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**ADVANCED TRAINING FEATURES:
BRIDGING THE GAP BETWEEN IN-FLIGHT
AND SIMULATOR-BASED MODELS OF FLYING TRAINING**

By
Ronald G. Hughes

**FLYING TRAINING DIVISION
Williams Air Force Base, Arizona 85224**

March 1979
Interim Report for Period February 1978 - May 1978

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This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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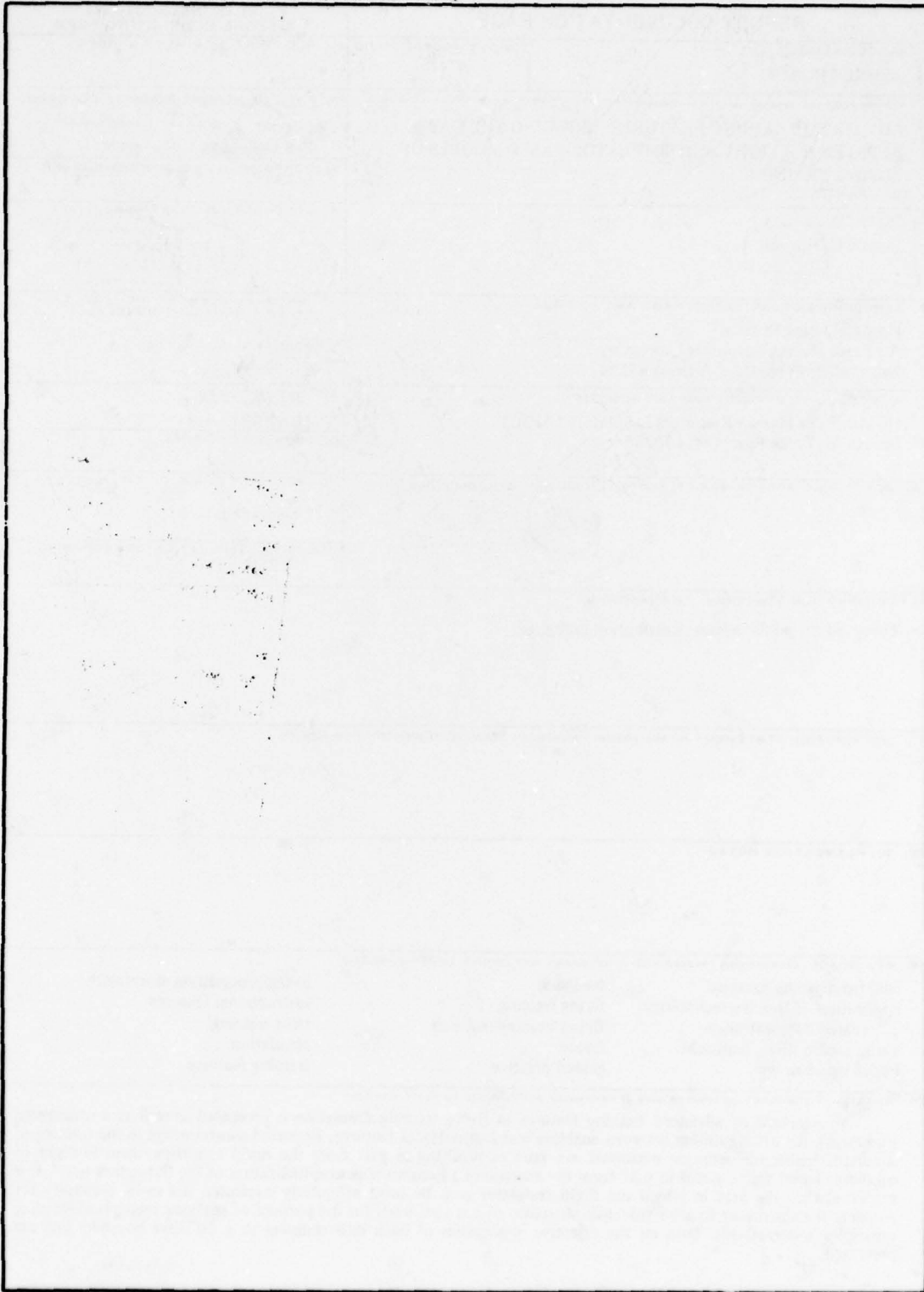
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) An overview of advanced training features in flying training simulation is presented as well as a conceptual framework for distinguishing between enabling and instructional features. Reported shortcomings in the training of simulator instructor/operator personnel are seen as resulting in part from the rapid transition from in-flight to simulator-based training and in part from the absence of a behavioral conceptualization of the flying task itself. It is suggested that the area in which the flight simulator may be most effectively exploited lies in its capability for allowing the instructor to alter the basic structure of the task itself for the purpose of applying recognized learning principles and methods. Data on the effective application of backward chaining to a 30° dive bombing task are presented. K		

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PREFACE

This effort was conducted by the Flying Training Division of the Air Force Human Resources Laboratory, Williams Air Force Base, Arizona. The project was completed under Work Unit 11230234 entitled Advanced Instructional Features and Methods in ASPT. The work unit supports Project 1123, Flying Training Development; Task 112302, Instructional Innovations in Flying Training. These efforts further support AFHRL Planning Objective G03, Specific Goal 2, Training Methods and Media.

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ADVANCED TRAINING FEATURES: BRIDGING THE GAP BETWEEN IN-FLIGHT AND SIMULATOR-BASED MODELS OF FLYING TRAINING

I. INTRODUCTION

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 & Ryan, 1977; McEnery & Lloyd, 1977; Povenmire, Russel, & Schmidt, 1977; Vandal, 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 & Worthey, 1975). While the use of simulation is not new to the Air Force (Rivers & VanArsdall, 1977; Smode, 1974; Valverde, 1968), the use of simulation on such a broad scale is.

Within the area of flying training simulation, concern has been expressed (Caro, 1977a, 1977b) 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 on the unique capabilities of simulators to free the instructional process of constraints imposed by the use of operational aircraft as training devices. In as much 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.

It is not the purpose of this report to provide an alternative to the traditional in-flight model of flying training instruction. Instead, the primary purpose is to address the area of advanced training features. Section II of the report provides a brief description of those features believed to be representative of those likely to be found on early-to mid-1980 generation flight simulators. Section III briefly addresses their current reported level of utilization in flying training simulation. Section IV represents the core of the present report. In Section IV a basic conceptualization of advanced training features is presented. Section V provides some examples where the various features might be used as well as a prototypical research design. The report concludes with Section VI and some comments on the need for continued research.

II. A BASIC DESCRIPTION AND OVERVIEW

The literature contains numerous descriptions of advanced training features believed to be representative of those to be found on early to mid-1980 generation flight simulators (Faconti & Epps, 1975; Faconti, Mortimer, & Simpson, 1970; Isley & Miller, 1976; Klein & Boff, 1977). A brief overview of these features is presented below for the reader not familiar with this aspect of flight simulation. The descriptions which follow are quoted either in whole or in part from Isley and Miller (1976). Questions to be considered in their operational use are generally those expressed by Miller, McAleese, and Erickson (1977).

Exercise Setup/Initialization

Exercise setups are preprogrammed sets of conditions and parameters for the simulated aircraft. The programs are so designed that when they are activated, the simulated aircraft automatically is initialized in a specific location and condition appropriate for the commencement of training. Parameters for exercise setups include attitude, altitude, velocity, heading, geographical location (including appropriate relationships to visual displays), engine and navigation instrument readings, aircraft configuration, weight and balance, and environmental conditions. Positioning of aircraft controls also is under computer control. Considerations in the use of this feature include: How many points are needed to allow the instructor flexibility within training tasks? Do the initialization points selected allow the instructor to utilize such learning principles as backward and forward chaining, or do they simply provide basic starting points for practicing a particular maneuver?

Automatic Briefing

The automatic briefing provides voice descriptions of training problems, maneuvers, and procedures to be presented to the trainee. It includes information regarding relevant displays and controls, the criteria of performance expected of the trainee, and other information to further the didactic objective of a particular automated feature. This feature is synchronized with, and typically occurs in conjunction with, other automated training features (e.g., automatic demonstration). A central question to consider in the use of the automatic briefing is whether or not the simulator itself represents the most cost effective medium for presenting this instructional function, or whether a form of pretraining such as that discussed by Smith, Waters, and Edwards (1975) might be more cost effective.

Automatic Demonstration

An automatic demonstration is a preprogrammed maneuver, series of maneuvers, or segment of a maneuver which is flown under computer control in a manner representative of ideal task performance in an aircraft. It includes actuations of indicators, controls and displays, as well as cockpit motion and sounds, and supplies the student at the simulator flight controls, with a model of the performance to be accomplished. The purpose of the automatic demonstration is to provide instructors with a means of presenting standardized examples of flight maneuvers or procedures. It is felt that the automatic demonstration is most valuable for providing general problem understanding and for pointing out the consequences of control or judgement errors. According to Miller et al (1977), the following important questions must be asked regarding the use of this feature: (a) What tasks will be demonstrated? (b) What will be the length of the demonstration? (c) Will the instructor observe and explain the demonstration? (d) Is there a standard of performance for the demonstration? (e) How will this standard be provided?

Performance Oriented Guided Practice

A performance-oriented guided practice is an automatic, computer controlled, preprogrammed training problem in which the computer retains control of a portion of the overall flight task by controlling one or more subtasks (sometimes referred to as "axis lock" or "parameter freeze"). This feature provides a part-task learning situation so that he can develop some initial proficiency prior to attempting a more complex task. It is generally felt that the feature is best used to aid the learning of perceptual/motor skills, such as those acquired in Undergraduate Pilot Training (UPT). Use of the feature requires models and rules for varying the basic simulation. According to Miller et al (1977), the following questions must be addressed: (a) What high priority training requirements warrant performance aiding? (b) Have performance measures been identified? (c) Have the rules for varying the simulation been defined?

Adaptive Training Exercises

Adaptive training is a technique whereby the complexity and/or difficulty of a task automatically is adapted to the skill level of the trainee. Thus, as the trainee acquires more skill at a given task, the task becomes more difficult until the difficulty level approximates or exceeds that of the operational task. Adaptive training is felt to be suitable for well-structured scenarios that require a few minutes to perform and to be most useful for repetitive training requirements that require skill integration. The adaptive training exercises are automatically sequenced under computer control to increase or decrease the difficulty level of the training task. Adaptive variables are preselected for each training task and may include incremental addition of degrees of control over the aircraft; variations of turbulence, winds and vibrations; initiating or inhibiting emergencies or malfunctions; simulation of air traffic problems and deferring or expediting the occurrence of events. The purpose of the adaptive training exercises is to provide the trainee with an automatically controlled training task of appropriate difficulty—neither too hard nor too easy—that he can practice to a defined level of proficiency. An obvious prerequisite for adaptive training is a performance measurement system adequate for making changes in task conditions contingent upon student performance.

Non-Adaptive Training Exercises

Non-adaptive training exercises consist of the practice of complete or part-task maneuvers and/or procedures under predetermined, preprogrammed, fixed conditions which are not modified or adapted to accommodate changes in trainee performance. In such exercises, trainee performance is automatically monitored against a predetermined flight profile and set of parameter tolerances. Instructor and/or trainee feedback during these exercises may include audio alerts and coaching messages, visual alerts and/or hardcopy printouts of deviations from established performance standards. Effective use of non-adaptive exercises requires a model of correct performance against which student performance is monitored. Use of on-line performance alerts must reflect current aircraft conditions rather than recent history. Displayed performance data used by the student and/or instructor must be formatted in ways that are meaningful for that person's particular purpose.

Preprogrammed Malfunction Insertion

This feature consists of simulated systems failures or emergency conditions that have been preselected to occur under specified conditions, such as time (i.e., the malfunction occurs at a predetermined period of elapsed time in a training problem) or a specific event (i.e., the malfunction is activated by an event such as passing a checkpoint or reaching a specified altitude). Once initiated, the program simulates the gradual or abrupt failure or malfunction of a system or component in the same manner as would occur if the malfunction was introduced under positive instructor control. Decisions must be made by the user as to whether the occurrence of malfunctions is to be preprogrammed or is to remain under operator control. If preprogrammed, the user should be alerted prior to their programmed occurrence as well as have the capability for inhibiting their occurrence.

Hardcopy Printout

Hardcopy printouts typically are produced by a high speed printer or by some other device which provides a permanent record of trainee performance of simulated flight maneuvers that can be used as a debriefing and/or performance monitoring aid. The use of a hardcopy printout is considered to be valuable if the number of parameters is limited, and if they are relevant to the training requirements and easily interpretable by the instructor or student. If the parameters are numerous or difficult to interpret, it is likely that the printout will go unused.

Maneuver Playback

The maneuver playback feature is an automatic function in which a temporary record of trainee flight performance, e.g., the last 5 minutes of flight, is continually available for replay. Controls are provided to recall the recorded performance, typically in 1-minute segments. The playback repeats the exact instrument readings, control movements, motion platform actuations, and/or the visual scene for the number of segments selected. Synchronized voice recordings are provided to play back all communications that were transmitted during each recorded segment. Control also may be provided to freeze the playback or to replay the segment in real time or slow time. The purpose of the maneuver playback is to permit the trainees to observe their own performance (self-confrontation) and to provide timely feedback that can be used by the instructor for critiquing and debriefing the performance. The feature is felt to be most valuable for providing general problem understanding and for pointing out the consequences of control or judgement errors. Ideally, data files can be easily tagged and accessed to allow replay of a segment out of sequence. Other considerations in its use include the following: (a) What tasks will be evaluated by record and playback? (b) Will the instructor observe and explain the playback? (c) How will the instructor observe the playback? (d) Can the length of the playback be varied? (e) Will audio and video be synchronized during the playback? (f) What is the benefit to be derived from utilizing fast/slow playback modes? (g) Can freeze/continue be used in conjunction with the playback? (h) Does the student have the capability to "fly out" of the replay?

Automated Performance Measurement

The feature involves the capability for recording desired input and/or output measures of trainee flying performance. Such information may be further used to derive scores based upon predefined, prioritized listings of parameter tolerances. Automated performance measurement data may be output either "on-line" via CRT or graphic displays or in hardcopy format either during or following a training segment. Such performance data may be used either to supplement subjective performance ratings of instructors or to provide the basis for manipulation of the adaptive variable(s) in adaptive training situations.

Freeze

The freeze feature provides the instructor with the capability of immediately freezing all simulator systems. The feature may be used to point out student errors, to draw the student's attention to particular aspects of the in- or out-of-cockpit environment, or to terminate a training segment prior to resetting the simulator to either the same or a different set of initialization conditions. Primary considerations involved in use of the freeze feature lie in the actions to be taken following the decision to freeze, particularly when the freeze is used to interrupt ongoing student performance as opposed to the termination of a training segment. Alternative actions might consist of returning the student to the beginning of the maneuver segment; returning to a preprogrammed point in the maneuver; or having the student fly out of the situation following instructor remarks and guidance.

III. CURRENT UTILIZATION

While a considerable body of literature describes the design and implementation of automated training features, there is a dearth of information on the operational use of these features. Isley and Miller (1976) and Charles, Willard, and Healey (1975) have drawn attention to this fact in their reviews of flying training simulation in the Army and Navy, respectively. Their observations were essentially the following:

1. The instructor pilot (IP) will continue to be responsible for pilot flight training. The degree of IP involvement in simulator operation will in all likelihood increase.
2. The IP and simulator operator are not adequately trained in simulator operation or utilization. Typically, each receives only limited on-the-job training, a situation that results in poor use of simulator capabilities and nonstandard use.
3. The IP is not trained in "how to instruct techniques" that apply especially to simulators. The result is a wide variation in instructional capability and a general lack of standardization.
4. Detailed syllabuses for simulators are not available. Existing syllabuses are too vague and flight oriented to exploit simulator capabilities.

The remarks of Isley and Miller (1976) and Charles et al. (1975) must be taken within the context of the rapid transition from use of operational aircraft as training devices to the extensive use of simulators and the absence of behavioral, "simulator-based" models of instruction.

There exists little doubt that essential instructional functions and events can be effectively automated and that such automation can improve the efficiency if not the effectiveness of flying training. There is little doubt, too, that the problems associated with lack of adequate training for the instructor pilot and simulator operator can be effectively solved. The development of a simulator-based, behaviorally oriented model of instruction that makes effective use of the unique capabilities of the simulator is currently the topic of AFHRL sponsored research under the project title of "STRES" (Simulator Training Requirements and Effectiveness Study).

It is thus not the purpose of the present report to propose such a model nor even to suggest its basic elements. 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.

IV. TRAINING FEATURES: A CONCEPTUAL FRAMEWORK

It is suggested that the unique training features of flight simulators might best be characterized as consisting of (a) enabling features and (b) 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, and boats; and multiple objects such as offensive weapons, surface-to-air missiles, 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, and malfunctions). 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 on 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 non-adaptive 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," and auditory/visual performance alerts), 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, and axis (parameter) lock.)

V. 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 inflight 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 inflight-type demonstration. Rarely is the demonstration capability used jointly with other features to create an instructional capability beyond that which is possible under normal inflight 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, etc.), innovative applications of simulation to flying training reside in manipulation of Class C and Class D type instructional features.

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 one's 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 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 numerous repetitions 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, & Jones, 1978; Cyrus, Templeton, & McHugh (Note 1)) that provides a continuous and immediate depiction on the ground of the point where the bomb will impact. Finally, consider the use of the parameter freeze or axis lock feature to hold constant the student's airspeed 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 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 watches passively 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 the pilot 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 the 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 of 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 integrated 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 flare, as well as in such tasks as 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 (a) repeating the original demonstration (either in part or in whole), (b) making available to the student or instructor alternative, pre-recorded demonstrations of the maneuver for viewing on subsequent trials, or (c) foregoing 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 it serves to establish a "standard" against which the students compare their 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 argued 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 pre recorded 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 any selected portion of that previous performance.

The alternatives, all realistic and feasible, give rise to an experiment where the following 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 maneuver, 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 allotted to students in Condition 1 for subsequent viewings of the demonstration, practices 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, etc. is a potentially important variable, the placement of these events 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, is less preferred than continued practice on the part of the student.

VI. CONCLUSIONS

Developments in learning theory over the past 50 years have led to principles of behavior which have been shown in innumerable applied settings to be valuable in analyzing and modifying human behavior. When applied to flying training using simulators, these principles suggest that a significant contribution could be made toward improving the way in which IPs teach new students via more effective use of simulator functions. When the simulator is conceptualized as merely an inferior copy of an aircraft, its potential as a teaching device is likely to be overlooked. It is believed that a behavioral analysis of the optimal conditions of learning could make a major contribution to both the design and use of current and future flight simulators.

Results presented by Bailey, Hughes and Jones (Note 2) provide an illustrative case. Bailey et al. have discussed how many complex behaviors involved in flying may be thought of as "chains" of behavior. An instructional technique often used outside the area of flying training is known as *backward chaining*. This technique basically arranges the task so that the last member of the chain occurs first; it is followed by feedback or reinforcement as the case may be; and then the next-to-last response in the chain is added, and so on. While the procedure seems clear enough and the implications for solving applied problems are not difficult to envisage, there exists little or no applied evidence outside these data supporting such an application.

Bailey et al. (Note 2) have presented data on the application of backward chaining to a 30° dive bomb task. Figure 1 depicts the major elements of the task as seen from the side, as well from overhead. The maneuver bears a striking resemblance to the overhead traffic pattern acquired during UPT. Figure 2 shows how the dive bombing task was segmented for the purpose of this study. The student first acquired performance (met Tactical Air Command (TAC) criterion for qualified performance) on the final leg segment. The student then added to the final, the next-to-last segment (roll-in to final), and so on, until all "links" of the chain were performed to the established criterion.

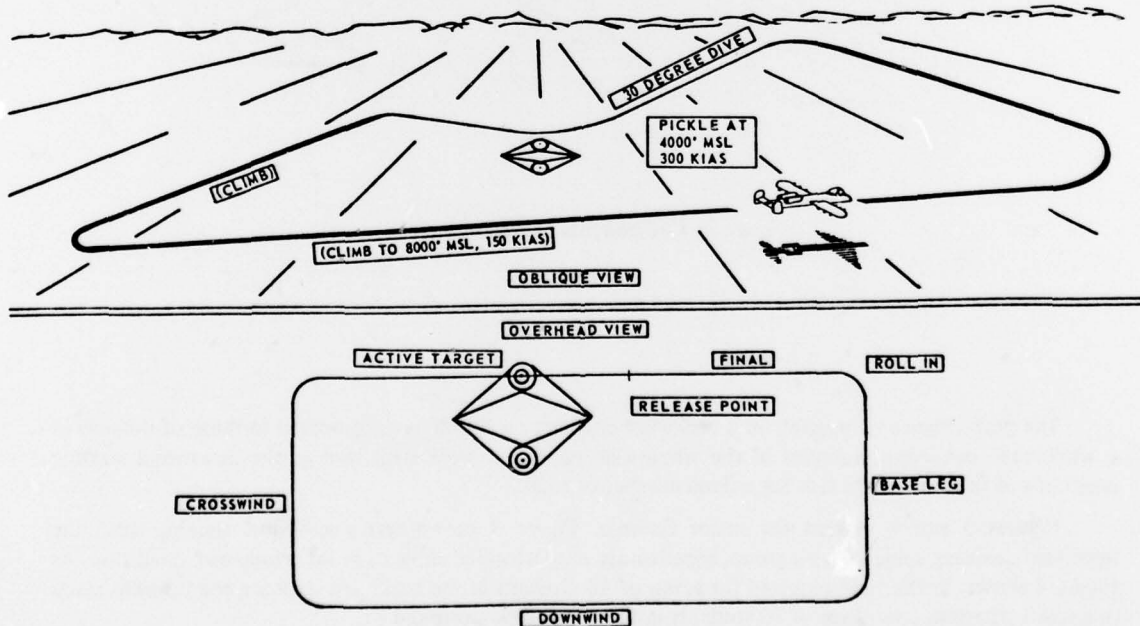


Figure 1. Major elements of 30° dive bomb task.

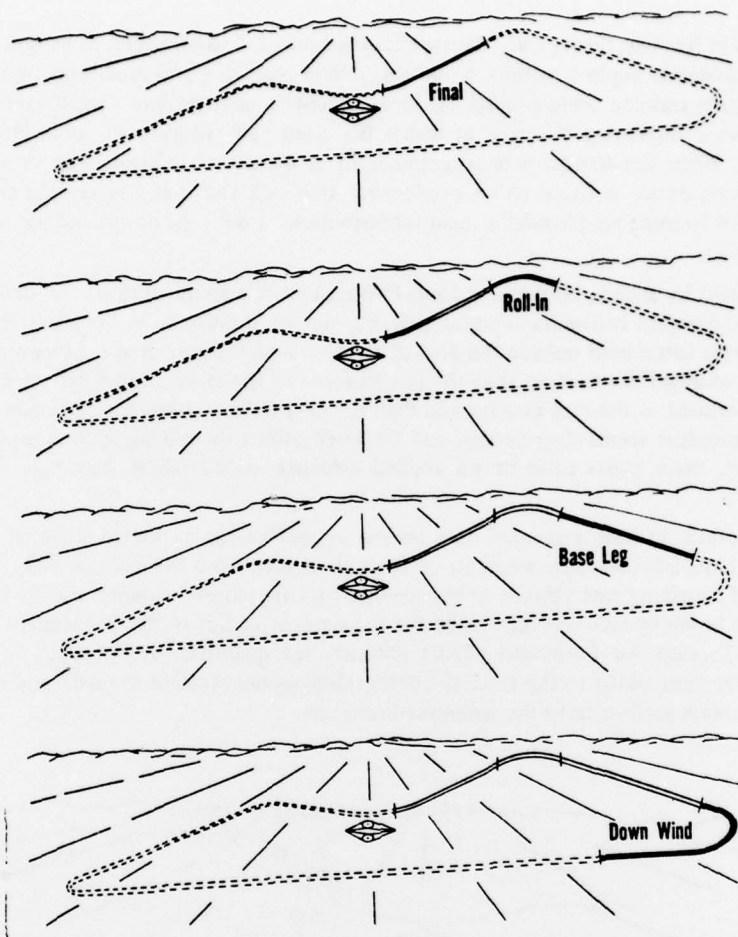


Figure 2. Components of response chain.

The performance of subjects in a backward chaining condition were compared to those of subjects in a whole-task condition. Subjects in the whole-task condition were initialized at the downwind starting position and flew the whole task for a fixed number of trials.

Figures 3 and 4 present the major findings. Figure 3 shows that given equal training time, the backward chaining subjects, as a group, significantly outperformed subjects in the whole-task condition. As Figure 4 shows, in the time required for seven of 10 students in the backward chaining condition to reach or exceed criterion, only three of 10 students in the whole task group did so.

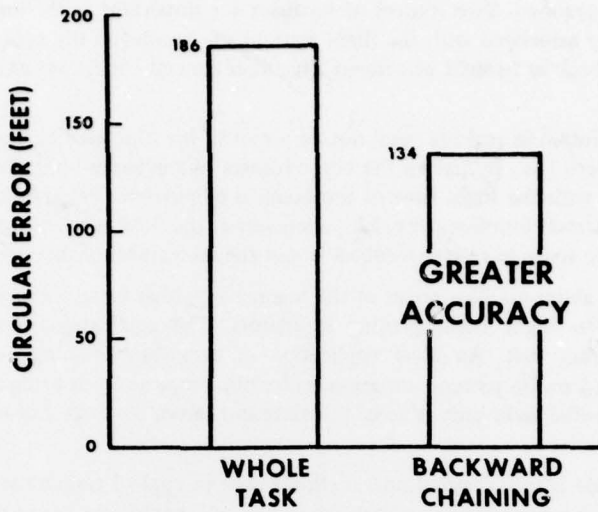


Figure 3. Comparison of performances given equal training time.

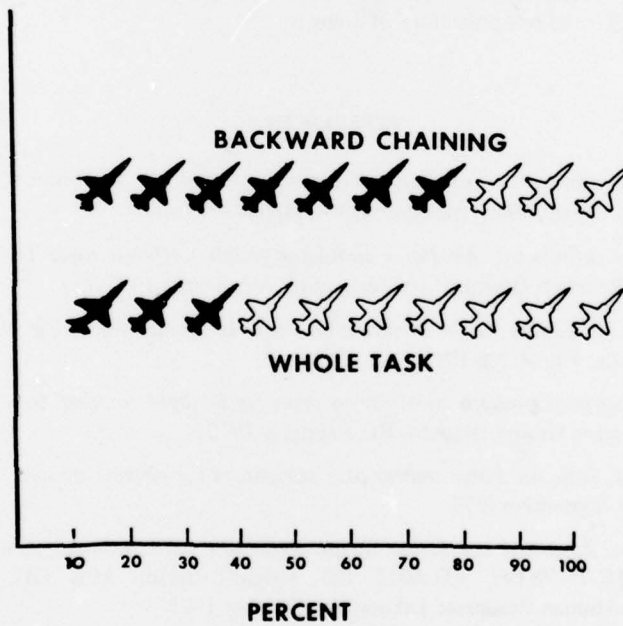


Figure 4. Percent reaching criterion.

Follow-on efforts have sought to further improve the efficiency of methods used to teach the air-to-surface task, while at the same time providing evidence of the validity of basic learning theory applications to flying training. One such effort involves the application of the principle of delayed feedback. Learning theory has, through the years, pointed to the importance of the temporal contiguity of a response and the feedback produced by that response. In simple language, the shorter the feedback delay,

the faster the response is acquired. Two sources of feedback are important in the bombing task. The first involves the inherent delay associated with the flight time of the bomb (on the order of several seconds). The second involves feedback as to sight placement and other general conditions existing at the time the pilot releases the bomb.

The inherent delay found in real life need not be a part of the simulated air-to-ground environment. By setting the delay to zero (i.e., by having the bomb impact immediately upon the pilot's release), the feedback delay associated with the flight time of the bomb is eliminated. By capturing through the use of an in-flight condition store/reset function the exact parameters at the time of release, pilots can instantly be reinitialized to that point in space to receive feedback about the correctness of their performance.

The cases described above are illustrative of the manner in which basic principles of learning theory can be directly applied to flight training using simulators. The applications are not limited to the air-to-surface type of flying task. An ideal application of backward chaining, for example, may be acquisition of the overhead traffic pattern, a maneuver identified repeatedly as being a difficult one for the UPT student. Other sequential tasks such as aerial refueling and carrier landings may also benefit from such an approach.

The point to be made is this. Instructional methods used in applied training settings are most often the product of accumulated experience rather than the produce of empirically derived principles of learning and performance. Such need not be the case with the development of instructional methods used with flight simulators. A behavioral technology exists and has existed for over 30 years. Never in the history of flying training has there been such an ideal opportunity for applying the principles contained in this technology—simulators offer the real possibility of doing so.

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