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ARI's Research Program to Determine Training Simulator Characteristics

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Abstract

The Army Research Institute for the Behavioral and Social Sciences (ARI) is developing a data base on the relationship between training simulator charateristics - in particular fidelity - and training effectiveness. In order to guide and organize the collection of empirical data for the data base, a two factor definition of simulator fidelity was chosen. The definition was limited to physical and functional similarity to the actual equipment. Several research efforts, using this definition, are currently being conducted or have just reached completion. This paper presents the results, to date, of completed research efforts, the anticipated results of ongoing efforts, and plans for future efforts. The goal of these efforts is to produce a data base which may serve as the foundation for the development of systematic guidance to support the specification of training device characteristics.

Introduction

The Army, the other services and the training community lack specific guidance to determine the characteristics which will enable training simulators to provide effective training at affordable costs. In the past it has too often been the case that the characteristics of a training device or simulator were determined by a mix of intuition (what someone thinks the device should be like) and cost (buy as much "realism" as we can afford). This approach to training simulator design is no longer a viable option given budget and other resource constraints. Accordingly ARI has undertaken a program of research to develop user oriented, empirically based guidance to aid in determining the characteristics of training simulators which will maximize training effectiveness. The program, from its conceptual development stage, through two ongoing empirical efforts and finally to its future goals, is summarized in this paper.

Defining Training Simulator Fidelity

The first step in developing ARI's training simulator research program was to adopt a working definition of simulator fidelity. An extensive literature search[4] indicated a large amount of inconsistency in how fidelity has been defined by the training R&D community. In particular, the term has been used somewhat indiscriminantly to label different categories of independent and depent variables which characterize both training systems and trainees. It was concluded that a limited, parsimonious definition of fidelity would best serve the compilation of a data base on how device characteristics are related to training effectiveness. Accordingly, the following definition was chosen:

> Training Simulator Fidelity is the degree of similarity between the training simulator and the equipment which is simulated. It is a two dimensional measurement of this similarity in terms of:
>
> 1) The physical characteristics of the training simulator.
>
> 2) The functional characteristics (i.e., the informational or stimulus and response options) of the simulated equipment.[2]

It was further determined that for purposes of empirically testing and validating this definition as well as for generating empirical data on the relationship of training simulator fidelity to training effectiveness, a three level ordinal scale would be used for each aspect of fidelity (physical and functional). This approach yields the matrix like the one in Figure 1. This nine cell matrix serves as the "basic" experimental design for use in subsequent empirical efforts.

Functional Similarity \ Physical Similarity	High	Medium	Low
High	HH	HM	HL
Medium	MH	MM	ML
Low	LH	LM	LL

Figure 1: Nine cell Matrix for Training Simulator Fidelity Experiments

Descriptions of possible devices which

would fit into each cell of Figure 1 may clarify this research approach. Cell HH: The actual equipment could serve as the exemplar of a high physical-high functional device and would therefore fit into the high-high cell of Figure 1. Cell HM: The high functional-medium physical cell could contain a fully functional device but one with some combination of reduced size, number and accuracy of its components relative to the actual equipment. Cell HL: The high functional-low physical cell could contain a computer graphics type device. This device would consist of interactive computer graphics which would function in an analagous manner to the actual equipment but which would look like line drawings. Cell MH: The medium functional-high physical cell could contain a partially disabled actual device. In this case, the device would look exactly like the actual equipment, but would be only marginally functional. Cell MM: A medium functional-medium physical device could be both partially functional and also be degraded in terms of size, number and accuracy of components as in cell HM. Cell ML: The medium functional-low physical cell could contain a device which consists of a two-dimentional display (line drawings) of the actual equipment. These drawings would afford the trainee a means for indicating control choices or test points, but would not provide complete system responses to these choices. Cell LH: The device in the low functional- high physical cell could be a totally disabled piece of actual equipment. Controls would be frozen, displays and test points would be non functional. The device would look just like the actual equipment but would not work at all. Cell LM: The low functional-medium physical device could be a totally disabled version of the degraded device used in cell MM. Cell LL: Finally, the low functional-low physical cell could contain a device which consists of a set of line drawings. These drawings would be physically the same as those in cells HL and ML, but would be totally non functional. These examples are not the only way the nine cell matrix could be filled, but they are one concetualization which ARI hopes will be fillowed by others. The idea is to apply as many alternate approaches to the question of physical and functional device characteristics and transfer of training as possible, but always trying to maintain the nine cell matrix as an organizational framework.

The goal of the empirical efforts in this research program is to provide data on the relationship of training device characteristics (fidelity) to training effectiveness as that relationship is modifiec by the many training system variables which interact with fidelity. Previous research efforts has not attempted to systematically control these interactive variables but hav rather looked at whole devices in the context of already established training programs. ARI believes that it is only by conducting controled, systematic experiments will we be able to generate the necessary data to provide useful guidance to individuals who must specify the characteristics of training devices and programs of instruction.

Table 1 displays a list of some of the variables which are believed to be those which

TABLE 1

Variables Which Interact With Fidelity

1. Task Type
   - Operations
   - Maintenance
   - Others
2. Task Difficulty
3. Specific Skills
   - Motor
   - Perceptual
   - Cognitive
   - Others
4. Trainee Sophistication
   - Novice
   - Intermediate
   - Expert
5. Stage of Training
   - Introduction
   - Procedural Training
   - Familiarization Training
   - Transition Training
6. Training Context
   - Institutional
   - Field
7. Incorporation of Device into POI
8. User Acceptance
   - Instructors
   - Students
9. Use of Instructional Features

interact with fidelity. ARI's goal is to accumulate data on all of these interactions (including data from previous experiments and experiments conducted by other research organizations) into a data base which can then serve as the basis for user oriented guidance in specifving the characteristics of a training simulator. The first of ARI's empirical efforts examined how physical and functional fidelity were related to training effectiveness in a perceptual motor task.

Simulator Fidelity in a Perceptual Motor Task

Honeywell SRC, under contract to ARI, conducted an experiment to determine (1) adequacy of ARI's definition of simulator fidelity, (2) the appropriateness of a nine cell physical-functional fidelity matrix, and (3) the relationship of simulator fidelity to training effectiveness in a perceptual motor task. Baum et al.[1] discussed the criteria used to determine the task selected in this experiment.

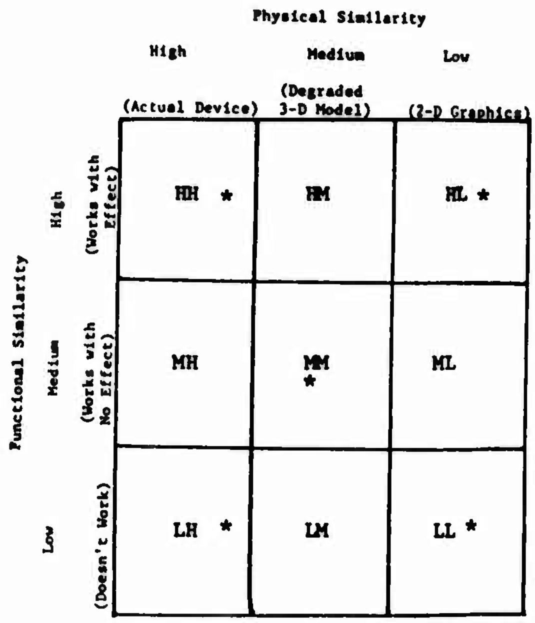
1. The task must embody the skills required in an actual maintenance task enviroment.

2. Task performance must lend itself to straight forward measurement; the measuremetns must be valid, reliable, and sensitive.

3. The task must be learnable in a reasonable period of time.

Based on these criteria the task chosen for this experiment was the truing of a bicycle wheel.

The wheel truing experiment used the fidelity definition and 9 cell matrix discused above. In this effort, only 5 of the nine cells were investigated. Figure 2 shows the nine cell matrix with the relevant cells indicated. By comparing the results in cells HH, MM, and LL the general relationship of fidelity (both physical and functional) to training effectiveness was determined. By comparing cells HH, HL, LH, and LL an indication of the relative contributions of the physical and functional aspects of fidelity was determined.



*Devices in these cells are included in the perceptual/motor experiment

Figure 2: Application of the nine cell matrix in the perceptual/motor experiment

The data collection portion of the wheel truing experiment was completed in June of 1982. Detailed analyses of the data are not available at the time of this writing, but tentative results can be presented. Overall, there was an improvement in trainee performance under all training conditions. Ten t-tests were computed which compared the starting and finishing points in each performance trial. Performance showed significant improvement (p less than .005) in all conditions.

In one analysis, the combined effects of physical and functional similarity on training effectiveness were assessed. A one way analysis of variance (ANOVA) was used to compare the performance, on actual equipment, of subjects trained on the devices in cells HH, MM, and LL of Figure 2. In this analysis, subjects trained in the lower fidelity conditions performed almost as well as subjects trained in the high fidelity condition. There was in fact no statistically significant difference between these groups. The indication is therefore that training devices for a simple perceptual motor task may not necessarily need to be designed with high fidelity.

Another analysis attempts to separate the effects of the physical and the functional aspects of fidelity. This analysis compares the performance of subjects trained on devices in cells HH, HL, LH, and LL of Figure 2. When these data are analyzed using a 2x2 factorial design, there is no significant effect of functional similarity, but there is a significant effect of physical similarity (F=4.157; df=1,75; p less than .05). In other words, no matter how the simulator functions, in this task subjects perform better if the simulator is more physically similar to the actual equipment.

These results must be considered inconclusive and further analyses are required. Though the above analyses are only on terminal performance, additional analyses will compare the subject's rate of learning by examining performance over time. Also some form of blocking of subjects may be attempted to reduce within group variance. Even so, these data are an important first step in validating the 9 cell approach to fidelity research and show that this is a viable method for generating basic data on the relationship of simulator fideltiy to training effectiveness.

Generating Data on Interactive Variables

The above perceptual-motor experiment yielded valuable data on the relationship of the physical and functional aspects of fidelity to training effectiveness, but only for that specific task. Other tasks and other interactive variables require further investigation. ARI, through its basic research (6.1) program, is beginning to collect data on these interactive variables.

One 6.1 effort, currently underway at George Mason University, involves constructing both a generic device to use as an electro-mechanical/hydraulic reference system and several degraded simulations of that reference system. The idea here is that the reference system will serve in the role of actual equipment. It will function in a variety of ways such as turning on pumps, generating tones, turning on lights or fans, none of which really "do" anything. However malfunctions will be introduced into the system and trainees will have to troubleshoot and repair it.

Different groups will be trained on either the actual equipment (the reference device) or on one of several simulators of the reference system with varied degrees of fidelity. The performance of individuals from each group will then be measured on the reference device to determine the degree of training transfer for each level of fidelity and mixture of interactive variables.

This experimental paradigm will provide an opportunity to generate, under controlled laboratory conditions, the basic data needed on many of the interactive variables in the fidelity training effectiveness relationship (see Table 1). Data collection will begin in the Spring of 1983 after the reference device and simulators have been constructed. Systematic inclusion of interactive variables will begin after initial baseline data have been collected. The entire effort is expected to conclude in the Summer of 1985.

The Future: Building a Data Base

The goal of ARI's Training Simulation research program is to produce a user oriented guidance package to help determine the characteristics which should be incorporated into training simulators to insure both training and cost effectiveness. It is the strategy of this research program to base such a guidance package on empirical data.

Data Base Sources

Three major sources of data will be used to construct the training device characteristics data base. First, previously conducted studies will be evaluated to determine whether the data generated from these efforts are suitable for inclusion in the data base. If so, the data will be categorized and added to the data base. If not, the particular study will be categorized so that additional efforts can fill in the gap in the data base. At present, this evaluation of previous research is under way and it is expected to be completed during the Fall of 1982. An ARI Technical Report (5) which accumulates and reviews the literature on training device research issues and which will serve as the organizing framework for the data base is in preparation. This paper is expected to be completed by January, 1983.

A second source of data for the data base will come from ARI's research efforts as described above. These efforts will not attempt to reinvent the wheel by duplicating previous studies which have been deemed adequate. They will rather focus on gaps in existing data, either because previous efforts have not addressed the right questions, because data are not valid and reliable, or because the results are not systematic enough for inclusion in the data base. The wheel truing experiment described above is the first entry from this data source. Other basic (6.1) and applied (6.2) research efforts are presently being conceived and statements of work (SOWs) are in preparation.

It is anticipated that enough data will be accumulated by 1984 that a preliminary iteration of the guidance package may be produced. This guidance package will probably start as a workbook but will eventually be automated for access via computer terminals.

Accessing the Data Base

In order to make the training device characteristics data base more than just an academic exercise, it is necessary to insure that the individuals who need guidance in specifying training device characteristics have access to the data base. At this time there are tentative plans to automate the data base in order to allow users direct access to the data. A preliminary step to automating the data base is to organize it arround user oriented research issues. This organizational effort is currently underway and a data base framework should be produced in the Fall of 1982.

Once a basic framework for the data base is developed it can be used as the basis for an automated delivery system. Such a system, using computer terminals, would afford access for decision makers at various points in the ISD process. It would also allow frequent updating as new and better data are developed. The iterative nature of the proposed data base can insure that the training community will have the most recent data available on a wide variety of training device research issues. With access to such data, the development of training devices need not rely on intuition but rather on the best available information on training effectiveness.

Conclusion

ARI is pursuing a broad research program aimed at building a data base which will relate training simulation design characteristics to transfer of training effectiveness. An initial framework for data collection built around a parsimonious definition of simulation fidelity has been constructed and is being used to guide a series of on-going and planned laboratory experiments. The long range objective is to create a comprehensive simulation design data base and to evolve that data base into a tool which can aid in specifying training device requirements.

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