ENABLING FEATURES VERSUS INSTRUCTIONAL FEATURES IN FLYING TRAINING SIMULATION

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In recent years, economic and resource constraints have forced members of the training community to actively seek more cost - effective approaches to routine training needs (Diehl and Ryan, 1977; Vandal, 1977; McEnery and Lloyd, 1977; Provenmire, Russel, and Schmidt, 1977). Within the Air Force, these constraints have resulted in efforts to reduce the overall number of flying hours (i.e., hours used for training in actual aircraft) by 25 percent by the early 1980's (Flight Simulators, 1976). In order to accomplish this goal, the Air Force is moving rapidly into the area of simulation in flying training (Dunlap and Worthey, 1975). While the use of simulation is not new to the Air Force (Valverde, 1968; Smode, 1974; Rivers and VanArsdall, 1977), use of simulation on such a broad scale as that directed by Congress is.

Within the area of flying training simulation, the concern has been expressed (Caro, 1977ab) over the extent to which instructional methods based upon traditional "in-flight" models provide the most effective set of techniques and procedures for conducting training in simulators. Such models, while obviously valid for teaching persons to fly, fail to capitalize upon the unique capabilities of simulators to free the instructional process of constraints imposed by the use of operational aircraft as training devices. Inasmuch as in-flight instructional models promote the continued use of simulators as surrogate aircraft, an upper limit on the effectiveness of simulators is set by the limitations of actual aircraft as training devices.

Bridging the gap between continuation of the traditional in-flight model of flying training instruction and a simulator-based model are those aspects of a simulator referred to as "advanced training features." It is not the primary purpose of this paper to review the present scope of advanced training features available for the conduct of flying training. Descriptions of training features believed to be representative of those likely to be found on early- to mid-1980 generation flight simulators have been described elsewhere (Faconti, Mortimer, and Simpson, 1970; Faconti, and Epps, 1975; Isley and Miller, 1976; Knoop, 1973, Smith and Simpson, 1972). Neither is it the intent to propose an instructional model for the most effective utilization of such features. The latter effort is currently being addressed by the Air Force Human Resources Laboratory under Project STRES (Simulator Training Requirements and Effectiveness Study).

Instead, the primary purpose is to present a conceptual framework for organizing and giving direction to research and development in the area of advanced training features. . . a framework that hopefully will not only bring structure to what is currently a poorly defined area, but that will also promote further instructional research into utilizing the "active" instructional capabilities of the modern day flight simulator.

Training Features: A Conceptual Framework

It is suggested that the unique training features of flight simulators might best be characterized as consisting of (1) enabling features, and (2) instructional features. One possible scheme for treating the differences between these two types of features is given below. It is hoped that the framework to be presented here will contribute to distinctions among training features in a manner that will also aid in clarifying those dimensions along which the effectiveness and suitability of such features can best be evaluated. While the chief concern here is with flight simulators, the distinctions to be made need not be restricted to this type of simulation device alone.

I. Enabling Features. Enabling features arrange for the occurrence of physical events and conditions that are necessary to support training but not for the manipulation of these events instructionally. Their training effectiveness lies in their ability to create the conditions under which training may occur, not in their direct effect upon pilot performance. Enabling features are typically the "given" part of the familiar three part behavioral objective. To the extent that enabling features can be separated from their particular application, the relevant dimensions along which their effectiveness should be evaluated are fidelity, ease of user operation, domain of task conditions simulated, etc.

Class 1: Environmental Conditions. Environmental conditions consist of simulated elements of the natural or man-made environment and/or their effects upon the aircraft being simulated. (e.g., maneuver and disturbance motion cues; visual sky/horizon/earth scene; sun image; G seat/G suit, grayout/blackout, target performance, size, and display, gaming area, electronic warfare and communications jamming, runway conditions, visibility/ceiling; day/night; other aircraft as in refueling, air-to-air combat maneuvers, or formation flight, tactical conditions and targets, cultural features, moving objects such as truck convoys, tanks, boats etc, and multiple objects such as offensive weapons, SAMs, antiaircraft artillery, or opposing aircraft launching a missile.

Class 2: Aircraft Conditions. Those features which relate directly to the physical operating status of the aircraft (e.g, fuel supply, center of gravity, engine status; malfunctions, etc.). Such features may also permit manipulation of the performance characteristics of opponent aircraft (e.g., varying the percentage of optimal performance of the opponent). In instances such as the latter, an enabling feature may be used instructionally for placing the student at a desired advantage or disadvantage.

II. Instructional Features. Instructional features consist of those provisions (available either through software manipulation or actual hardware component) by which the operator is able to manipulate enabling conditions in order to bring about desired changes in pilot performance. Evaluations of the effectiveness of instructional features are difficult, if not impossible, to make independently of the manner in which they are applied. Depending upon the intended function of the instructional feature, its effectiveness may be measured either in terms of instructor/operator performance or in terms of student performance directly. It is, however, the "effect" produced by use of an instructional feature that is of primary concern. Since instructional features do not represent "things" in any real sense, fidelity is not a relevant dimension for their evaluation.

Class 1: Passive Instructional Features. Those instructional features for which there is little or no direct contact with the student. Passive instructional features would include CRT and graphic displays used by the instructor, physical layout and actual utilization of console hardware, performance measurement in nonadaptive systems, procedural monitoring capabilities, etc. In general, the passive instructional features assist the instructor in performing monitoring and evaluation functions. To the extent that an instructor or operator must interact with information presented by such features, human factors criteria are appropriate both as a part of their design and their evaluation. To the extent that some designs may be more efficient than others, objective criteria based upon actual instructor performance in representative training settings are required. Evaluation methodologies such as those utilizing benchmark instructor/operator tasks for the evaluation of alternative display formats represent one alternative for further development as well as operational test and evaluation. The point to be made is that while such features are used instructionally, the primary effect is one measured in terms of instructor rather than student performance.

Class 2: Active Instructional Features. Those instructional features for which there is direct student contact with the feature. It is suggested that these features may be further subdivided into the following classes:

Subclass A: Those features which substitute for functions provided by the instructor in real-time and which may only indirectly contribute to more efficient training (e.g., recorded preflight briefings and flight demonstrations).

Subclass B: Those features that contribute to more efficient training by eliminating or reducing "dead" time (e.g., use of freeze and preprogrammed initial condition sets).

Subclass C: Those features which allow the instructor to augment the physical cues available to the student (e.g., visual, auditory, and/or kinesthetic cues not normally present in the pilot's "natural environment," auditory/visual performance alerts, etc), or to use instructional methods not available in the aircraft (e.g., performance record and replay).

Subclass D: Those features that enable the instructor to "restructure" the basic characteristics of the task or the way in which the task is performed (e.g., control of task "tempo," ground position freeze, axis (parameter) lock, etc.).

The Application of Instructional Features

While elements of the first two classes of "active" instructional features contribute to more efficient flying training (principally through making available more practice time per session), neither represents a true departure from the basic elements of the traditional in-flight model of instruction. The demonstration, for example, is most often used only in its most rudimentary form, that is, as a canned, prerecorded version of an in-flight type demonstration. Rarely is the demonstration capability used jointly with other features to create an instructional capability beyond that which is possible under normal in-flight conditions. While significant research problems still remain in these areas (for example, determining the most effective manner in which to manipulate the content and placement of the recorded demonstration), innovative applications of simulation to flying training reside in manipulation of Class C and Class D type instructional features.

An Example:

Consider, for example, the following application of advanced training features to the training of an air-to-surface weapons delivery task. As in many complex psychomotor tasks, the ability to diagnose ones own errors represents one of the difficult aspects of the task. In the air-to-surface task, one of the most difficult aspects to convey to the naive student is the notion of "compensating errors." While the "school solution" involves the student's being able to configure the plane so that certain release parameters are met, more often times than not the student hits the target because deviations in one parameter are compensated for by deviations in a second and/or third parameter. Under present methods of instruction, the manner in which these errors compensate is learned only through repetition of the task either in the aircraft or in the simulator. The conceptual aspect of this complex psychomotor task might better be taught through the integrated use of a number of the advanced training features.

Consider first the use of a preprogrammed initial condition set that when executed places the student at the correct release altitude, dive angle, airspeed, etc. Consider now the additional use of a bomb impact predictor cue (Hughes, Paulsen, Brooks, and Jones, 1978; Cyrus, Templeton, and McHugh (in press) that provides a continous and immediate depiction on the ground of where the bomb will impact. Finally, consider the use of the parameter freeze or axis lock feature to hold constant the student's airspeed, heading, and altitude, leaving dive angle free to vary. By employing the simulator now in a ground position freeze mode and giving the student control over the stick and rudder, the student can experiment with the effects of dive angle, for example, independently of other parameters and, thorough use of the predictor, see the results of these manipulations immediately on the ground without the normal delay associated with the flight time of the bomb. By freezing other parameters in a similar manner, the student is able to see directly how corrections in one parameter are able to compensate for deviations from ideal in another parameter. One might consider using such an exercise as part of an initial demonstration in addition to the traditional demonstration where the student sits back and passively watches a "canned" performance of the task.

Once the student begins performing the task, the instructor might consider the use of other features. For example, the feedback delay inherent in the bombing task imparts a significant delay between the actions of the pilot at the release point and the feedback for these actions obtained when he looks back to observe the point of impact of the bomb. Learning theory would suggest that such a delay degrades learning. The delay might be eliminated in one of two ways. In one way, the system might be frozen at the moment the pilot releases the bomb and the impact point immediately illuminated. While the freeze would give the pilot the opportunity to check his release parameters and out of cockpit visual references without having to attend to flying the plane, the continuity of the performance is disrupted. The effect of such a disruption on the acquisition on a motor task is not known. Another alternative would be not to employ the freeze, but to illuminate the target the moment the pilot presses the trigger. Continuity of the performance is thus not disrupted and the inherent feedback delay interval is eliminated. As with any intervention into the training setting that alters real world conditions for the sake of training, the instructor must also consider ways in which to systematically withdraw such cues.

While not an instructional "feature" per se, the principle of backward chaining might also be used effectively in performances involving the chaining together of subtasks. According to the principle of backward chaining, the terminal, as opposed to the initial, links of the chain are acquired first. On the bombing task, for example, the first link of the chain to be acquired would involve the pilot's release of the bomb at the correct pickle point. The system might be arranged so as to have the simulated aircraft fly this segment of the task under computer control requiring only that the student press the bomb release button at the proper time. As with the suggested applications described above, the freeze and replay capabilities might also be intergrated into this approach. Once the student is able to recognize the correct release point, that portion of the task between release and the time the pilot rolls out on final might be added to the chain. As performance on each portion of the chain reaches criterion, the system would arrange for the next portion of the chain to be trained. Similar application of such a backward chaining approach might also prove to be beneficial in tasks such as the overhead traffic pattern, straight-in approach and flair, as well as in such tasks as carrier landings and aerial refueling. In the latter task, training might begin with the student attempting to maintain contact with the tanker boom, proceed next with making contact from a short distance out, and only then proceed to making the initial approach to the tanker from a normal distance out.

A Further Example

Consider a second, perhaps less complicated, example than the first and the type of research design that might be appropriate for evaluating the effectiveness of alternative instructional feature applications. The particular example involves the use of the performance record/playback feature either in the recorded demonstration or replay modes and weighs the benefits of using the feature against those to be derived from allowing the student to continue to practice.

During the course of acquiring the skill associated with performing a particular maneuver, the student frequently watches the instructor perform a demonstration of the task. While automation of the initial demonstration is widely used in flying training simulation, an issue exists as to the relative merits associated with (1) repeating the original demonstration (either in part or in whole), (2) making available to the student or instructor alternative, prerecorded demonstrations of the maneuver for viewing on subsequent trials, or (3) forgoing any repetition of a demonstration, regardless of format, for the sake of allowing the student the opportunity for further practice.

Those who advocate not repeating the original demonstration might argue that the original demonstration serves to establish for the student a "standard" against which he or she uses to compare his or her own subsequent performance. To repeat the demonstration a second or third time would simply be a duplication of the function served by the first presentation. It might be arugued on the other hand that the naive student does not on the first viewing of the demonstration attend to all the proper elements of the demonstration, and only with repeated viewings grasps the full intent of the demonstration. A less obvious, but equally likely possibility, is that repeated demonstrations serve to break up periods of massed practice, giving rise inadvertently to an intermittent practice effect.

There are those who argue for the effectiveness of repeated demonstrations, but who call attention to the need for *adapting such demonstrations* to the particular needs of that student at that particular moment. These persons further argue that no prerecorded set of demonstrations will be found to be ideally suited to such individualized use. For *such* persons, a practical alternative to the use of the recorded demonstration might be the playback feature. By recording the performance of the student on each trial for subsequent playback, the instructor has the option for having the student view a performance that presents the very errors the instructor wants to draw attention to (in fact, the student's very own errors), to overlay on this visual presentation a narration that is ideally suited to that particular student at that particular point in time, and to present whatever portion of that previous performance he desires.

The alternatives, all realistic and feasible, give rise to an experiment where the following experimental conditions are present.

Condition 1: Following *an initial* demonstration of a maneuver, the student practices for some x-number of trials, sees a second presentation of the original demonstration, practices x-trials, etc. until some predetermined number of trials have been completed.

Condition 2: Following an initial demonstration of a manevuer, the student practices for some x-number of trials, rests for a period of time equal to the duration of the demonstration viewed by subjects in Condition 1, practices for some x-trials, rests, practices, etc. until some predetermined number of trials have been completed.

Condition 3: Following an initial demonstration of a maneuver, the student practices for some x-number of trials, continues to practice during that period of time alloted to students in Condition 1 for subsequent viewings of the demonstration, pratices for x-trials, etc. until some predetermined number of trials have been completed.

Condition 4: Following an initial demonstration of a maneuver, the *student* practices for some x-number of trials, then views an instructor-narrated playback of performance on his last trial, continues to practice, views playback, etc, until some predetermined number of trials have been completed.

Condition 5: Following an initial demonstration of a maneuver, the student practices for some x-number of trials, *views a live instructor* demonstration, practices for x-trials, views live demonstration, practices etc. until some predetermined number of trials have been completed.

While the spacing of demonstrations, playbacks, or whatever is a potentially important variable, their placement in the suggested study is arbitrary. So too is the student's "need" for the instructional event at the time it is programmed to occur in the study. The study, nevertheless, would serve to evaluate alternative instructional uses of the advanced features in terms of conditions having pragmatic consequences. Furthermore, it addresses the potential situation where the time -consuming use of an instructional event such as a demonstration or playback may be less preferred than continued practice on the *part of the student.*

The Need for Continued Research

While technological advances are likely to lead to *the more efficient design* of instructor/operator consoles and to more efficient management of the simulator's training features, basic instructional research is needed to determine the most effective manner for *utilizing these* features in actual training settings. As the move toward more fully automated training continues, one may expect to observe more and more functions currently performed by the instructor to come under computer control and management. There exists a limit, however, as to what extent such an engineering oriented approach to automation will ever fully utilize the unique capabilities of the modern day *flight simulator. It* is anticipated that the eventual outcome of such an approach will simply be the automation of an instructional approach derived from an in-flight model of flying training instruction. The *insufficiency of such* an approach for simulation-based flying training instruction has already been alluded to here and elsewhere.

In flying training simulation, as in any other area of training, engineering principles simply cannot be looked to as providing the basis for a technology of instruction. The application of engineering principles must be looked to as providing a means to an end. . . an end that is defined behaviorally. Such a behavioral definition of flying and the instructional process that supports flying training represents a key effort in current research of the Flying Training Division of the Air Force Human Resources Laboratory.

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