THE ROLE OF PSYCHOLOGICAL FIDELITY IN TRAINING SYSTEMS ACQUISITION

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ABSTRACT

In training system design and acquisition, some aspect of the procurement addresses the fidelity of the training system. Normally, physical fidelity is the sole concern, although some of the more sophisticated designs and acquisitions have also looked at the concept of functional fidelity as being equal to or greater than that of physical fidelity. This emphasis on functional fidelity to two-dimensional simulation of the three-dimensional systems. Experience has demonstrated, however, that regardless of the quality of both physical and functional fidelities, a substantial number of training systems are unused, unappreciated, and unsuccessful for their planned training mission. This paper identifies a missing ingredient in the study of training system fidelity, that of psychological fidelity. Whereas physical fidelity has to do with how closely something looks like the real thing, and functional has to do with how well it acts like the real thing, psychological has to do with how well it is perceived to train like the real thing. While related to user acceptance, psychological fidelity is the environmental perception of the learner, not the instructor. Users forget that they are in training, and learn as if working with actual equipment. The elements associated with psychological fidelity are identified. Relationships between psychological fidelity and both physical and functional fidelity are specified. Directions for including psychological fidelity elements during the fidelity analysis process are provided. Finally, recommendations are given for a methodology for incorporating psychological fidelity in training system acquisition in the next decade.

INTRODUCTION

Buyers and builders of training systems have struggled with a dual problem: that of needing the best training that money can buy, and a shortage of money to buy training systems. The solution to these problems requires that buyers obtain the maximum training value for the dollars available. However, experience has shown that some training devices and systems fail in their intended goal, that of training students to a specific level of competency. In some instances, it is not the fault of the training system or device. The ability of the students, the competency of the instructors, the curriculum itself can contribute to failure. For purposes of discussion, this paper uses the assumption, that AOTBE (all other things being equal), there are variances in the capabilities and effectiveness of various training systems, ignoring the potential effect of other factors.

Some of the first efforts to maximize the benefits of training system acquisition addressed the physical fidelity of the design concept. Based on results of these efforts and increased sophistication in design and acquisition, the concept of functional fidelity was introduced. Despite the inclusion of physical and functional fidelity in the design specifications during the acquisition process, some training systems remained unused, unappreciated, and unsuccessful for their planned training mission. A third fidelity dimension, psychological, is defined as having the potential to alleviate some of these problems. This paper directs the reader to background history leading to the definition of psychological fidelity. Discussions of the relationship of psychological fidelity to functional and physical fidelity, as well as the training process, follows the historical background. With these relationships and definitions defined and developed, the paper evolves into a prescriptive phase. The initial prescription specifies the integration of psychological fidelity with the Front End Analysis (FEA) process, specifically the fidelity analysis portion of the FEA, and then provides some recommendations for implementing the methodology for incorporating psychological fidelity in training system acquisition.

BACKGROUND HISTORY

The early history of training systems featured the use of actual equipment for training. This use of actual equipment was desirable because it was believed to be the only methodology for achieving learning objectives requiring "hands-on" skill acquisition. It also was also considered appropriate because there would be no problems transferring the learning to task performance on the job. In addition, the wide availability of actual equipment facilitated acquisition and repair of these training devices. Various forms of actual equipment training were possible. A whole system could be used, or, specifically for maintenance training, some sub-system could be used outside the total system as a part task trainer. As the demands for realism in training increased, methodologies were devised to "stimulate" the actual equipment, such as fault insertion devices for maintenance or signal generators for operations. This still had the advantages of actual equipment, but was a movement into the world of simulation.

The first simulators relied heavily on actual equipment. Even when using more advanced simulation techniques, the exterior panels and manifestations were often portions of the actual equipment, or identical to the deliverable system. The term "hybrid" is often used to describe these mixed trainers. Again, from the buyers' viewpoint these trainers offered values virtually identical to the actual equipment: high fidelity for ease of learning transfer, opportunity for complete hands-on training, ease of obtaining replacement parts.

Three major factors led to the increased use of simulation. The first was safety. For many tasks, actual equipment was not a safe medium for training. The second was cost. A major increase of complexity and cost made the use of actual equipment prohibitive, especially when the full costs (including the cost of military personnel to operate and maintain the actual equipment trainers) and life cycle costs became known. The third was effectiveness. Training realism was not being obtained because of the sustained difficulty in replicating situations in operations training and failure modes in maintenance training.

Simulation is now widely accepted in most government and business training environments. The range of simulation runs from computer and interactive video based two-dimensional training systems to full-scale, high-fidelity weapon systems trainers. These simulation systems are used for such diverse training programs as CPR, flight training, soldering, target acquisition, medical diagnosis, and typing. The new generation of training systems promises to include more and more kinds of simulation, training of tasks previously reserved for training with actual equipment and instructor administration. Users are still concerned, however, with the needs for high fidelity hands-on training, the transfer of learning to the job, and the maintenance of the equipment.

FIDELITY SPECIFICATIONS

With the increase in simulator procurements, there was a perceived need to specify the degree of fidelity a training device or training system would require. The concept is that physical fidelity would "guarantee" the ability to conduct hands-on training which could be transferred to actual job performance. Thus, procurement specifications included page after page of detailed measurements, paint colors, shapes, number of wires, and all of the other elements necessary to make the trainers look like the actual equipment. This requirement for physical fidelity still dominates the procurement process. The proportional number of pages and details relating to physical fidelity often dramatically exceeds that of the definition of the training objectives.

The problem with some of these procurements was that the results of training did not meet anticipated goals. Students many times did not perform as well as they had done after training with existing equipment, and at best they only did as well. Since the specified goal was to increase the quality of the training experience, procurers correctly recognized that the problem could be the training system that had been procured. But what to do about it? A group of scientists identified the problem as the inability to measure "transfer-of-training," which has been loosely described as the ability to perform a job on actual equipment with the same degree of competency that had been demonstrated on the training system. A major problem was that the skills learned on the training system could be different than those required on the job. Part of that reason was that the system did not or could not teach the required skills. And one reason identified for the failure of the training system was although it looked like the actual equipment, it did not function like the actual equipment. The problem was not that physical fidelity is undesireable, but rather that it is insufficient.

Thus a new generation of procurement specifications was created. These specifications identified all of the functional requirements. In addition to color, size, shape, etc., response times were identified. Not only response times, but also degrees of movement, interrelationships of multiple indicators, downstream effects, frequency of occurrence, numbers and types of failures, flight paths of target displays, etc., are often specified in detail. To meet these functional specifications, at a reasonable cost, procurers are sometimes willing to accept reduced physical fidelity, with the caveat that the reduction in physical fidelity will lead to a corresponding greater improvement in the system's functional fidelity. The concept is that the training curriculum is usually more concerned with function that with appearance. In some instances, training has shown improvement with the specification of functionality, even when the specification of physical fidelity has been reduced. Functional fidelity may be more important for training than physical fidelity.

Despite these advancements in the specification and procurement of training systems, there are still systems that fail to meet the training goals. When that happens, these training systems are often discarded, either through salvage operations or just by storing them in a closet or other out-of-the-way location. Even when they are continued to be used, the users are not happy with these systems. Because they are unsuccessful in fulfilling their planned training mission, the users will have negative feelings about some combination of training systems in general, the kind of simulation used in the system, the people who procured the training system, and the manufacturer of the training system. In some instances the deficiencies can be traced to the students, the instructors, the training curriculum, or the specifications for the training system, rather than the technology itself or the manufacturer. Yet there are those instances where all indications are that the training system should be successful, and it isn't. This leads to the important question, are there other factors in training system acquisition that are not being considered?

PSYCHOLOGICAL FIDELITY

The reasons for the failure of a training system to train can be complex and interrelated. Students may not have the prerequisite knowledge and experience. The training requirements could have changed subsequent to the acquisition of the training system. Instructors may be improperly trained. Any one or combination of these factors can cause the inability of the training system to provide appropriate training. Failure to look beyond these factors assumes that the methodology of the training system acquisition is correct. But if none of these other factors is the cause of the failure of the system to adequately train, while exhibiting acceptable levels of physical and functional fidelity, then there is a missing ingredient in the acquisition process. AOTBE, the missing ingredient in the acquisition of a training system could be the absence of psychology fidelity.

DEFINITION

Psychological fidelity is defined here as the degree to which the student perceives that the training replicates the environment necessary to perform the task on the job. The degree to which it actually replicates the environment is not the important criterion for psychological fidelity. It is perception that is important. Perception is more important than reality. Psychological fidelity draws upon the previous experiences and knowledges of the students to stimulate their imagination and make them believe that the current environment is realistic. Several important distinctions are relevant.

User Acceptance. Psychological fidelity pertains to the student, not to the instructor. The degree to which the instructor accepts the training system is important, but is a separate issue. In the realm of psychological fidelity it is only the student user's perception which matters. The instructor can facilitate or hinder student acceptance by attitude and example, but the instructor is not the one who needs the training. It is true that instructor acceptance, or rejection, can lead to acceptance or rejection of an otherwise effective training system. In this usage, however, instructor acceptance/rejection is important only in how it affects student acceptance. If the instructor's dislike of a device or system is not transmitted to the student, then it is not a factor.

Previous Experience. The degree to which a student is familiar with the system being trained, or with a reduced fidelity training system, will affect the psychological fidelity of a training system. Students with previous positive experience on a reduced fidelity training device of any type, for any skill, will be more likely to accept the reduced physical and functional fidelity training system. Students who are previously trained and experienced with actual equipment training or the actual equipment itself will be more likely to reject training systems with low physical and/or functional fidelity.

Age and Education. One advantage of youth is that it is uncontaminated by the prejudices and biases of their elders. Younger students are more likely to have experienced computer based training during their public schooling. They are also likely to be more receptive to innovative training concepts. Reduced fidelity has probably been experienced in the classroom, in the video arcade, and on the home computer. To some extent the same is true of the educated, or experienced. The basic corollary is that the greater the amount of previous education or experience, the more receptive to reduced fidelity training. However, this is directly related to the types of education or experience. If the education and experience cause "tunnel vision," then it is a negative effect. This may also be true of some cultural differences, particularly comparing foreign born to US born students. Even within the United States, various cultures may have an effect in one direction or the other.

Type of Training. It is a simple fact that certain kinds of training are more conducive to reduced fidelity training than others. To a large degree it depends on the types of cues that the student requires to perform the task. If spatial relationships, kinesthetic cues, and "touch" are important to job performance, it is difficult to reduce the fidelity of the training system. On the other hand, purely cognitive tasks have long been recognized as permitting reduced fidelity.

RELATIONSHIPS

All three fidelity aspects are related. For the most part, procurers have consistently applied the relationship between physical and functional fidelity over time. In most applications there has been some internal consistency regarding the degree of physical and functional fidelity. Neither is an absolute requirement, as the degree of fidelity should relate to the training needs of the system. This relationship can be altered by the introduction of psychological fidelity. To some degree, the requirement for psychological fidelity should dictate the degree of physical and functional fidelity. Figure 1 provides examples of student training behaviors and how the physical, functional and psychological fidelity concerns can be addressed in each example. Example 5 can be used to further illustrate the point. The physical fidelity concerns are that of the realism of the appearance of the controls, the approximation of the motion to that of a real aircraft, the fidelity of the displays. The target movements, the

Example	Physical	Functional	Psychological
1. Student verifies light illumination	Light is same size, place	Light is same color, timing	Illumination accepted
2. Replace WRA	Weight same	Overt action	Knows to remove/replace
3. Meter adjustment	Read meter and controls	Movement of meter same	Recognize that meter moved
4. Troubleshoot voltage malfunction	All access points active, actual DMM	Values are consistent with action taken	Recognize worth of action taken
5. Land airplane	Feel jar of landing	Visual scene consistent	Believes plane would land

FIGURE 1

movement of the aircraft indicators, the speed of screen update, are all concerns of functional fidelity. The psychological concerns are different. Does the pilot sweat when trying to land an airplane with one engine gone and the other on fire? Is there a queasy feeling when the radar indicators reveal that a possible SAM has been launched against the aircraft? Most pilots will agree that the better simulators give them the same feeling that they get in the actual airplane. This feeling is psychological fidelity. There are flight simulators that give the participant that "feeling in the stomach" and do not even have a motion base. That is an example of psychological fidelity.

For a different but realistic example, take some time and go to Disney World/EPCOT Center. There are several examples of simulations in various attractions and facilities that give you the psychological fidelity with reduced or even minimal physical and functional fidelity. Figure 2 tabulates some of the simulations there, with the reality and psychological perception annotated. If you have been exposed to these or similar experiences, you will have immediate understanding of psychological fidelity. If you have not experienced these phenomena, then you should try visiting some of these exhibits to aid in understanding psychological fidelity, and why partial physical and functional fidelity is often sufficient.

CHARACTERISTICS

The major characteristic of psychological fidelity is that of feeling. To have psychological fidelity the system must "feel" right to the student. This can have different manifestations. It could be ambient sound. There is an inherent difficulty in pretending that you are using a jack-hammer when there is complete silence in the training environment. It could be lighting, or the lack of lighting. If the task is visual identification of aircraft at night, something is wrong when you are looking at a well-lit pictorial display in a room flooded with overhead lights. Sometimes it has nothing to do with physical or functional fidelity, but rather with the training that occurs. It could be the frequency and difficulty of the problems being presented. When a student is engrossed with a fast-moving, difficult problem, there is insufficient time to critique the environment used to present the problems. It could be the syntax and difficulty level of the language used in text or narration. As an example, a text page that tells the student "You got it right!" will be better received than a text page that states "Your performance on this exercise demonstrates mastery of the behavior skill (or intellectual concept) being tested."

A specific example of the lack of psychological fidelity was in a vehicle maintenance training system (which shall not be identified). Each new task for the student was presented as a text or graphic frame. The frame would provide the initial problem identification, sometimes in a narrative format, and at other times as a discrepancy report. The students perceived the training as unrealistic. The reason was that experience had taught them that this should have been an audio presentation. The presentation format could have been sound, or a comic book format, with a graphic of a supervisor and the text inside of a balloon. The standard operating procedure required a discrepancy report, but in practice the supervisor would read the report and verbally provide instructions to the mechanic. When the training failed to provide that fidelity, the students' feelings about the training were tainted, regardless of the remainder of the training.

While some of the characteristics of psychological fidelity will remain unknown for some time, the following characteristics are useful for this discussion:

- Emotional feelings are enhanced
- Students are involved with training, the environment is invisible
- There is no "dead" time during instruction

Example	Reality	Perception
1. Spaceship Earth	Lights	Stars
2. Haunted Mansion	Various Projections	Ghosts Moving, Appearing
3. World of Energy	Simulated Odors	Smell of Fire and Brimstone
4. World of Motion	Lights and Film	Rapid Movement Down Road
5. Canada	Film	Movement of Aircraft
6. Cave - Tom Sawyer's Island	Angles of Floors and Walls	Gravity Changed and Defied
7. Gunfight - Frontierland	Simulated Gunfire and Padding	Cowboys Shot, Falling Off Building
8. Jungle Cruise	Mechanized, Constructed Animals, Recordings	Animals Moving and Making Sounds
9. Hall of Presidents	Life-Sized Animation and Recordings	Walking, Talking Presidents
10. Tinker Bell - Cinderella's Castle	Guidewire and Harness	Tinker Bell Floating in Air

FIGURE 2

- o A sense of competition is evident - students compete against each other or against the system
- o All students are involved in the instruction, regardless of who is doing what, when
- o Distractors such as temperature, noise, odors, etc., normally occur without being recognized
- o The passage of actual time becomes unimportant
- o There is rarely any argument with the results of training

This does not mean to confuse psychological fidelity with the environment of the video arcade. To some extent, the same principles are followed by successful video game designers, but the expectations of the students are different. They go to those machines looking for entertainment, recognition, or success, but not education. A majority of the video games would be unsuccessful as training systems, except for hand/eye coordination. Some, however, provide educational opportunities simultaneously with entertainment. One example is the series of computer games based on the villain "Carmen Sandiego."[2] These games mix graphics, animation and text to provide educational geographic and cultural experiences with entertaining problem solving. The key elements to these low physical and functional fidelity programs are the high psychological involvement (fidelity?) of the users.

PROCESS

Training system design and acquisition must be based on the training objectives, which are themselves based on the task and training analyses (TASA) that should precede any acquisition. With the current acquisition process, specifications frequently dictate detailed requirements for the functional and physical fidelity of a system, without revealing the instructional requirements. The process needs to be based on the instructional analyses, so that the design is a natural derivative of the analyses, not a separate and distinct activity. Figure 3 illustrates where the design effort belongs in the training system process. While not specifically identified, note that acquisition can occur at any place in the process, and that all steps in the process must be completed regardless of who accomplishes them. "Experience" and intuition are no substitute for an analysis performed by trained professionals.

During the analysis phase, there are certain kinds of questions that must be answered. These are attitudinal questions, usually ignored. They would include ones such as the feeling:

- o What environmental factors, if any, are necessary to provide a realistic training environment? These could include sound, temperature, lighting, etc.
- o Are there special "feelings" that the student needs to be aware of during either training or on-th-job that can affect performance?
- o What is the first thing that you think of when you think of _____? The blank is filled in with the name of the task, skill, or system to be trained.
- o All sorts of "HOW" questions, such as "How do you know when you are in the right area?" or "How do you feel when you are near the _____?" The same blanking rules apply.
- o Other "WHAT" questions, such as "What is the most important thing about _____?"
- o Any questions that begin with a "WHY" are usually helpful, especially if you can obtain the answers.
- o Other questions that allow you insight to the subjective part of training.

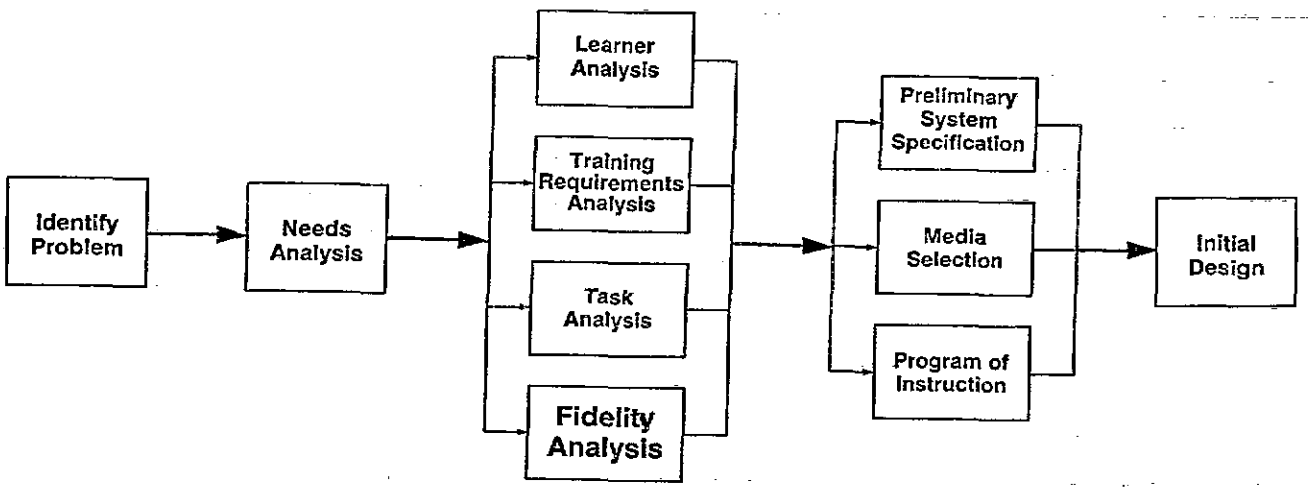

FIGURE 3

While this kind of information can be derived during the task analysis, and used during the fidelity analysis, it is often not used even when obtained. Quite simply, this information is frequently omitted from the documentation. There is a need to ensure complete and retained documentation of this information so that it does not get "lost" during the process.

METHODOLOGY

The critical step in the acquisition process is to ensure that the entire process illustrated in Figure 3 is followed. Omission of any single step can jeopordize the results. Specifications must then be developed that ensure that psychological fidelity is included. A major requirement is to put more emphasis in the specification on the desired training outcomes, and less on the physical and functional fidelities to build a pseudo-replication of the actual equipment. The point is that it is the training that should be the deliverable, not the fidelity of the hardware.

The following is a short checklist, more of a guideline, that can be followed.

1. Incorporate requirements for psychological fidelity in the front end analysis (FEA).
   - o Include attitudinal studies.
   - o Use observational techniques to determine what students attend to during training and during actual performance of their duties.
2. Ensure fidelity analysis incorporates data collected.
3. Provide a means for resolving differences in requirements for the different fidelity dimensions.
4. Include psychological fidelity requirements in media analysis and tradeoff studies.
5. Include instructors and other key personnel from target installation(s) in creating specification for the system.
6. Develop specification around training objectives, not the physical and functional description of the hardware.
7. Verify specification meets original training requirements.
8. If possible, make paper tryout of system and use target tasks for validation.
9. Ensure specification is understandable to all potential builders.
10. Reward creativity and results, not ability to mimic hardware design parameters.
11. Provide subject matter expertise and guidance during all phases of the acquisition of the system.
12. Use formative evaluation during design and acquisition to ensure that the project is proceeding as intended. This is insurance policy that can pay big dividends.
13. Report the results, for all stages, so that others can learn from the experience

This checklist is intended as a summary. More detailed checklists should be developed by each agency/user. The primary value of this checklist is as a reminder, for procurers and designers, to think about the psychological requirements in the fidelity of a training system. A mature methodology will continue to be developed over time, as the benefits of psychological fidelity are determined over time, and government and industry become more attuned to the incorporation of the concept.

CONCLUSION

There needs to be a new methodology of determining fidelity to meet the new generation of students, those who can look at a video terminal and immediately recognize symbology, because they are attuned to the fact that the symbol is the object.

This paper has presented the concept of psychological fidelity, tracing the evolution of fidelity concerns to the definition of the phenomenon of psychological fidelity. The paper discussed the relationship of psychological fidelity to physical and functional fidelity as a precursor to the specification of a methodology for incorporating psychological requirements in the process of designing and specifying fidelity for training systems acquisitions.

Much discussion, analysis and experimentation will be required to further define and implement the aspects of psychological fidelity. It is premature to suggest that this introductory discussion of the phenomenon provides definitive resolution to the problem. Rather, a body of literature must evolve that further defines, implements and reports both successes and failures in the application of psychological fidelity in training systems. When a sufficiently diverse and redundant base of knowledge has been presented, more universal truths will be identified that will permit broader and more exact use of psychological fidelity in training system design and procurement.

NOTES

[1] *Disney World/EPCOT Center and the various* attractions identified in Figure 2 are all trademarks of the Disney Corporation and/or its subsidiaries.

[2] BrØderbund of San Rafael, CA, has three disks currently in the series: Where in the World is Carmen Sandiego, Where in the USA is Carmen Sandiego, and Where in Europe is Carmen Sandiego.

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