for this component? The answer to this question could be translated into the form of a number from the rating scale. For example, if an infinite amount of practice would result in only poor discrimination, the number at the top of the scale would be assigned to this task component. On the other hand, if perfect discrimination could be achieved with a moderate amount of practice, the number at the middle of the scale would be assigned to this component. This number would represent a learning difficulty. However, a very high discrimination difficulty rating would indicate more than simply a training problem. For example, if a display were poorly illuminated, an accurate reading of the callibrated scale on the display might exceed the limits of human visual acuity. In such a case, no amount of training would overcome this difficulty. Thus, a high discrimination difficulty rating probably should be taken to indicate a needed modification in some aspect of the informational display. In fact, if criterion performance on this task component requires a high degree of accurate discrimination, especially if it must be achieved quickly, even a moderate level of discrimination difficulty might indicate the need for a modification of the display.

It should be evident that both discrimination difficulty and performance difficulty are probably the result of poor human factors engineering, and both may be indicative of needed modifications of the operational device. A high discrimination difficulty would indicate the need for a modification in the display, while a high performance difficulty on a manual task component would indicate a need for modification in the operator's controls.

However, the existence of either of these two difficulty factors should not be taken as an automatic indication of a need for device modification. That judgment always should be made within the context of the ratio of criterion level to entry level performance, plus the risk factor estimated during task selection. The decision formula would be: If the ratio of criterion level to entry level is large, and if risk is high, substantial discrimination or performance difficulties should require device modification. On the other hand, if the ratio of criterion level to entry level is moderate, and if risk is low, even a significant performance or discrimination difficulty probably would not require a device modification. In this case, it probably would be more appropriate to minimize the discrimination or performance difficulty by employing some form of specialized training, even if it means a reduction in the acceptable level of performance.

The fourth difficulty factor to be considered is conceptual difficulty. This is a purely training type difficulty. The conceptual difficulty of a task component may be defined in terms of the extensiveness of training required for trainees to learn the concept involved and to be able to correctly apply it. As in the case of the other difficulty factors, SMEs would first analyze a task selected for training to determine whether it contained any components that were identifiable as concepts. It would then be necessary to determine the logical nature of each concept. Concept types may be differentiated by means of certain specific logical operations. As these operations become more complex, the concepts become more difficult for humans to learn. Five concept types (each type has its complementary type) may be distinguished logically. Progressing from least complex to most complex, the five concept types are: affirmation, conjunction, inclusive disjunction, conditional, and bi-conditional. It has been found that concepts based on affirmation alone are more easily learned than concepts based on conjunction, inclusive disjunction, and conditional relations. Concepts based on bi-conditional relations are the most difficult for humans to learn. Thus, three levels of conceptual difficulty have been identified, with affirmational concepts the easiest and bi-conditional concepts the most difficult. Concepts involving conjunction, inclusive disjunction, and conditional relations appear to be of intermediate difficulty. Determination of the relative difficulties of the concepts in the intermediate level group must be left to future research. The point here is that any training program designed for humans involves the learning of concepts. And, since concept difficulty depends on the logical relations that compose concepts, a straightforward procedure is suggested for determining the conceptual difficulty factor for task components. After SMEs identify the conceptual components in a task, they would then simply determine which set of logical operations define each task component. Once the logical operations have been determined, the type of concepts have also been established. And these types fall into three classes of relative difficulty. Hence, the only problem facing SMEs would be determination of the logical operations.

The five sets of logical operations corresponding to the five concept types are: (1) affirmation - "all things that are 'A' belong to the same class"; (2) conjunction - "all things that are both 'A' and 'B' are members of the same class"; (3) inclusive disjunction - "all things that are either 'A' or 'B' are members of the same class"; (4) conditional - "the relationship between events 'A' and 'B' is such that instances of 'B' occur only if instances of event 'A' have occurred, but not the converse"; (5) bi-conditional - "if an event is an instance of 'A', then it must be accompanied by an event that is an instance of 'B', and vice versa."

Some concrete examples of these conceptual relations are: (1) affirmation - "all red lights signal danger"; (2) conjunction - "if both red light 1 and red light 2 illuminate simultaneously, system malfunction has occurred"; (3) inclusive disjunction - "if either red light 1 or red light 2 illuminate, system malfunction has occurred"; (4) conditional - "the illumination of red light 2 indicates system malfunction only if red light 1 was illuminated, otherwise, illumination of red light 2 means something different"; (5) biconditional - "illumination of red light 1 indicates system malfunction if, and only if, illumination of red light 2 has occurred; and illumination of red light 2 may indicate system malfunction if, and only if, illumination of red light 1 has occurred." It should be clear from the foregoing examples that most rules are, in fact, concepts.

It is recommended here that SMEs estimate the difficulty of such concepts by first identifying the type of concept involved, and then by determining the decisions or actions which must be taken on the basis of that concept. With these two elements in mind, SMEs should be able to use a rating scale of difficulty to establish difficulty levels of conceptual task components.

The result of the foregoing analyses would be a list of task components each of which would have associated with it five numerical indices: (1) recall difficulty level, (2) performance difficulty level, (3) discrimination difficulty level, (4) conceptual difficulty level, and (5) ratio of criterion level to entry level performance. These factors form a cluster which specifies, for each task component, how far the trainee must be moved by the training program, and what types of difficulty the task hierarchy must be designed to minimize. This information should make it possible for the ISD expert to determine the magnitude of importance of each training objective at the time he constructs the task hierarchy. Furthermore, this information should make it possible for the ISD expert to construct an hierarchy for a set of task components which will (1) avoid unnecessary training on any task component, (2) specify the particular type of training needed in order to overcome the major sources of difficulty associated with any task component, and (3) organize the task components into an hierarchy which will take into account the skill, conceptual, and temporal interdependencies of task components. The latter point will be discussed further in this section.

This system of task component analysis appears, on the surface, to be somewhat more complex than that recommended in the specs. This is probably not entirely correct. The apparent complexity of the approach recommended here, as compared with that recommended in the specs, is probably due to the fact that here an attempt has been made to objectify the kinds of considerations that probably would be present in any task components analysis. However, the specifics of the approach recommended here need to be subjected to further theoretical and empirical examination.

Some examples of questions that need further examination: (1) are the difficulty factors specified in the above approach both the necessary and sufficient ones for valid characterization of the problematic elements of task components; (2) what special problems might SMEs encounter in using such a system as that recommended above; (3) what system will afford the most workable and effective application of findings from research on conceptual operations, concept formation, and concept learning; and (4) how may such an approach as the one recommended here be incorporated least disruptively into the specs? These are but a few of the questions raised by the approach suggested here. Because of the potential benefit of such an approach to the ISD process, one or more independent studies in this area would appear warranted.

TASK HIERARCHY ORGANIZATION

According to the specs, it is the task hierarchy which specifies the organization of what is to be trained. However, the kind of organization called for in the specs would not appear to be one that is optimal for syllabi development. The hierarchy organization laid out in the specs follows a simple reduction logic, i.e., objectives are arranged according to the relations superordinate, ordinate, and subordinate. The only pieces of information that this organization contains are (1) the list of objectives to be trained, and (2) the ordinal relation among those objectives. However, as pointed out in Assessment of Difficulty of Behavioral Objectives above, the reduction type hierarchy does not contain the sort of information which would make possible (1) the avoidance of unnecessary training on task components, (2) any indication of the type of training needed in order to overcome the major sources of difficulty associated with task components, and (3) the kinds of relationships among task components which must be learned (as opposed to those which are purely logical) such as the skill, conceptual, and temporal interdependencies among task components. The information needed for items (1) and (2) was thoroughly discussed in question above. It is the purpose of this question to consider the information in item (3), i.e., to consider an alternative organizational structure for task hierarchies.

The general strategy of the approach recommended here is to first identify the task components which require training, then, to establish the type and extensiveness of training required to achieve criterion level performance for each component, and finally, to arrange these components into an hierarchical organization such that actual dependencies among components are preserved, and difficulty factors are overcome at the component level of organization. Given that a difficulty analysis has been performed and the result is a list of task components, together with a cluster of difficulty factors for each component, then the components may be organized into an hierarchy by means of the following rules: (1) difficulty rule - arrange the hierarchical organization such that, the task components which appear at any organizational level are ordered according to the extensiveness of training required to bring each component up to its criterion level so that, when the individual components are combined at the next higher level of the hierarchy, performance on each individual component in the combination is at criterion level; (2) sequential rule - the sequential relationships among temporally dependent components is to be represented as a compound component at a higher level of hierarchical organization than the individual components, and the compound enumerates the sequential order to be learned (if, in addition to performing the compound action sequence, practice on some mnemonic device, such as verbal recall of the sequence, is judged necessary, this may be included as a separate compound component at the same hierarchical level of organization); (3) skill rule - if the relationship between any two components is such that competent performance on one is a prerequisite for performance on the other, the prerequisite component should appear before the dependent component in the organizational hierarchy whether or not the prerequisite component is more or less difficult than the dependent component; (4) concept rule - organize the components of a concept according to their logical operations, such that the least complex conceptual components (class concepts) appear first in the hierarchy and the more complex conceptual components (relational concepts) appear at higher levels of the hierarchy.

These rules for hierarchy construction are somewhat overlapping. For example, the difficulty rule and the concept rule are redundant if, and only if, the compound of task components is conceptual. Otherwise, the concept rule would not apply, but the difficulty rule would. Likewise, if the compound of task components is sequential, the sequential rule and the skill rule would be redundant. Otherwise, the skill rule would apply.

Syllabi developed to incorporate the hierarchical relations among task components generated by these four rules should maximize learning by (1) reducing to a minimum component difficulty at each hierarchical level, (2) ensuring criterion performance of each component in a compound at each hierarchical level, (3) ensuring the component completeness of compounds at each hierarchical level, (4) preserving conceptual, temporal, and skill dependencies among components throughout hierarchical chains, and (5) providing a behaviorally meaningful procedure for integrating compounds of entirely different kinds of components. Furthermore, since difficulty analysis of components already would have been carried out prior to hierarchy construction, the kind of training, as well as the extensiveness of it, would have been made evident for each component.

It would appear that the merits of some such organizational structure for task hierarchies would warrant a full-scale study of its potential for inclusion in the ISD process. Perhaps, as a way of determining its advantages and disadvantages, a specific system of very limited scope could be used to generate a task analysis on the basis of which several approaches to hierarchy construction (that suggested here as compared with the reduction approach contained in the specs) could be evaluated empirically. Since there would seem to be little question about which of the two types of approaches would lead to more efficient training, the main question to be answered by such a study would be: Can the more appropriate form of hierarchy construction be carried out successfully, if not efficiently, by SMEs?

CONCEPTUAL ANALYSIS AND DIFFICULTY

The pertinence of operational analysis of concepts, and concept learning difficulty, to the ISD process has been described in detail in this section. Thus, the question here has been included to focus attention on two problems which emerged in the previous questions. Because of the special nature of these problems, and because they both involve conceptual analysis and learning, it is recommended that an independent study be undertaken to explore them further. The two problems are: (1) the relationship between concept learning difficulty and conceptual logical operations, and (2) the usefulness of conceptual logical operations as a basis for task component hierarchy organization. The findings of a study directed at these two problems could provide important inputs to the studies suggested under the two previous questions.

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