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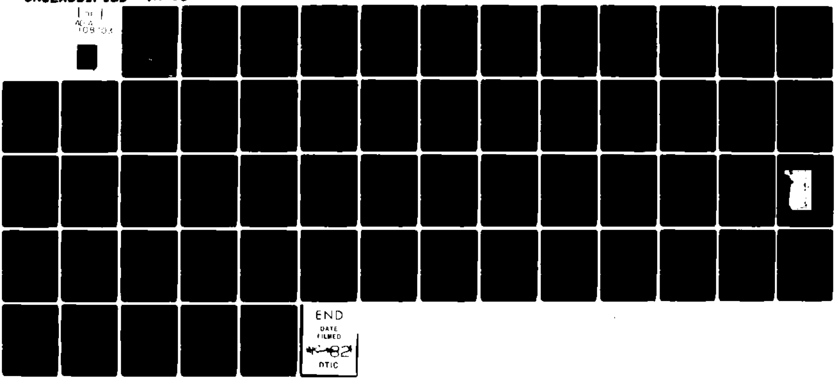

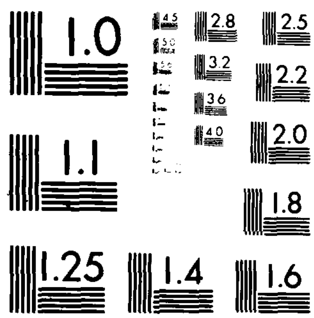

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An Experimental System
for Research on Dynamic Skills Training

Allen Munro
Douglas M. Towne
Michael R. Fehling

September 1981

BEHAVIORAL TECHNOLOGY LABORATORIES

Department of Psychology

University of Southern California

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Academic research on computer based instruction (CBI) has dealt largely with CBI of knowledge systems, coherent bodies of essentially propositional knowledge. Little research has been performed on techniques for effective CBI of dynamic skills, those amalgams of perceptual, motor, and decision-making skills that are required by many real-time event-driven tasks. The demands of dynamic skill training on student processing resources are different from those of knowledge system teaching. These differences suggest that the techniques found to be effective in conventional CBI may not be applicable to dynamic skill training CBI. Two classes of research issues

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Early plans for the experimental training system described here were influenced by discussions with Michael Grady and Robin Halley of Logicon. We thank them for sharing with us some of the findings of their work on a prototype Air Intercept Controller training station.

AN EXPERIMENTAL SYSTEM

FOR RESEARCH ON DYNAMIC SKILLS TRAINING

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INTRODUCTION

We intend to draw a distinction between the teaching of knowledge systems and the training of dynamic skills. By "knowledge systems" we mean to refer to sets of related facts that are commonly taught as a body of coherent subject matter. Examples of knowledge systems include the history of England under the Plantagenate kings, the geological features of Western North America, and the multiplication tables. By "dynamic skills" we mean sets of intellectual processes responsible for selective perceptions in a real time driven context and for the selection and perfomance of appropriate responses in that context. Examples include vehicular control skills, such as driving a car or piloting an aircraft, and the observational and decision-making skills of an air traffic controller. The teaching of knowledge systems is characteristic of pedagogy in schools, while dynamic skills training is typical of many instances of on the job training. Probably as a result of this distribution of these two types of learning, there has been more research on the teaching of knowledge systems in academic research in education. It cannot be assumed, however, that the findings of this academic research will apply to dynamic skills training.

The distinction is important because it cannot be assumed that those techniques which have been found to be effective for teachning knowledge systems will also be effective for teaching dynamic skills. Dynamic skill training typically involves intense student involvement in the practice of the skill. Under these conditions it cannot be assumed that students have the same attentional resources available to process instructional messages. Dynamic skill training typically involves practice sessions in which students must learn how to allocate resources to the tasks of global and local planning. Unlike typical knowledge system training, dynamic skill training imposes inflexible, strict time limitations on student responses to events. Cognitive processing differences in the nature of the learning processes suggest that effective teaching of dynamic skills requires different methods than effective teaching of knowledge systems. The research program described here is designed, in part, to test this hypothesis.

Research on computer-based instruction and training (CBIT) has emphasized techniques and principles for teaching knowledge systems. There are a number of reasons for this emphasis. Most CBIT course implementations were developed to convey knowledge systems, and these existing courses have provided convenient test beds for research. In addition, many researchers are inclined by both training and experience to focus on the transmittal of knowledge systems such as those taught in academic school and university courses. Knowledge systems are not, however, the only class of subject matter for CBIT. A number of computer-based training systems are in use whose function is not to teach a knowledge system, but rather to convey a dynamic skill to the students. In particular, a significant financial committment has been made to dynamic skill training in the field of airplane and helicopter simulators for use in training pilots. These simulators can be expected to be made more effective as a result of basic research on dynamic skill training in CBIT. Yet the training of dynamic skills has thus far received little attention in the academic community.

For the most part, the CBI research community has dealt only with the teaching of knowledge systems. Whole books have been written on

CAI/CBI (Burson, 1976; Taylor, 1980; and O'Neil, 1981, for example) without even mentioning dynamic skill training in CBIT (although others such as Hickey, 1975, have dealt with the topic of simulation training). There is clearly a need for basic research in this important training area. There is scope for considerable development in training systems to teach dynamic skills. Vehicular control skills, certain production control systems in industry, and many military jobs (such as ground controlled landing controllers and air intercept controllers) require combinations of perceptual, motor, and decision making skills. These training opportunities can be productively addressed by computer based training systems, but there is reason to believe that the challenge cannot be met only with the pedagogical techniques and theories developed on the basis of research on CBI for knowledge systems. The attentional demands of dynamic skill simulation training, for example, may make conventional approaches to instructional feedback to student actions ineffective.

The research community now has an opportunity to conduct a new course of research on CBIT of dynamic skills. There are several reasons to expect this. Dynamic skill training typically implies fast real-time processing, often of analog inputs from the student/trainee. Conventional CAI implementations on large time-sharing computers, tied to remote terminals limited to a 300 to 1200 baud data rate over telephone lines, are not conducive to the development of courses on real-time dynamic skills. Many such dynamic tasks may require processor dedication to ensure prompt handling of interrupt conditions and other real-time aspects of the task. Recent advances in hardware and systems software will now make such training systems more economical. On the hardware side, inexpensive microcomputer systems make single-user CBIT systems financially feasible. On the software side, the development of a number of microcomputer operating systems that support faster executing and more structured high level languages than were formerly available make dynamic simulation programming on these systems both feasible and maintainable.

Increased feasiblity of research on dynamic skill training is not the only reason to expect increased efforts in this area. There is a growing demand for practical CBIT systems in this area for training skills, such as vehicular or other machine system control, that require the fusion of perceptual, motor, and decision-making skills. In particular, the military services require superior training methods to accomplish these tasks, given the decreased level of education and training of entry-level personnel in the all-volunteer military.

There is an extensive history of simulation training (or, at least, computer-based simulation drill and practice) in the area of flight training. The development of these simulation drill systems, frequently at very great expense in relation to the projected costs of the new generation of dynamic skill training systems, was motivated by compelling considerations of safety and economy. As the complexity of other vehicular systems (such as military tanks) increases, and as the cost of fuel for such systems continues to climb, it can be expected that there will be an increased demand for other vehicular skill simulators. Maximum effectiveness will be obtained from these training systems if they are not used merely as imitation environments, but also provide other instructional features. For example, a simulator that can provide tutorial interactions in addition to imitating the skill environment should be able to reduce training time and increase its effectiveness by drawing the student's attention to individual aspects of the simulation or his responses to it.

In addition to vehicular control, other complex tasks call for the development of economical and effective CBIT of dynamic skills. For example, the Naval Training Equipment Center has contracted for the development of experimental innovative CBIT systems to train Ground-Controlled Landing Specialists and Air-Intercept Controllers. These jobs require that the worker not exercise direct vehicular control, but rather assist the pilot. This is accomplished through observations relevant to the successful control of aircraft and by transmitting information and advice to the pilots of the aircraft. These real-time driven tasks require the acquisition of dynamic skills for successful performance. It is to be expected that many tasks that call for dynamic man-machine interactions could also benefit from operator training in a CBIT simulation system. The demand for such systems can be expected to grow when CBIT of dynamic skills adds other training techniques to drill and practice, and presents evidence that it can make effective use of more advanced pedagogical techniques.

Our laboratory is currently engaged in a program of research on the nature of dynamic skill acquisition and effective approaches to dynamic skill training in CBIT. Under funding from the Office of Naval Research<1>, a low-cost experimental data collection system for research on such task training has been developed. Our project has four goals:

1. Find pedagogical principles for CBIT of dynamic skills.

There is a substantial body of research on effective pedagogy for conventional CBI of knowledge systems. It is likely that many of the findings of this research will also apply to instruction of dynamic skills. It is also likely, however, that significant departures from conventional approaches will be shown to be beneficial. For example, it is likely that classic findings on the efficacy of immediate feedback (knowledge of results) will not be upheld for highly demanding real-time dynamic tasks, in which the intrusion of results information would be expected to disrupt the training task.

2. Model cognitive processes in dynamic skill exercise.

CBIT systems for dynamic skills instruction will provide an important source of data for psychologists interested in modeling the cognitive processes that underly dynamic tasks. A CBIT system based on a dedicated processor can record a wealth of data about a student's or an expert's actions during a simulated task. This facility can be used to explore cognitive issues in dynamic skills, including the representation of skill components, using data obtained from student training with the experimental CBIT simulation system.

3. Study the acquisition of complex skills.

The acquisition and integration of the skill components found in complex natural tasks probably cannot be studied economically except through data acquired from a dynamic skill CBIT system. A study of the acquisition of vehicular control skills, for example, could be conducted in a much more controlled fashion through the use of a simulator than through observation of a student in a real vehicle.

4. Study the consequences of voice I/O in simulation training.

Modern dynamic simulation trainers will make increasing use of the new technologies for speech understanding and production. These features are likely to significantly modify the students' perceptions of the responsiveness and intelligence of the computer-based systems with which they are interacting. For example, voice input to the system may contribute to an unconscious expectation on the part of the student that the system or some simulated component of the system will behave in a very human manner. If a CBIT system includes a simulated human fighter pilot with whom the student communicates by voice, then the student may be more inclined to expect the "pilot" to understand deviations from the presecribed voice responses than if communication were restricted to keyboard console interactions. The pedagogical consequences of such perceptions may be beneficial or detrimental, but they will undoubtedly require careful study.

To work toward these goals, we have developed an inexpensive experimental data-collection system for research on computer-based training of real-time-driven tasks. The system makes use of standard, off-the-shelf microcomputer products. It employs the UCSD Pascal operating system, which provides many times the execution speed of interpreted BASIC and more readable and maintainable code than would result from the use of BASIC, Assembly Language, or Forth. The system includes more than 8000 lines of Pascal source code in experimental simulation and training programs developed in our facility. These programs were developed to permit the implementation of a range of pedagogical strategies, so that experiments with different pedagogical approaches can be performed. In addition, the programs have built-in record-keeping functions to keep track of student interactions with the simulation-training system.

TEACHING DYNAMIC SKILLS

An Example of a Dynamic Task

In order to facilitate understanding of the dynamic task training, an example of a dynamic task is presented here. This is an artificial task developed for use in our first series of experiments on dynamic skill training in CBIT. The task is a moderately complex simulation game, called Air Intercept Controller. It is based on the task of a Navy Air Intercept Controller, and includes many of the features of the real task.

The student plays the role of a ground-based Air Intercept Controller. Figure 1 shows the student training environment. He or she is seated in front of two display screens, with access to a keyboard of special function keys and a joystick. The screen on the right serves as a simulated radar display. Students observe the appearance of points of light called blips on the screen which represent aircraft in a defined airspace. Once every eight seconds, a "radar sweep" is completed and the blips are repositioned on the display. The second display screen and its special function keyboard serve as a simulated tactical data system console. The student uses this console, together with the associated joystick, to acquire information about the speeds and headings of the aircraft represented by the blips on the screens. The student presses special function keys on the console keyboard to send directions to the student's fighter aircraft. These directions include sending appropriate intercept and attack headings so as to direct the fighter aircraft to correctly approach the enemy aircraft. When the student judges that a fighter is within firing range of an enemy craft, he or she can direct that a missle be fired at it. The student wins a game when his aircraft survive and and all the enemy aircraft are shot down. The task proceeds at a rapid pace. Even expert students are hard-pressed to perform all the necessary actions in order to attack and defeat a number of the enemy aircraft in the advanced problems.

The experimental training system, unlike many much more elaborate and expensive simulator-trainers, such as those commonly used in flight training, is designed to do more than to provide simulated practice. It can also interact with the student on an instructional level. In addition, a detailed record of the student's interactions with the system, including a record of the errors made, is maintained. This record can serve as a basis for post hoc tutorials and replays.

Although the experimental training system was developed as a research tool, it is likely that inexpensive training systems such as this will play a useful role in many training applications. A microcomputer-based simulator might offer less superficial fidelity than the real environment or than a more elaborate simulator, and yet offer more effective training. A simulator system that includes facilities for tutorial and other instructional interactions combined with simulation may prove to be a more powerful instructional environment than even the most realistic simulation system that lacks an instructional component. Such training-simulators can be used to teach conceptual aspects of real-time tasks, to develop subskills called for by these tasks, or simply to teach essential safety procedures before high fidelity training commences. A training system incorporating this philosophy would make extensive use of low-fidelity simulation to accomplish particular training objectives, and then polish the training with practice on real systems or on higher fidelity (and therefore more expensive) simulator-trainers.

Issues in the Training of Dynamic Skills

There are undoubtedly a large number of important issues to be resolved about effective approaches to CBIT of dynamic skills. Our research group is concentrating currently on two classes of training issues: presentation strategies and knowledge-of-results strategies for effective training. The dynamic nature of the training under discussion implies a wealth of presentation options not found in conventional computer based instruction. The relative merit of these different approaches to presenting simulation training should be explored. A specific major training issue to explore is to isolate the most effective means for conveying to the student or trainee the quality of his or her responses to the simulation. It is expected that the findings of conventional CBIT for giving knowledge-of-results during knowledge system teaching will not apply directly to dynamic skill training. If they do not, then how can we give effective performance feedback to the students?

Presentation Strategies

The dynamic nature of the simulation training being considered here means that there is a controllable rate at which events occur in the simulation. Changes in the simulated environment can take place more or less rapidly, or even halt, under program control, allowing the student to process some aspect of an ordinarily dynamic process in a static manner. The range of options dealing with changes in the pacing of events we call _event rate manipulations_. A second class of presentation strategies are those which permit repetition of simulated episodes or episode segments. These we refer to as _repetition manipulations_. A third class of strategies are _partial-task manipulations_.

Event rate manipulations

Event rate manipulations include stop action, slow motion, and fast action episode segments. The effectiveness of each of these techniques must be explored in a variety of simulation environments. For example, if slow motion simulation has a beneficial training effect in comparison with natural speed simulation in any context, one would expect to observe the favorable result in simulated contexts of rapid pacing that impose significant processing demands on the student. In addition, it is to be expected that there will be an effect due to locus of control (program or student initiation) of these options. Whether students can employ these features to their benefit in training is a matter for empirical determination.

Stop action. During interactive training episodes, students sometimes feel that they just need a second or two to stop and think, in order to assimilate something they have just encountered or to plan a response. A training system that provides a student-controlled "stop" feature, perhaps in the form of a menu choice or a special "stop" key on the keyboard, would give students in dynamic simulation training such an opportunity to exercise some control over the pace of events. Use of such an option would often mean that a student was using a conscious decision-making approach to the task at hand rather than simply reacting in an automatic manner to the information displayed. Whether a problem-solving orientation to the tasks of a dynamic skill is an effective method for acquiring that skill is an empirical issue. It may be that students trained with this method will perform less competently in the field because they become dependent on the use of the slower-paced problem solving method encouraged by the training system. On the other hand, it is possible that students would use the stop action feature, and the problem-solving approach it encourages, only as a stepping-stone to automatic competence. If this is the case, the stop action feature may promote learning, particularly among less practiced students. Experiments are called for to resolve this issue.

Stop action may also prove an effective instructional device under program control. During expository simulation, the task could be halted to direct the student's attention to some feature of the simulation. Instructional feedback may benefit from the use of stop action. Because students' information processing loads are likely to be quite high during the training of difficult tasks, the additional processing load imposed by instructional feedback is likely to be intellectually overwhelming in a continuous simulation. By interrupting the simulation during a feedback presentation, some student processing resources that were dedicated to tracking the simulation should become available for attending to the instructional feedback.

<u>Slow motion and speeded motion</u>. The participant in a real-time event-driven task often senses that the action is beginning to get ahead of his or her ability to keep up with it. Shortly thereafter, the action is likely to outpace the student, and a catastrophic decline in performance will result. This kind of time-driven student failure may or may not have desirable pedagogical consequences. Such failures may motivate students to automatize their processing so as to acheive more responsiveness to the task. On the other hand, these episodes may be confusing and discouraging for students. If time-driven failures are not pedagogically productive, an optional, student-controlled slow motion mode might prove useful. In the case of the Air Intercept Controller simulation described above, slow motion would mean that the radar screen would update at longer intervals than normal, and the blips on the screen would appear to move more slowly than in the normal speed simulation. Use of optional slow motion would lead to several logistic problems for the training. One would be to provide a means for returning to normal presentation rate. If this is under student control, we may find that students prefer to spend too much time in slow motion mode and actually retard their acquisition of the skills. However, if the simulation simply returns to normal rate after an arbitrarily short period of time, the student may still be in an overloaded state. The best long-term solution to this dilema lie in the development of an intelligent student monitor routine that estimates the student's overload state on the basis of the speed and appropriateness of his responses to the simulation. This monitor would then have control over the return to normal speed. In fact, such a monitor could be used to put the simulation into a reduced speed mode

when it perceived a need to reduce the student's processing load.

In addition to use as a pacing device during practice of dynamic skills on simulators, slow motion may prove to be an effective instructional presentation tool. When a complicated new series of actions is to be taught to a student, he or she could be required to step through the sequence at slower than natural rates the first few times.

Ideally, the rate of presentation of the simulation should be continuously variable. If a sophisticated student monitor can evaluate a student's momentary processing load with some accuracy, then the simulted rate of events could be slowed down or speeded up to match the student's present ability to handle the incoming data. One problem with this approach is that the student may actually be getting misinformation about the task. If one of the things a student learns in acquiring a dynamic skill is the natural pace of events, then an inconsistent simulation pace may not give the student a realistic view of the real world task. Only empirical study can reveal whether dynamic task training benefits from slow motion or fast motion presentations.

<u>Repetition Manipulations</u>

<u>Action replays</u>. In an action replay, a portion of a simulated task is repeated in order to provide a student with repeated practice on the elements of the skill required by that portion. One potential application of action replays is as a method for instructional feedback. When the system determines that performance on a portion of a practice task was not acceptable, it can require of the student that

that portion be repeated. This form of simulation instruction borrows a simple looping technique from conventional computer based instruction, in which students repeat a module until they meet some performance criterion.

Another possible use of action replays is under student control. Sometimes after completing a short sequence in a simulated event a student feels that he or she then understands how the sequence should have been done. If the student is required to continue with the next portion of the task immediately, the insight may be lost, and, in any case, there may be no immediate opportunity to apply it. If the student has the option to replay the sequence, applying a new understanding of what should be done, this extra practice could give the student a chance to consolidate his or her understanding. At the end of the replayed segment, the simulated action would continue as though the student had made those responses on the original segment.

Such action replays would allow students to practice short sequences of actions at times when they believe the practice will be useful. There may be positive motiviational effects from such replays, since they would allow students to avoid simulated catastrophes, if they observe that such a consequence is about to occur as a result of an error. Students could be expected to use the feature to drill on a sequence representative of new skill demands until they believe they have attained mastery. A possible negative consequence of the availability of this option is that some students may overuse the option, as a result of unrealistically high performance criteria. Too much time could be spent in training of relatively simple procedures if students have total control over pacing through unlimited use of the action replay feature. Tests of the use of this dynmaic skill training feature may therefore reveal a need for the system to ration use of this mode of training.

Partial-task Manipulations

In the past, computer-based simulator trainers for dynamic skills training, as developed for flight training and military systems training, have been sophisticated and very expensive devices capable of simulating very realistically almost the whole range of activities that could be performed with the real world system. Visual, auditory, and often proprioceptive stimuli are provided by these elaborate simulators. The increasing availability of inexpensive stand-alone microcomputer systems suggests that it may be desirable to determine to what extent portions of the training task can be performed by simpler simulation devices.

One approach to more cost effective training might be to make use of trainers that are not designed to simulate the whole of the task to be learned, but only some portion of that task. For example, decision-making components of an air-intercept controller task could be taught separately from information-acquisition skills and from communications skills. The processes of information acquisition, in particular, call for a high degree of motor skills in this task. It is possible that some basic decision-making skills and resource-allocation skills could be taught without making use of a completely accurate representation of a real air intercept controller environment, using a simpler but functionally related simulated task. Experiments are called for to determine whether there is a transfer of training from a primitive simulation to performance on a more sophisticated simulator or to performance on the real task. Part task training research has yielded mixed results. In some cases, the partial tasks teach response patterns which are antagonistic to those required in the transfer task. In such cases, part-task training can have a negative impact on performance on the target task. Part-task training is most often shown to be effective for cognitive, decision-making components of complex tasks, rather than for teaching motor responses. These findings suggest a course of research for part-task training of dynamic skills.

In addition to research on traditional part-task training approaches, dynamic skill simulator training calls for research on progressive task enlargement. In this technique, a problem or problem type is successively enlarged or complicated. Students are taught a few simple skills and are given simulated practice problems that are quite natural, but are unusual in that they require only the already presented skills. Then more skills are taught to the students and somewhat more complex practice problems, which call for these skills, are used for practice. This technique is commonly used in introductory computer programming classes. In this environment, students are taught only portions of a programming language at a time, and the problems they are assigned are appropriate for that portion of the language that they know.

Progressive task enlargement offers a natural approach to incrementing a student's performance level. For dynamic skill training, it may provide a method for manipulating problem difficulty without artificially manipulating the natural rate of events as do the other event rate manipulation techniques discussed above.

Instructional Feedback

One of the most firmly established principles of learning research is the importance of prompt knowledge of results following student responses. Feedback about the correctness of a student's interactions is not provided immediately by most dynamic skill simulators. Students can, of course, often deduce the appropriateness of their responses on the basis of the simulated outcomes. If the student "pilot" of a simulator takes an action and shortly thereafter is told that the simulated aircraft has crashed and burned, then the student may conclude that the action was inappropriate in the circumstance. This type of "natural consequences" feedback has its limitations, despite the powerful impact it can sometimes provide. One such limitation is that it does not explicitly pair actions and consequences. In the case of the simulated crash just mentioned, it is likely that the pilot would attribute the responsibility for the simulated accident to the last non-emergency action he took . This attribution could be erroneous. A natural consequences approach to feedback requires that students interpret their own errors. In addition, some student actions may be incorrect or inappropriate and yet not result in perceptible problems most of the time. In these cases the student will not get feedback about the incorrect action except under certain conditions.

Benefits can be expected from providing instructional capabilities in dynamic interactive trainer simulators, such as the air intercept controller discussed above. What form such feedback augmentations should take is a matter for basic research. Feedback techniques used for knowledge system teaching probably cannot be straightforwardly applied to training real time driven decision making tasks. One reason for this is that the dynamic simulation acquires its realism in part form the ongoing, episodic nature of the simulated events. Feedback (other than natural consequences) serves to interrupt the natural episode, and to distract the student from the simulated event. When knowledge system training is the goal of a computer-based simulation, such interruptions are no problem. Attention can be briefly diverted and then returned to the evidence at hand. In many cases (e.g., the BTL Trainer Simulator -- Rigney, Towne, Moran, & Mishler, 1978; Munro, Towne, & King, 1980; Towne & Munro, 1981), the student can replay portions of the simulation in order to reconstruct his findings if his memory is disrupted. Such an approach is not ordinarily possible in the simulation of a dynamic event.

The experimental system described below has been developed in part to explore the pedagogical consequences of two aspects of the presentation of feedback information in dynamic skill training. The first aspect is the continuity of the simulation during feedback episodes. The second aspect of feedback presentation to be studied is student control over when feedback will be presented, a factor we will refer to as feedback intrusiveness.

In order to anticipate the impact of either simulation continuity or feedback intrusiveness upon training effectiveness we need to consider the demands which are placed upon the cognitive resources of the student when confronted with a dynamic skills training task. Two primary types of cognitive skill are likely to be affected by these training task variables. First, during a dynamic skills training task the student's attentional resources are often heavily taxed. Students must attend to the flow of events in the simulation, and they must attend to other essential training information, such as feedback. Second, students' encoding and representational skills are exercised to produce accurate cognitive representations of the task and its structure, in order to produce immediately required responses and to plan for future contingencies. The factors of simulation continuity and feedback intrusiveness must be evaluated in terms of their impact upon attentional and representational skills.

Simulation Continuity

Consider the following two strategies for simulation continuity during administration of instructional feedback; the training simulation can be stopped until the feedback is complete or it can be allowed to continue normally during presentation of the instructional feedback. Consideration of the cognitive factors just mentioned -- attentional monitoring and representation formation -- seem to lead to contrary points of view about the relative effectiveness of these two strategies for presenting the simulation.

With respect to the attentional processes of the student, the interrupted simulation strategy has the potentially beneficial feature of reducing the attentional load during feedback episodes by eliminating the need to attend to the simulation when feedback information is being presented. In the case of a continuously presented simulation, a student's processing capacity is likely to be largely taken up with attending and responding to the simulation. The addition of the task of attending to the instructional message while the simulation continues is likely to overload attentional mechanisms, to the detriment of both performance on the simulation task and attention to the feedback. It is therefore reasonable to expect that performance under training conditions in which the simulation is interrupted during feedback episodes will be superior to performance when presentation of the simulation is continuous throughout the training session.

On the other hand, the formation of a precise and accurate representation for a task in which there are real time elements may be hindered by frequent interruptions of task continuity. It is reasonable to expect that a complete mental representation of a task involving coordination of responses to real time events must contain some accurate portrayal of the temporal relationships among the various task elements. That is, if one of the things students learn is the rate at which a series of simulated events is to occur, then the interruption of this pacing may be disruptive to the representational mechanisms. There is no direct experimental evidence for such representational mechanisms, at least in the context of training. However, the studies by Shepard and his colleagues (Shepard & Metzler, 1971; Cooper & Shepard, 1978) suggest that mental/imaginal processes can provide detailed representations for certain types of continuously variable physical events such as rotation of a physical object. It is an open question whether such representational abilities extend to the diversity of temporal relationships which exist in a typical dynamic skills task. In addition, it is possible that a student could overcome the disruptive effects of interrupting the simulation by performing some kind of "mental subtraction" of any feedback time which intervened between two simulation events to be temporally related. Therefore, it is possible, but by no means certain, that interrupting the simulation during feedback episodes will intefere with the student's ability to develop a complete and accurate representation of the simulated task.

Feedback Intrusiveness

The second research issue in instructional feedback for dynamic skills training is feedback intrusiveness and its effect upon a student's attentional and representational cognitive processes. Feedback intrusiveness refers to whether the student controls the time at which feedback information is presented in a training task. Feedback under student control is termed non-intrusive feedback, and externally paced presentation of feedback is termed intrusive. This terminology is motivated by noting an analogy of student-training system interaction to a conversational context.

The student's interaction with the dynamic skills CBIT system has parallels to a conversational interaction between two people. In normal conversation, the participants exchange indications of their readiness to accept input from each other; that is, they signal turn-taking in the conversation. In conventional knowledge system teaching in CBI, each student response (such as typing in the answer to a question) can be thought of as a signal that the student has surrendered a conversational turn. After making a response, the student expects a reply from the teaching system. In dynamic skill training, however, each student interaction with the simulation system is not a conversational turn surrender. Instead, the student remains actively engaged with the simulation, preparing a series of actions in response to observed and expected simulated events. In this context, the interjection of an instructional feedback message is an intrusion. The system is, in some sense, breaking in on the student's turn.

Consider the impact upon attentional processing of providing feedback by intrusive versus non-intrusive means. During a complex training session, a student's processing resources are likely to be largely absorbed in attending and responding to the task simulation itself. If the task is suddenly intruded upon -- whether or not the simulation is stopped during the feedback episode -- the intrusion is likely to require additional processing resources to perform the attentional shift. This surge in processing resource demand is likely to interfere with the normal learning and performance processes. If the disruption occurs at a point in the task when a large percentage of cognitive resources are already committed, then either or both of the attention to the feedback and task performance are likely to suffer. The student will presumably shift attention from the task simulation to feedback information only at points where processing requirements are relatively low so that the attentional shift may be accomplished with a minimum of disruption to response and learning processes. If the argument just given is sound then we expect that feedback given intrusively will be more disruptive of both learning and performance than will feedback provided non-intrusively.

These points about attentional processes underscore our analogy between conversation and student interaction with the training system. It seems likely that conversational cooperation is required for reasons quite like those just discussed for skills training. In this view, conversational cooperation is an adaptation to information processing resource limitations. Therefore, it is our expectation that a dynamic skills training system that partially emulates some of the features of conversational turn-taking in instructional feedback will prove superior to a system that arbitrarily interrupts student task processing with instructional messages. This emulation consists of signaling a readiness to provide feedback in a non-intrusive way, and then postponing the presentation of the message until the student explicitly surrenders a turn and requests presentation of feedback.

It is plausible to claim that the non-intrusive feedback condition (student paced presentation of feedback) could present difficulties for representational (as opposed to attentional) processes. This is due to the fact that the student will frequently wait to see a feedback message until some time after the context to which the message refers has passed. The traditional results on delay of reinforcement during learning indicate such a delay will be detrimental to learning. Thus, if feedback serves as a reinforcer (positive or negative) the delays which occur in the non-intrusive conditions should impair overall student performance. We can put this in a more cognitive perspective by noting that when the feedback message is delayed it should be more likely that the content of such a message will not be correctly related to the student's representation of the task. The student could readily be confused as to the context to which the feedback message refers. Thus, we have two types of argument that students in the non-intrusive condition will be at a disadvantage in making use of the feedback information. The students whose feedback is presented intrusively always receive the feedback message immediately following the context for which it is generated and so should not suffer this representational and reinforcement disadvantage.

These arguments are challenged if we postulate that students have some ability to reinstate the context to which a feedback message refers from the content of that message. The research specifically addressed to delay of knowledge of results tends to support this point of view (Kling & Schrier, 1971). In these studies it appeared that making students wait for feedback was not detrimental if little or no responding was required during the wait interval. A cognitive interpretation of these findings is that students were (due to memorial processes) able to maintain a trace of the context for the knowledge of results information. If students in a dynamic skills training task were similarly able to recall the context of a feedback message, then it would follow that students receiving feedback non-intrusively would not suffer a difficulty. Therefore, it is an open question as to how the variable of intrusiveness will affect students in a dynamic skills task. Attentional demand considerations suggest superior learning performance for students in a non-intrusive feedback condition. Representational and reinforcement considerations argue for the conclusion that students' performance in the non-intrusive feedback condition will be adversely affected unless the feedback messages they receive are sufficiently clear that they reinsatate the referent context.

A Design for Feedback Research.

The table below represents a two factor design for studying the effects of simulation continuity during feedback and feedback intrusiveness.

Simulation Continuity		Intrusiveness: Intrusive	Intrusiveness: Non-intrusive
	Interrupted	1	2
	Continuous, Visible	3	4
	Continuous, Invisible	5	6

Six different conditions for the presentation of instructional feedback messages are presented here:

1. Intrusive feedback with interrupted simulation. The student has no control over presentation of the feedback messages. When the system detects a student error or a condition that demands student attention, it freezes the simulation, sounds an audible feedback warning tone and presents the feedback message in a reserved area of a display screen. The simulation remains frozen until the user "accepts" the feedback by depressing a special key. At that point the simulation resumes.

2. Non-intrusive feedback with interrupted simulation. When the training system detects a student error or other condition that warrants instructional feedback, it sounds an audible feedback warning tone. The simulation continues without interruption. When the student feels ready to see the feedback message, a special "help" key is depressed. At this point the simulation freezes and the student can read the message. The user then "accepts" the feedback by depressing another special key. At that point the simulation is unfrozen and

continues normally.

3. Intrusive feedback with continuous simulation. In this mode of instruction, the system presents feedback messages, as in 1, whenever their conditions occur. The simulation is not interrupted, however, during presentation of the instructional message.

4. Non-intrusive feedback with continuous simulation. The system signals the availability of feedback messages, but presents them only upon student request, as in 2. As in 3, the simulation is not interrupted during feedback presentation.

5. Intrusive feedback with continuous but invisible simulation. As in 1 and 3, the instructional messages are presented whenever their conditions arise. The simulation screen goes blank for the student during the feedback. When feedback ends, the simulation becomes visible again, but in the state to which it advanced during the feedback presentation.

6. Non-intrusive feedback with continuous invisible simulaton. As in 2 and 4, instructional messages are presented at student request. The simulation continues in an invisible mode until the student accepts the feedback message.

The first goal of our research project is to explore the consequences of different combinations of the simulation continuity and feedback intrusiveness factors on the success of dynamic skill training. To that end, an experimental test bed training system has been developed. The features of this system are described in the next section.

THE EXPERIMENTAL SYSTEM

Figure 2 presents the functional structure of our experimental dynamic skill training system. A student training episode is viewed as having two major components. The first is a pre-training session, in which the student is introduced to the task and to the activities that comprise the skill. The second is a practice training session, in which the student receives a combination of simulated practice and tutorial. These tutorial components are not separate from the practice episodes, but are intertwined with the practice activities. One of the research questions being pursued with the system is how to most effectively mix practice and tutorial instruction.

A complex set of data is recorded during each student practice training session. This data set includes records of student actions, of the occurence of certain simulated events, of detected student errors, and of tutorial interactions with the student. A set of data extraction programs are applied to these data to produce data relevant to research issues of interest. These extracted data are then analyzed with the SPSS data analysis package on the University mainframe computer.

The Simulation Trainer Program

The current version of the dynamic skills trainer program simulates a game-like task similar to that of an air intercept controller. Students are trained on the task in a single training session of approximately four hours. training consists of an introductory session of one and one half hours in which the student sees viedeotaped explanations of the task and the equipment and works through an introductory training program. This introductory program requires that the student read brief explanations of each of the controls available to the student on the simulated control console. After reading each explanation, the student is required to briefly interact with a simple simulation that requires the exercise of the just-discussed function. Students who fail to correctly use any of the controls are required to repeat the module that explains how the control is used.

After viewing the introductory videotaped sequences and completing the introductory training program, students practice the skills by interacting with the main simulation training program. The student spends about two and one half hours in a series of thirty training exercises in this program. These exercises are blocked (5-10-10-5) in blocks of increasing difficulty, with problems of approximately equal difficulty within a block. Appendix II gives a detailed narrative description of a simple problem interaction.

The simulation program has the top level structure depicted in Figure 3. Note that the system uses a system of frequent checks of the real time clock for pacing the simulation rather than clock-based interrupts. This feature facilitates straightforward structured programming in Apple Pascal. The heart of the simulation is the Probloop procedure, which constantly checks for student errors, for new student actions, and for new simulated events. The form of the exercises are determined by coded data files that prescribe the simulated events that are to occur in each exercise. An exercise comes to an end when either the student or the simulated enemy aircraft win or the time alloted for the exercise in its coded file is expended.

SUMMARY

We have shown that dynamic skill training differs in important ways from knowledge system instruction. The demands placed upon students' cognitive processing resources are different in these two types of learning. These differences suggest that computer based training of dynamic skills offers scope for research projects that will differ in methods and results from conventional computer based instruction research. Issues for dynamic skill training in particular need of empirical resolution include finding the most effective simulation presentation techniques and the most effective means for providing instructional feedback. Dimensions of presentation dynamics to be explored include manipulations of the rate of simulated events, repetition techniques, and partial-task training approaches. Instructional feedback issues include whether simulation should continue during feedback and whether students or the training programs should have control over the presentation of feedback.

In order to address these and other issues in dynamic skill training, a low cost experimental simulation training system has been developed. This system trains experimental students to perform a task similar in many respects to that of an air intercept controller. The training program permits controlled differences in instructional treatments for different subjects. The system is being used as a tool for the empirical resolution of dynamic skill training issues.

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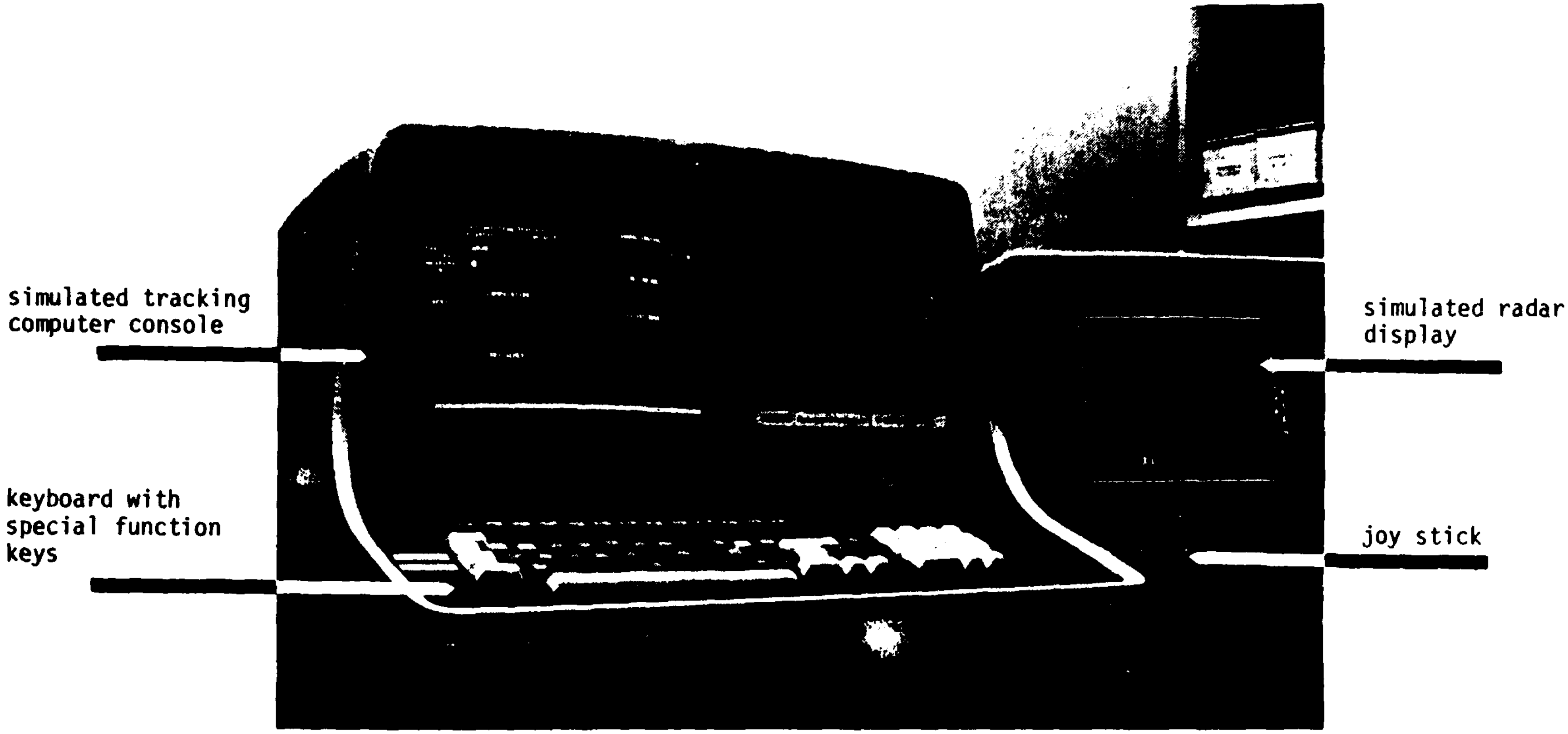

Figure 1. The student training environment

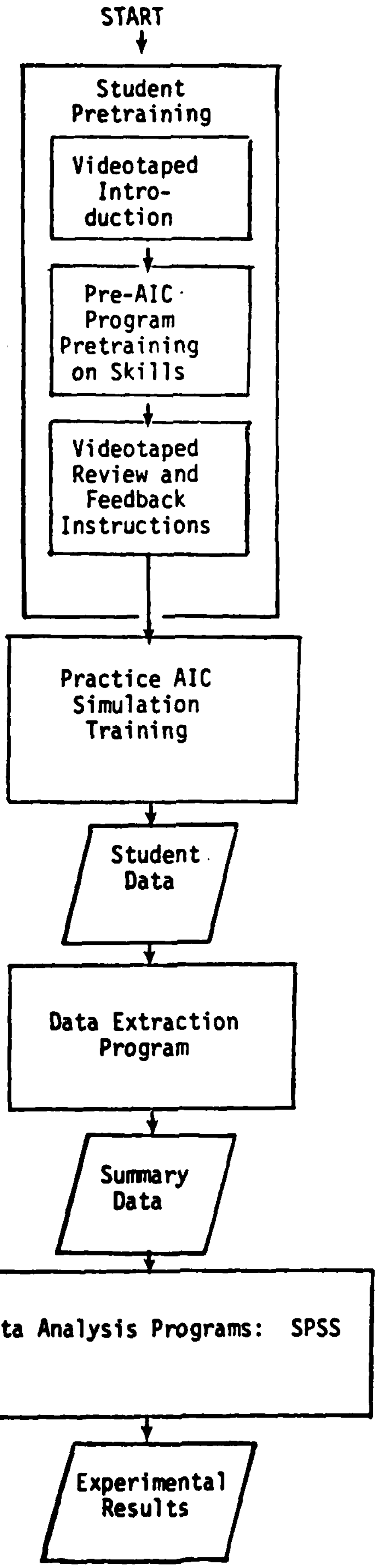

Figure 2. The functional structure of the experimental dynamic skill training system

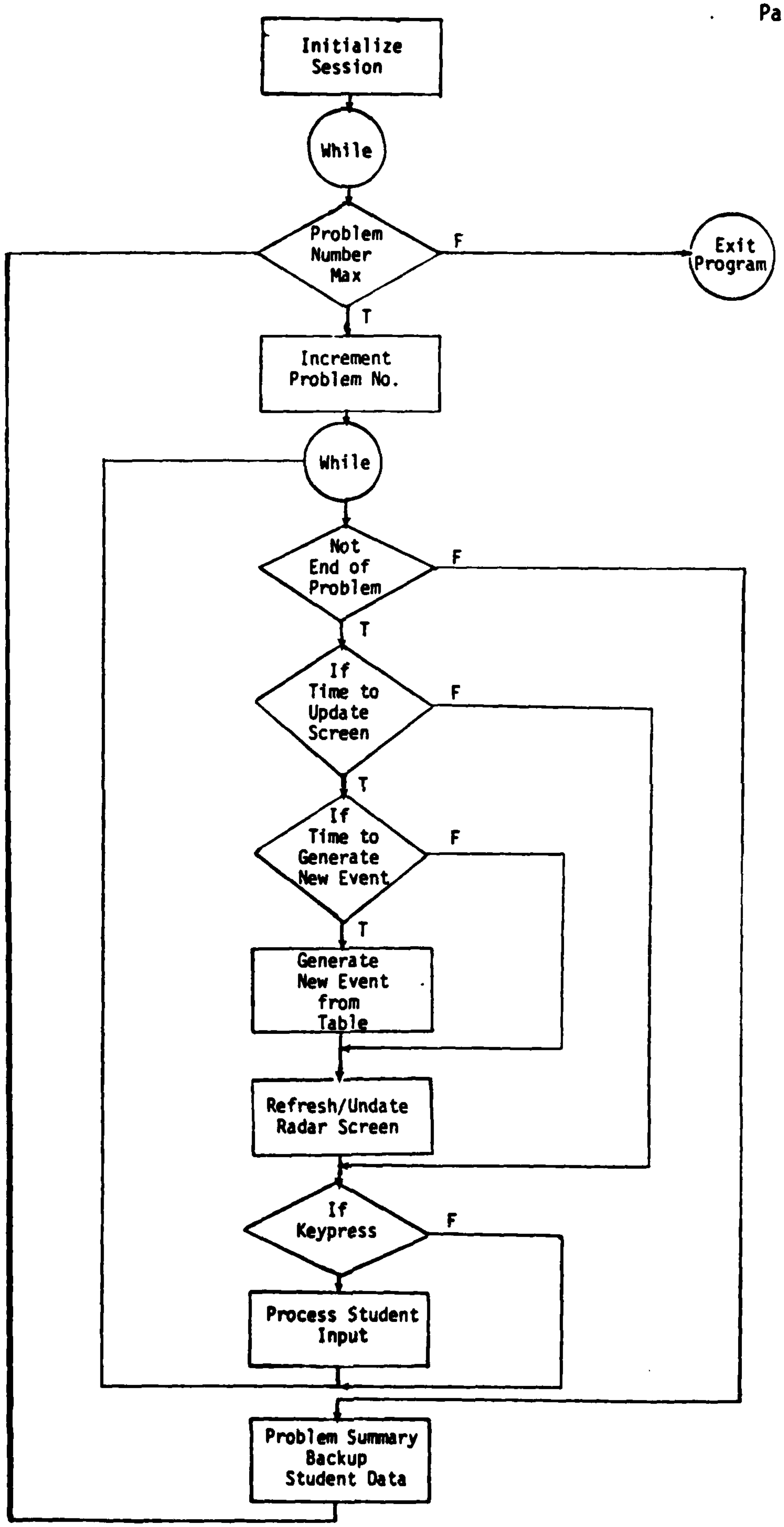

Figure 3. Simulation Program: Top Level Structure

APPENDIX 1

Hardware and Operating System

Figure 1 diagrams the hardware of the experimental system for conducting research on computer-based training of real-time driven tasks. Only the major, system-level components are shown here. The shaded elements are planned for but not currently integrated into the complete hardware/software package. An Apple II micro-computer is the heart of the system. This computer uses the Apple Pascal operating system, within which the simulation-training programs have been written. A Corvus 10-megabyte Winchester technology hard disc drive provides mass storage for the system. The speed of this drive in accessing and transferring data is very important to the success of the simulation. The program uses overlaid segments, so fast disc transfers are important to maintaining a realistic pace in the simulation. The Corvus disc drive provides a 16K RAM buffer which typically holds the next required program segment. As a result, overlays from the disc drive are accomplished very quickly.

Three display screens are used for the simulator trainer. The first of these is a standard RS-232C-compatible 80 column CRT terminal. The keyboard of the terminal has been modified with special key caps corresponding to simulated functions. This display serves as the alphanumeric console of a simulated radar-control computer. The second display screen is a high bandwidth green phosphor video monitor. This screen displays the medium-resolution graphics output of the Apple II. It functions as a simulated radar screen in the CBIT system. The third screen is a color monitor used to display videotaped instructional sequences under computer control. The computer-based videotape controlling device (a Cavri V controller), which permits random-access of videotaped segments, also has the capability of controlling a videodisc player.

Student interaction with the simulator trainer is by means of key presses of the specially coded key caps on the CRT terminal and through the use of the linear joystick connected to the Apple II. In addition, the system will make use of voice input and output technology in future experiments. An internal real time clock permits accurate recording of the times of student actions.

APPENDIX II

The Task

A narrative description can only partially convey the nature of the simulation, but one is attempted here. A problem of relatively low difficulty might consist of the following events. The Radar screen is initially blank. A few seconds later, the first radar sweep takes place, and a blip appears in the lower left corner of the radar screen. The student depresses a key labeled "JOY" in order to activate his joystick. When the joystick is activated, a small crosshairs cursor appears on the radar screen. The student manipulates the joystick to position the cursor on the blip. A new radar sweep occurs (eight seconds after the previous one) and the student must reposition the cursor, using the joystick. With the cursor centered, the student "hooks" the blip by depressing a symbol key, "C1", on the console keyboard. The simulated IFF function (Identification: Friend or Foe) determines that the symbol is appropriate for the blip, so the symbol "C1" appears on the radar screen next to the blip. The joystick cursor disappears, because pressing the symbol key (C1), turned off the joystick. Another radar sweep takes place, and the blip advances again toward the upper right corner (NE). The symbol has been left behind because the simulated tracking computer requires two fixes to project a course for the symbol. The student reactivates the joystick by depressing the "JOY" key, and goes through the same process of hooking the blip with its symbol again. Now the system draws a track for the blip and advances the symbol on the projected path with each radar update. (Note that if the simulated pilot of the blip changes the course or speed, the symbol and the track will continue on the old course until the student rehooks.)

Once the student has hooked and rehooked the blip, he or she will depress the "FUL" and "WPN" keys to find out aircraft C1's fuel and weapons status. These figures will be posted in the appropriate display area of the simulated tracking computer console display screen. The student then observes a second blip appearing near the top of the screen. The joystick is activated and the student attempts to hook the new blip with the "C2" symbol. A beep from the console indicates that the simulated IFF function has determined that C2 is not an appropriate designation. The student now depresses the "B1" symbol key, and the symbol appears. This means that the new blip is a Bogey (a bad guy). The student reactivates the joystick, and, after the next screen update, rehooks the B1 blip. Now that the tracking computer has a fix on the location and course of the Bogey, an intercept can be computed. The student depresses the gray "INT" key. On a reserved portion of the simulated tracking computer console display the student sees a request for the symbol of the combat air patrol to be assigned to the intercept. He depresses C1. The system then asks for the Bogey to be intercepted. The student enters B1. The system then displays a recommended intercept heading, say 270 degrees. The student must now send this recommendation to the pilot of C1 quickly. This is done by depressing the yellow "INT" key and following the system's directions.

As the two blips near each other, the Bogey may take evasive action, which the student must respond to by making the simulated tracking computer recompute intercept or attack headings. Attack headings must be computed when a fighter is within attack range of a

Bogey. The new recommendations must, of course, be relayed to the pilot. Finally, when the student judges that the fighter is within firing range of the blip, he directs it to fire a missle. If the fighter is within range and on the correct attack course, the Bogey is downed and the student wins the exercise. The student can lose an exercise either by allowing the Bogey to shoot down the combat air patrol or by allowing the Bogey to escape.

The exercise dscribed was a simple problem in that only one Bogey and one combat air patrol were present. The example was further simplified in that events were regularly paced and the student did not make mistakes that might have resulted in the presentation of instructional feedback messages.

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