A MECHANISM FOR COMMUNICATING SIMULATOR INSTRUCTIONAL FEATURE REQUIREMENTS

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BACKGROUND

The history of flight simulation has been characterized by almost constant advances in the capabilities and complexity of flight training devices. Most of these advances have involved increased fidelity of simulation. That is, simulator design has emphasized physical correspondence between the device and the aircraft simulated and between the simulated and aircraft (real) environments. As a result, flight simulators increasingly look, feel, sound and perform like aircraft.

The emphasis upon fidelity in simulator design has resulted in devices that are costly to procure and operate. In spite of such costs, however, fidelity in flight simulators is widely acclaimed as useful and, in many cases, even essential to effective training. Because of the cost of high fidelity devices, the development of simulator designs that permit more efficient training is a necessary goal.

A simulator designed to permit efficient training is one whose instructional and other features permit instructional activities to be conducted with a relative minimum of time and effort. Several recent efforts to develop more efficient simulators have sought to achieve greater efficiency by eliminating the instructor from portions of the instructional process through development of instructional features that permit automatic training and performance measurement (e.g., Brown, Waag and Eddowes, 1975; Semple, Vreuls, Cotton, Durfee, Hooks, and Butler, 1979). Others have concentrated on developing new measures of performance (Walsh, Burgin, and Fogel, 1979) or on manipulation of the task cues present during simulator training (Hughes, Paulsen, and Brooks, 1978). A few studies have examined the role of the instructor in non-automatic simulator training and the manner in which the simulator's instructional features facilitate or hinder that role. These latter studies have concentrated upon simulator instructor/operator stations (IOS)--the locus of control of most instructional features--and the extent to which IOS design impacts instructional efficiency.

In one study of IOS designs, Charles, Willard and Healy (1976) observed that some of the newer flight simulators are less efficiently designed than older ones. They noted that earlier designs, while not based on systematically derived training requirements, were sufficiently constrained by display and control technology to result in a meaningful and relatively efficient IOS arrangement for the instructor.

SUMMARY

Although current generation simulators incorporate a number of presumably useful instructional features, several researchers have noted that the designs of these features often make them awkward and inefficient to use. It appears that these features were designed without sufficient information about how they were intended to be used during training. An examination of the simulator design and development process indicates an absence of a convenient mechanism for providing this information to simulator designers. The project described here was undertaken to develop such a mechanism.

Descriptions were developed of simulator instructional activities associated with instructional features found on current generation flight simulators. The purpose of these descriptions, or Simulator Instructional Feature Design Guides, was to facilitate communications between simulator users and designers by documenting information about the intended use of simulator instructional features. Guides of this type provide the simulator designer with the kinds of information required to evaluate the utility and efficiency of instructional feature design alternatives. By using such guides the designer may effectively simulate the training process as a part of his design efforts.

The content of the guides is based on observation of simulator instructional activities and reviews of training requirements and practices associated with a fighter/attack type aircraft. The 12 design guides developed during the project were reviewed by personnel involved in all phases of the design, development, and training uses of flight simulators. It was their consensus that the guides would be useful in future simulator projects as a mechanism for clarifying simulator design requirements, communicating between training and design personnel, highlighting design shortfalls, and clarifying simulator testing requirements. In addition, the guides have been used, in modified form, to clarify requirements for the design of a simulator for a tank and to facilitate communication of design information between that device's eventual user and the device developer. The guides are currently being used in conjunction with the development of simulators for a utility-type jet airplane and a helicopter. Experience gained with the guides on these projects will provide further information concerning their utility during the simulator design process.

Two of the design guides developed during the project are presented.

Today, by contrast, advanced control and display technology has been exploited seemingly to cover all possible contingencies rather than to permit conduct of necessary instructional activities in an efficient manner. Charles, et al, concluded that "Efficient training console design can be accomplished, but only if display and control designs are based on information and action requirements . . .. Thus, the role of the [simulator instructor/operator] must be defined in detail and the operational concept developed" (pg 76).

Inefficiencies in IOS design were also noted by Isley and Miller (1976) during an examination of both military and commercial flight simulators. They reported that modern simulators incorporate a large number of presumably useful instructional features, but that many of these features were not being used in the conduct of simulator training. Two reasons were given to account for this situation: (1) the designs of simulator instructional features were inefficient, and use of the features often proved time consuming and awkward; and (2) the features themselves were in some cases inappropriate to the training being conducted in the devices. Isley and Miller noted that the designs of the simulators they examined appeared to have been developed in the absence of information about an operational concept of the training to be provided or about the intended role of the instructor. That is, the kind of information needed for design of an efficient IOS (as identified by Charles, et al) probably was not available to the designers of the simulators Isley and Miller examined.

Review of the process in which simulators are designed, especially U.S. military flight simulators, confirms the general absence of such information. Simulator specifications and other design and procurement documents seldom address operational training concepts or instructor roles. By contrast, information about the aircraft to be simulated and its operational environment is addressed in these documents and serves as guides for simulator design. Usually, training objectives documents provide further design guidance to assure that the required skills and knowledges can be developed in the planned simulator. But, there is no guide to aid the designer in assuring that the operations necessary for efficient training in the planned simulator can be conducted. While instructional features may be specified in the design documents, the manner in which they are expected to be employed by the users of the simulator simply is not made known to the device designer.

Isley and Miller did note, however, that there are simulators in which some of the instructional features were efficiently designed in spite of the absence of information about the manner of their intended use. Such features were used during training with these simulators and were judged to increase the efficiency of training in the devices. After further study by the present authors of several of the simulators examined by Isley and Miller, it was concluded that the relatively efficient design of instructional features probably was achieved in part by "simulating" representative training activities, using a mock-up of the simulator's IOS and trainee station, and modifying the mock-up as required to permit training activities to be conducted efficiently. Unfortunately, those efforts tended to be unsystematic and incomplete because of the limited time during which the mock-up was available to personnel familiar with simulator usage. Further, these efforts usually occurred only after most of the design decisions were made, and only questions related to control-display arrangements remained to be answered.

Thus, it would appear that information about the intended use to be made of a simulator's instructional features, if available during the design process, can be used to design a more efficient simulator. The needed information must convey to the designer the prospective simulator user's concepts of how the device's various instructional features are to be employed during simulator instruction. The problem, then, is to assemble the needed information and to make it available to the designer early in the simulator design process. A *convenient mechanism* for resolving this problem does not appear to be available at the present time.

PURPOSE

The present paper describes a project in which a solution to the problem identified above was sought. In the project, descriptions were developed of simulator instructional activities associated with a number of instructional features found on current generation flight simulators. The purpose of these descriptions is to document information about the intended use of simulator instructional features for use by simulator designers. Thus, it was intended that design guides would be developed that would provide the mechanism needed to facilitate communication between simulator users and designers and would lead to the development of more efficient simulators.

APPROACH

It might seem desirable to develop a single design guide for each instructional feature. Such guides then could be used in the design of all future simulators. However, such an effort would be comparable to that of seeking a single aircraft, environment, or training objectives model that could be employed in the design of all future simulators. Instead, it was assumed that, while some of the guides would be suitable for a wide range of simulators, others would have to address instructional features and activities that might be specific to major types of simulators. The principal factors of concern that distinguish types of simulators and that could influence instructional feature design are the crew configuration of the aircraft simulated (e.g., single vs multiple-crew positions), the aircraft mission (e.g., transport or attack), the kinds of training intended (e.g., instrument flight, full mission, or procedures), and simulator configuration (e.g., IOS adjacent to or remote from the cockpit, with or without an extra-cockpit visual display).

It was decided to develop the guides for the instructional features of a specific simulator currently under development. This approach would provide a context within which to consider instructional activity alternatives and would afford access to simulator design personnel should their advice be required. At the time the project was initiated, the development of a simulator for the F-16 aircraft was underway. The F-16 is a single crewman, fighter/attack aircraft. The simulator has a one-window visual display and a remote IOS, and it was designed for instrument, *intercept, weapons, and limited transition training.* Similar simulators will be required for other fighter/attack type aircraft in the future, thus offering the possibility of using and evaluating the instructional feature design guides during the subsequent development of such devices. Therefore, it was decided that the guides would be oriented toward instructional features suitable for a device such as the F-16 simulator then under development.

It was also decided, however, that the guides would not be limited to the proposed design features of the F-16 simulator or of any other existing or planned device. Further, to avoid interference with the F-16 simulator project, there was no attempt to employ the guides being developed to influence the design of the F-16 device. Thus, except for observation of selected F-16 simulator design activities during scheduled Progress Review Conferences and discussions with F-16 simulator project personnel, the present effort proceeded independently of the project in which the F-16 device was being developed.

In preparation for the development of the guides, a number of simulators of recent vintage were inspected, and instructional activities in progress were observed. The purpose of these observations was to take note of both efficiencies and inefficiencies in simulator designs and to determine the apparent rationale underlying the design of the instructional features of these devices. In addition, current fighter/attack training practices in both aircraft and simulators were reviewed so that consideration could be given to the instructional activities involved in such practices during subsequent guide development.

Another factor considered was the learner himself, i.e., the pilot undergoing instruction. The issue was addressed as to whether there were characteristics of pilots, in this case, candidate F-16 pilots, that might require special consideration in instructional feature design. A search of the psychological literature was included in the project to determine whether individual learner characteristics might have implications for design and use of simulator instructional features.

Next, a list was developed of the simulator instructional features for which design guides would be developed. Not all instructional features of the F-16 simulator were included on the list. The list was limited to those features judged to have maximum potential application to other types of simulators as well as to the F-16 device. In addition, instructional features were selected for design guide development that were representative, with respect to function of other instructional features, and thus could serve as examples for the development of guides for such similar features. Several instructional features identified in the F-16 simulator were combined and described in a single instructional feature design guide, because it was judged that they were not likely to be employed independently during the process of simulator instruction, e.g., instructional features involving the recording and on-line playback of both digital and audio data, were treated as a single instructional feature for the purpose of the *present project.*

Finally, a design guide format was developed. The format was designed to communicate process-of-use information to engineering and other simulator design personnel with little or no knowledge of how training in a simulator is conducted or how instructional features might be employed during that training. The guide format was developed through an iterative process that continued until a format evolved that permitted presentation, both verbally and diagrammatically, of information judged to be needed in order to design an instructional feature with which efficient training could be conducted.

LEARNER CHARACTERISTICS AND SIMULATOR INSTRUCTION

Characteristics of the F-16 pilot candidate population have been investigated by Gibbons, Thompson, Schmid, and Rolnick (1977). These investigators concentrated largely upon demographic data and identified no unique characteristics of that population that were judged to require special consideration in the design or use of simulator instructional features. However, they did note that a wide range of skills will be represented. F-16 pilots will include newly rated pilots as well as highly experienced combat veterans. Such a range suggests that the training to be conducted in simulators such as the F-16 device currently under development will include the acquisition of new skills as well as the refinement of already highly developed ones.

The survey of the psychological literature dealing with learner characteristics examined in particular stylistic cognitive variables that are beginning to be recognized as important in the learning process. While further investigation is needed to clarify the possible impact of stylistic cognitive variables, the concepts underlying these variables place an emphasis on the individual learner rather than on the learning process itself. This emphasis upon the learner *suggests a need to examine stylistic cognitive* characteristics of pilots to determine whether such characteristics have implications for the way simulator instructional features should be designed or used.

The investigation of the F-16 pilot candidate population conducted by Gibbons, et al, did not consider stylistic cognitive variables, and the distribution of such variables within any pilot population is not known. However, ten stylistic cognitive variables have recently been identified as potentially important in technical training (Regan, Back, Stansell, Ausborn, Ausborn, Butler, Huckabay, and Burkett, 1978), and several of these would appear to have implications for pilot training as well. One variable in particular, field independence-dependence, appears relevant to instructional activities in a simulator.

The literature suggests that the field independent individual would likely benefit more than the field dependent individual from simulator training which he was largely able to control himself. His success as a learner in a flight simulator would not depend upon an instructor for performance feedback, reinforcement, or direction. Field dependent individuals, on the other hand, would likely be more dependent upon instructor-mediated feedback, reinforcement, and direction during training. In the absence of information to the contrary, it may be assumed that both field independent and field dependent individuals will be found in most pilot groups, including fighter/attack aircraft pilot populations. Therefore, the design of simulator instructional features should accommodate *both field independent* and field dependent pilots.

From the report by Gibbons, et al, and the survey of the learning literature, several requirements were derived for the planned design guides. First, the instructional feature must accommodate relatively unskilled pilots who are unfamiliar with the tasks to be trained and may need extensive coaching, demonstration, and criterion-referenced feedback concerning their performance. However, these features must also accommodate the relatively skilled pilots who will require little coaching and no demonstration, but much more detailed feedback so that they can hone skills that are already highly developed. Additionally, the instructional features should permit field independent pilots a degree of self-instruction and freedom to evaluate their own performance and to pursue their own perceived needs for further skill development. However, instruction under the direct and structured control of an instructor should also be permitted for the field dependent pilots.

INSTRUCTIONAL FEATURES

Design guides were developed for 12 simulator instructional features. *These design guides* took into account the learner characteristics identified above. In order to achieve the instructional flexibility required by these characteristics, some of the guides described instructional features that include control and display functions exercisable from the cockpit as well as from the IOS. However, these cockpit functions were limited in order to maintain the degree of fidelity of the cockpit area believed necessary to effective training. All of the guides describe instructional features that can be employed by the simulator instructor to perform coaching, demonstration, feedback, and other instructional functions for relatively unskilled pilots and to conduct highly structured instruction for field dependent pilots. Some of these same instructional features also accommodate the instructional requirements of the relatively skilled pilots and permit pilots to control much of their own instruction, freeing them from dependence on a simulator instructor.

The 12 instructional features for which design guides were developed are identified below, along with a brief description of each.

Record/Playback. Permits the replay of a recent or immediately preceding segment of recorded flight.

Store/Reset Current Conditions. Permits the simulator to be reset by the pilot or the instructor to a situation or set of simulated conditions that existed at an earlier time. It provides a means for rapidly returning to previously encountered events of interest or for repositioning the simulated aircraft for repeated trials of a particular maneuver or maneuver segment.

Remote Display. Permits alphanumeric and graphic data displayed at the IOS to be displayed simultaneously to the pilot in the cockpit. It permits the pilot to review his own performance data and facilitates communication between the instructor and the pilot, particularly when the communication involves reference to graphic or symbolic information.

Hardcopy. Enables the instructor to reproduce on paper perishable information displayed on a CRT at the IOS.

Manual Freeze. Enables the instructor or the pilot to freeze or suspend ongoing simulated activity resulting from actual or recorded input to the aircraft's controls.

Automatic Freeze. Similar to Manual Freeze except that it is initiated automatically, contingent upon specified events (e.g., a crash).

Parameter Freeze. Enables the instructor to freeze one or more of the simulated flight parameters.

Demonstration. Consists of one or more prerecorded aircraft maneuvers to be used as models of the desired performance.

Demonstration Preparation. Enables a simulator instructor to prepare a Demonstration for repeated use during subsequent periods of pilot training. It is a necessary feature if the Demonstration feature is to be incorporated into simulator design.

Malfunction Simulation. Enables an instructor to fail, partially or totally, a simulated aircraft component.

Automatic Malfunction Insertion Exercise. Consists of a training exercise in which simulated aircraft malfunctions are inserted automatically when previously specified conditions have been met. This feature is representative of a class of automatic training exercises in which a training situation is programmed to occur or is modified contingent upon the occurrence of one or more prior events. The feature design guide itself may serve as a model for the description of other features in which contingent relationships may be established, e.g., target insertion, hostile weapons release, weather modifications, and/or communications/navigation station failures.

Automatic Malfunction Insertion Exercise Preparation. Enables a simulator instructor to prepare an Automatic Malfunction Insertion Exercise for repeated use during subsequent periods of instruction. As with the Automatic Malfunction Insertion Exercise feature, this feature design guide also can serve as a model for other features having similar functional requirements.

FORMAT OF THE DESIGN GUIDES

A six-element format was developed for the instructional feature design guides. Each element is described below.

Feature. Identifies the simulator instructional feature for which the guide was prepared.

Definition. Defines the instructional feature. The intent of the definition is to assure a common understanding of what is meant when a particular feature name is used.

Purpose and Intended Use. Describes the purpose served by the feature in a simulator and the manner in which it is intended to be used by the instructor and/or the pilot during the conduct of simulator training.

Function Description. Describes each function involved in the employment of the instructional feature from its initial accession to completion of its use. While the Function Description is somewhat redundant with Purpose and Intended Use, this guide element isolates and defines more precisely each function associated with use of the feature and specifys relationships among functions.

Concurrent Events. Specifies intended restrictions on feature use, if any, and identifies other simulator instructional features that may be employed concurrently.

Feature Diagram. Diagrams the functions involved in the use of the feature. Each item on the diagram corresponds to a function identified under the Function Description element. The format for the diagram is a flow chart in which each function is presented in the sequence in which it might be performed, and in which each decision required in the use of the feature is represented in binary form.

As an example of the design guides developed during the project, the guides developed for Demonstration and Demonstration Preparation instructional features are presented following the references.

INITIAL DESIGN GUIDE VALIDATION EFFORTS

The purpose of the guides developed during this project is to provide information about how flight simulator instructional features are intended to be used so that such information can be incorporated into simulator design. The extent to which this purpose has been met and will result in the design of more efficient simulators can only be determined after the guides have been used in the design of simulators, and the efficiency of those simulators has been determined during operational training activities. Such an effort will take several years to accomplish. In the meantime, there are more immediate uses to be made of the guides.

Uses to be made of the guides will depend upon the requirements of those who are using them. In most simulator development projects, these uses could include the following:

- Clarifying design requirements. The guides can be reviewed by training personnel for whom the simulator is to be developed to insure that instructional activities and simulator usage are correctly stated. If not, the guides may be revised by these personnel to fit their unique training requirements. Such reviews and revisions should result in clarification of the expectations as well as the requirements of the eventual simulator users.

- *Communicating between training and design* personnel. The guides provide a convenient mechanism for communicating to the designer the simulator capabilities required by training personnel. The guides might best serve this purpose if they are referenced in simulator performance specifications as an amplification or clarification of requirements for particular instructional features.

- *Highlighting simulator design shortfalls.* In some instances, the design expectations of training personnel may not be attainable due to cost or technology limitations. In such instances, the simulator designer or developer would be able to identify instructional feature functions specified in the guides that cannot be provided. Training personnel could then assess the impact of such shortfalls and seek alternate instructional activities for use with the device.

- Clarifying simulator testing requirements. The guides can provide a basis for the design of simulator acceptance or operational tests to determine the adequacy of each instructional feature incorporated into the device. The tests could examine individually and in an applications context each function of each feature, and the extent to which use of each feature is compatible with other features that must be used concurrently.

As an initial indication of whether the guides could be used for any of the purposes indicated above, they were reviewed by personnel involved in the F-16 simulator development project. The reviewers included a former member of the F-16 Instructional Systems Development (ISD) team, who participated in the specification of instructional feature requirements for the simulator and represented the interests of the ISD team in those activities; an F-16 Project Officer from the U.S. Air Force Tactical Air Warfare Center, who represented the interests of the training personnel who eventually will use the simulator; and personnel from the project engineering staff of the developer of the simulator. These reviews were constrained by the fact that the F-16 simulator was already in the manufacturing process and did not incorporate all of the functions described in the guides.

The reviewers were asked to judge whether the guides would have been useful had they been employed early in the F-16 simulator project to clarify the requirements of training personnel, to communicate those requirements to the device designer, and to identify design shortfalls. The expressed judgments of the reviewers were positive, and suggestions were made by the reviewers that resulted in clarification of several feature descriptions. The reviewers were not asked to judge the utility of the guides during future testing of the F-16 simulator, since the device was not designed to comply with the descriptions contained in the guides.

CONTINUING DESIGN GUIDE VALIDATION EFFORTS

Although the guides were prepared specifically for use in the design of a fighter/attack simulator, their utility with respect to other types of simulators is also of interest. The utility of the guides will be partly a function of how easily they may be adapted to other particular efforts. To date, the guides have been used in several simulator design efforts. One of these was the project to develop a simulator for the Army's XM-1 tank. The simulator was intended for training-related research use, rather than for operational training. Several of the guides that describe instructional features relevant to the tank simulator requirements were reviewed with the researchers for whom that device was being developed. The purpose of those reviews was to assess the utility of the guides as a mechanism that would facilitate communication between the researchers and the device developer with respect to the researchers' planned uses of the device, and that would clarify for those researchers' which functions described in the guides could and could not be performed in the simulator as designed. Both uses of the guides appeared to have merit, and modifications to the device's design were initiated as a result of the reviews.

Two additional simulator development projects in which the utility of instructional feature design guides are being assessed have been initiated. Both projects involve flight simulators for the U.S. Coast Guard: one is for the HU-25A twin-engine jet aircraft, and the other is for the HH-65 short range recovery helicopter. The guides developed during the present project which describe instructional features that are to be included in the Coast Guard simulators will be used during the design of those simulators. These guides were modified where necessary to reflect the multi-crew configuration of each aircraft and the configuration of each of the simulators, and to comply with the instructional activities expected to be employed by Coast Guard training personnel. The guides were reviewed by personnel from the Coast Guard's Aviation Training Center to assure that they were consistent with the training requirements of these personnel and with the manner in which they plan to employ the simulators during training. After further revision, the guides were annexed to the simulators' specifications to provide amplification and clarification of instructional feature design requirements identified in the specifications.

In responding to solicitations for the development of the two Coast Guard simulators, each offeror will be requested to indicate any requirements identified in the guides that cannot be met through his proposed design approach. Design shortfalls thus identified will be subjects for clarification conferences with the offerors and with Coast Guard training personnel. The purpose of these conferences, which may result in further revision of the guides or modifications to the proposed design approaches, will be to seek simulator instructional feature design alternatives that will allow the required instructional activities to be conducted in an effective manner. Subsequent simulator acceptance testing activities related to the simulators' instructional features will examine whether each of the functions described in the design guides can be performed under the conditions prescribed for it. The above activities will provide additional information about the utility of the guides.

CONCLUSION

The purpose of a flight training simulator is to permit required instructional activities to take place. The purpose is not for the device to simulate an aircraft, except to the extent that simulation of an aircraft is relevant to the intended instruction. It is inconceivable that one would expect a designer to design a flight training simulator without giving him a great deal of information about the intended instructional activities. Yet, it is apparent from inspection of numerous existing simulators, from review of simulator design procedures, and from review of the relevant literature that designers typically are given very little information about the instructional activities intended to be used with the device they are to design and the functional purposes of those activities.

This situation is believed to be in part a consequence of the lack of a convenient mechanism for assembling relevant information and conveying it to the designer. The purpose of the present project has been to develop such a mechanism. The mechanism developed is a description of the instructional activities to be undertaken in the use of a simulator instructional feature. It is believed that such descriptions can be used as guides to clarify simulator design requirements, to communicate those requirements to device designers, to highlight design shortfalls due to cost and technological limitations, and to clarify simulator testing requirements.

Twelve design guides for instructional features suitable for a particular type of simulator were developed during the present project. The features were selected in part because of their assumed adaptability to other types of simulators or because they were representative of a type of feature of potentially wide interest. To date, several such adaptations have been made with relative ease. Users of these guides must be prepared to make the necessary adaptations to their particular requirements and/or to prepare design guides for other instructional features where such may be desired for their simulator.

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