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INSTRUCTIONAL CONTROL AND PART/WHOLE-TASK TRAINING: A REVIEW OF THE LITERATURE AND AN EXPERIMENTAL COMPARISON OF STRATEGIES APPLIED TO INSTRUCTIONAL SIMULATION

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This experiment examined the effects of learner and program control and part-task and whole-task training strategies in a microcomputer-based instructional simulation program. Undergraduate Reserve Officer Training Corps (ROTC) students were taught how to use a simulated head-up display (HUD) and radar-electric optical (REO) display to estimate the location and heading of aircraft symbols on a computer screen. The part-task version of the program delivered instruction and practice on each of four parts of the target-estimation task. The whole-task version taught the entire task in one lesson. Subjects under learner control had the option to complete additional instruction after each practice activity, while those under program control received additional instruction when their practice performance was below criteria. Under program control, part-task subjects estimated targets significantly faster and spent significantly less time on instruction than whole-task subjects. Results also revealed a significant control by training task interaction that identified complex relationships among the instructional treatments.

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PREFACE

This report documents the results of a literature review and an experiment that addressed training design issues relative to Air Force Undergraduate Pilot Training using microcomputer-based instructional simulation. The experiment reported herein represents a continuation of previous research reported by Mattoon and Edwards (1993) in the Technical Report, Theoretical Implications and Empirical Findings on Instructional Control and Part/Whole-Task Training (No. AL/HR-TR-1993-0089). The objective of this research is to identify and define factors that influence the effectiveness of instructional simulations used in Air Force training programs and other technical training environments. The work was conducted under Work Unit 1123-25-15, by the Unit Level Training Research Applications (ULTRA) group. The work unit monitor was Dr. Bernell J. Edwards, and the investigator was Dr. Joseph S. Mattoon.

INSTRUCTIONAL CONTROL AND PART/WHOLE-TASK TRAINING: A REVIEW OF THE LITERATURE AND AN EXPERIMENTAL COMPARISON OF STRATEGIES APPLIED TO INSTRUCTIONAL SIMULATION

INTRODUCTION

The purpose of this report is to expand the literature review and experimental findings presented in Technical Report, AL/HR-TR-1993-0089, Theoretical Implications and Empirical Findings on Instructional Control and Part/Whole-Task Training (Mattoon & Edwards, 1993). The present experiment examined the effects of learner and program control and part- and whole-task training on learning a radar display-interpretation skill.

An important goal in the design of effective training is to provide an appropriate amount of instructional support for learners as they attempt to achieve performance objectives. Instructional support is ". . . a set of events external to the learner which are designed to support the internal processes of learning" (Gagné & Briggs, 1979, p. 155). These events take place through learners' interactions with training materials such as examples of concepts, descriptions of rules, practice exercises, and feedback on their performance. Instructional control is a key factor in accommodating the individual needs among learners for instructional support (Carrier, Davidson, & Williams, 1985; Hannafin, 1984). The amount of support needed during a learning activity depends on the individual's initial ability, knowledge of the subject matter, and rate of progress toward performance goals.

Computer-assisted instruction (CAI) provides a good deal of flexibility in the control of instructional support. Theorists have suggested that instructional support within CAI can be effectively controlled by individual learners (Hannafin, 1984; Milheim & Martin, 1991), but research has shown that learners may not possess such a capability without the assistance of advisement that is presented simultaneously with instructional support options (Johansen & Tennyson, 1983; Santiago & Okey, 1992; Steinberg, 1977, 1989; Tennyson, 1980, 1981; Tennyson & Buttrey, 1980).

There are two basic types of instructional control strategies, learner control and program control. Learner-controlled instruction enables the individual to alter the type and amount of instructional support received during a learning activity. In program-controlled instruction, a predetermined body of content information and practice activities are delivered (fixed program control), or a computer program adjusts the content and amount of practice based on each individual's performance (adaptive program control). Fixed program control is usually not as effective as adaptive program control unless the instructional content consists of a simple linear sequence of events (Goetzfried & Hannafin, 1985). Adaptive program control is a strategy that exploits the advantages of computerized instruction by continuously regulating instructional support as a function of learners' interactions with the program (Tennyson, 1980, 1981).

Research has repeatedly shown that learners have difficulty in choosing the most appropriate type and amount of instructional support and tend to terminate instructional activities before achieving objectives when given control (Steinberg, 1977, 1989). Positive effects for learner control do not appear to permanently affect learning (Gray, 1987; Mattoon & Klein, 1993). Munro, Fehling and Towne (1985) found that learners did not perform as well under program control as under learner control, but this difference was due to the intrusive quality of the instruction rather than type of control. Some researchers have successfully reduced the time students spend on instruction via learner control without negatively affecting their performance (Carrier et al., 1985; Tennyson, 1981, Tennyson & Buttrey, 1980), while others did not detect this advantage (Avner, Moore, & Smith, 1980; Ross & Rakow, 1981) or found the opposite effect (Goetzfried & Hannafin,1985). Carrier et al. (1985) and Gay (1986) point out that students who attribute their success to their own ability may do better under learner control than under program control. Yet, the results of their studies show that lower-ability learners performed better under program control than under learner control, so learner control may be ineffective for subject matter that is especially complex or difficult.

Researchers have attempted to increase the effectiveness of learner control by designing CAI that advises learners on the best choice of instructional support options based on their ongoing progress (Santiago & Okey, 1992). Advisement can be generated from diagnostic summaries that reflect measures of learners' initial ability and their performance on practice tasks. These summaries can be used to generate individual prescriptions in the form of advisement (learner control), or the summary information can be used to automatically adjust instructional support (program control).

Instructional control has not been thoroughly examined in the context of instructional simulation, a type of computer-based training that is quite different from conventional CAI (Alessi, 1988). Instructional simulation has become important to military and other technical training programs (Gray & Edwards, 1991), but few studies have examined instructional support strategies for simulation-based training (Andrews, 1988). Training simulations are often used to teach adults how to perform specific tasks such as flying an aircraft or operating sophisticated electronic systems (Mané & Donchin, 1989; Reigeluth & Schwartz, 1989).

The complex skills needed to perform such tasks consist of an integrated unit of intellectual, perceptual, and motor abilities (Schneider, 1985). When learners engage in complex tasks via instructional simulations, performance is assessed by continuous measures of speed and accuracy instead of discrete responses to test questions as in conventional CAI (Mattoon & Thurman, 1990).

In conventional CAI, learners typically read text material, and their performance can usually be assessed with short-answer or multiple-choice questions. This type of performance is primarily a function of declarative knowledge, whereby the recall of information from long-term memory is a slow and deliberate process. In contrast, complex skills are primarily a function of procedural knowledge, whereby the learner quickly transforms stimuli or data structures into information that can be, to some degree, automatically acted on to perform a specific task (Gagné, 1985). Instructional simulations graphically reproduce environments in which learners acquire complex skills by manipulating dynamic variables and simulated objects (Mattoon & Thurman, 1990). For example, Air Force student pilots develop complex aviation skills by interpreting information shown on computer-driven visual displays and controlling simulated aircraft and weapons systems (Gray & Edwards, 1991). This type of training involves dynamic procedures that are performed in real-life situations as opposed to declarative knowledge that is taught in conventional CAI programs.

Complex tasks usually involve the execution of multiple subtasks (parts of the whole task) to accomplish a single goal (Gropper, 1983; Naylor, 1962; Stammers, 1982; Wightman & Lintern, 1985). Part-task training helps learners understand the relationships among subtasks and develop initial skills that enable them to perform an entire complex task. When part-task training is applied to instructional simulation, the criterion task is demonstrated as a set of subtasks, and instruction and practice are given on each subtask and groups of subtasks as a prelude to practice on the whole task. The decomposition of a task into a set of components reduces the complexity of task descriptions, examples, and practice activities. In contrast, whole-task training programs describe and demonstrate the entire criterion task, and students practice the whole task (Gopher, Weil, & Siegel, 1989).

Comparisons between part- and whole-task training have produced mixed results. Most studies from 1900 to the early 1960s concluded that whole-task training is superior to part-task training (Naylor, 1962), but more recent studies show greater favor for part-task methods when they are applied to simulation-based training (Fabiani, Buckley, Gratton, Coles, Donchin, & Logie, 1989; Frederiksen & White, 1989; Mané, Adams, & Donchin, 1989; Mattoon, 1992).

REVIEW OF LITERATURE

Two major aspects of an instructional simulation are (a) the strategy used to control instructional support and the simulation and (b) the manner in which the criterion task is represented in the program. The instruction may be controlled by the individual learner (learner control), by the program (program control), or control may be shared in some manner. The criterion task may be broken down into subtasks (part-task training) or represented in its entirety (whole-task training), or some combination of these two strategies may be employed. The present literature search revealed only a few studies that examined instructional-control issues in instructional simulation, and no studies were found that examined the potential joint effects of instructional control and part/whole-task training. Therefore, the first part of the review consists mostly of summaries of experiments done with conventional CAI. This section is followed by a review of part/whole-task training research.

Instructional Control

The most common procedure for comparing the effects of different instructional control strategies is to expose different groups of subjects to different versions of CAI. Subjects usually study instructional content, complete practice items, and respond to short-answer or multiple-choice questions. In these studies, measures of treatment effects are based on number of correct responses on posttests and the time learners spend on instruction.

Most instructional control studies have shown that learners interact with more appropriate instructional materials and expend more time on instructional events under program control (Steinberg, 1977, 1989). Avner et al. (1980) administered program- and learner-controlled CAI that taught laboratory procedures for a beginning chemistry course to undergraduates. The program-control version required subjects to correct each of their errors on practice questions by branching back to the content material for review and requiring the individual to respond again to the same question that was incorrectly answered. The learner-control version enabled subjects to advance through the lesson or review content regardless of their errors. Subjects under learner control tended to advance without reviewing and consequently made significantly more errors and performed slower on lab exercises administered after the instruction. Evidently, subjects under learner control did not realize the importance of reviewing key parts of the content material that they had not understood or memorized, or they chose not to expend additional effort on review.

Some researchers have used pretest scores to control type and amount of instructional support. Ross and Rakow (1981) compared learner control to fixed and adaptive program control using self-paced written modules that taught math rules to undergraduates. The number of examples used to teach each rule was either fixed according to the individual's pretest score, controlled via adaptive program control, or controlled by the learner. Those who received the adaptive instruction achieved higher posttest scores than the learner-control and the fixed program-control treatment groups. Also, subjects under learner control chose fewer examples than those presented to students in the fixed and adaptive groups and spent less time on the instruction than either of the program-control groups.

Some instructional control studies have focused on individual differences among learners. Carrier et al. (1985) divided learners into two groups according to their scores on the Internal Achievement Rating Survey. Subjects who scored high were described as possessing a high degree of locus of control which is associated with the tendency to engage in more autonomous behavior and attribute success to personal effort. Gay (1986) divided lower and higher ability subjects according to their scores on a pretest on the subject matter being taught. In both studies, program-controlled CAI that presented a fixed sequence of content material was compared to learner-controlled versions that enabled subjects to control sequence and amount of practice. Results by Carrier et al. (1985) indicated that subjects with a high degree of locus of control performed better under learner control and were able to complete the instruction in significantly less time. Gay's (1986) results also showed that high-ability students were able to complete instruction in less time under learner control, but the lower ability students received significantly lower posttest scores under learner control than under program control. Evidently, learner control provides some benefits for certain types of learners, but these may be outweighed by the deficits it produces for others. Also, these studies may have yielded better results for adaptive program control, because a fixed amount of instructional support is seldom appropriate for students with different levels of ability.

Providing learners with performance feedback and specific information on their control decisions has been shown to improve the effectiveness of learner control but not beyond that of program control. Schloss, Wisniewski, and Cartwright (1988) administered different versions of CAI to adult subjects. One learner-control version displayed feedback in the form of a cumulative practice score and the number of times the subject chose to review material after incorrectly answering a practice question. The other learner-control version did not supply the information on review choices. One program-control version provided the cumulative score, and the other did not. Those who received cumulative scores during practice achieved higher posttest scores than those who did not.

The effect of performance feedback was compared with the effect of advisement on learners' control decisions in a study by Santiago and Okey (1992). Feedback consisted of the individual's practice score and a criterion score, and advisement consisted of a specific number of practice questions to complete. Three different learner-control CAI lessons were administered that taught graduate students some basic principles of instructional design. Each subject received either advisement, performance feedback, or both types of information together. Subjects who received adaptive advisement completed more practice questions and achieved significantly higher posttest scores than those who received only performance feedback. Yet, the only implication of these results seems to be that direct advisement is more likely to induce learners to cover additional instruction than low practice scores. If a training situation requires that learners be told exactly what to do, providing them with the specific instructional support that they need may be more practical.

Performance feedback is important to learners' and can be helpful to them for making certain types of control decisions such determining when to terminate a practice activity or seek additional instructional support. Periodically summarizing and displaying learners' performance appears to improve learning under both types of instructional control (Schloss et al., 1988). The value of presenting informative feedback to learners during practice activities is well established for written instruction (Kulhavy, 1977) and for CAI (Gagné, Wagner, & Rojas, 1981), but their is little evidence that feedback or advisement can boost the effectiveness of learner-controlled CAI beyond that of program-controlled CAI.

Tennyson and his associates stress the importance of both performance feedback and adaptive advisement in learner-controlled CAI. They conducted several studies that compared different forms of learner- and program-control strategies (Johansen & Tennyson, 1983; Tennyson, 1980, 1981; Tennyson & Buttrey, 1980). In these studies, advisement consisted of information on the individual's progress toward mastery, specific examples to study, and specific practice items to complete as a function of the individual's initial ability and their ongoing practice performance.

In one of the studies (Tennyson & Buttrey, 1980), two program-control treatments were compared with two learner-control treatments. One of the program-control treatments and one of the learner-control treatments provided advisement, and the others did not. Similar treatments were compared by Tennyson (1981) and Johansen and Tennyson (1983). These studies produced about the same results. Those under learner control who received advisement performed at about the same level on posttests as those under program control. However, subjects under learner control spent significantly less time on instruction than those under program control. Subjects under learner control, who were not presented with advisement, earned significantly lower posttest scores than subjects in the other treatment groups.

Investigations of learner and program control indicate that performance feedback and adaptive advisement are important in CAI. Yet, they do not provide any strong evidence for choosing one control strategy over another. In Tennyson's studies, subjects under learner control may have rejected some of the advice and bypassed examples and practice items to finish in less time than those under program control. However, specific conditions under which advice was followed or rejected were not described. If the performance criteria were too stringent in these studies, the choice to reject advice would have guaranteed less time on instruction under learner control. Therefore, performance criteria may have been responsible for the differences in training time rather than type of instructional control.

Instructional support must be carefully administered, so that it does not interfere with learners' acquisition of skill during practice on complex tasks. Munro et al. (1985) compared learner- and program-controlled simulation training that taught adults how to perform a simulated air-intercept control task. Subjects monitored a simulated instrument display that showed the location and heading of radar-detected aircraft and fuel and weapons status. Subjects made a series of key presses in response to specific situations described by the display symbology. Subjects under learner control were able to display performance feedback messages when they wished, whereas those under program control automatically received a message each time they made an error during practice. Subjects performed better under learner control than under program control. Evidently, the mental processing demands in this dynamic environment could not tolerate the constant interruption produced by feedback messages in the program-control condition.

Many training simulations are designed in a manner that assumes learners will be able to effectively control instruction and simulation events. This assumption is contrary to the findings of educational research and may lead to the development of poor training simulations (Andrews, 1988). Mattoon and Klein (1993) point out that the additional tasks learners must engage in to control an instructional simulation may produce performance deficits. They administered a whole-task CAI lesson that taught undergraduates how to estimate the location and heading of target symbols on a simulated radar display. (This task was basically the same as the criterion task used in the present experiment.) Subjects in one learner-control treatment received immediate (per response) and cumulative performance feedback and were instructed to adjust the "level of challenge" (task difficulty) for response time and accuracy criteria as their practice score improved. A second learner-control group received the same information plus advisement messages that recommended specific challenge levels. A program-control version of the simulation automatically set levels of challenge as a function of each learner's incremental improvements in speed and accuracy. Two posttests, one immediate and one administered one week after training, consisted of 30 targets each. Subjects under learner control performed the target-estimation task at a slower rate on the delayed posttest compared to the immediate posttest. Yet, the program-control group performed the task at the same speed on both posttests. The additional task of controlling challenge under learner control appears to have interfered with subjects' retention of skill over the delay period.

Part- and Whole-Task Training

Part-task strategies appear to be most appropriate when (a) time on practice activities is limited, (b) the criterion task consists of subtasks that are highly integrated--performance on one subtask affects performance on another subtask or on the entire task, or (c) learners lack prior knowledge of the task being taught (Adams, 1960; Briggs & Naylor, 1962; Holding, 1965; Naylor, 1962; Wheaton, Rose, Fingerman, Korotkin, & Holding, 1976; Wightman & Lintern, 1985).

Several part-task methods have been devised and compared with whole-task training. Progressive part-task training may be the most effective method to teach complex tasks that consist of highly integrated subtasks (Frederiksen & White, 1989). This strategy specifies a sequence of training events whereby the learner advances through a number of transitions from subtask descriptions to the execution of the entire task. The learner begins by studying descriptions and examples of a single subtask, then practices the subtask until a desired level of proficiency is achieved. Then, a second subtask is introduced and combined with the first, so the two subtasks can be practiced together. The training progresses in this manner until the learner is able to perform all of the subtasks together which is equivalent to whole-task practice. In contrast, whole-task training teaches the entire task as a whole unit, and learners practice the whole task rather than parts of the task.

The main purpose of decomposing a complex task for part-task training is to separate it into a set of manageable "chunks." The assumption is that learning will be improved because of the reduced load on working memory during instruction and practice. This step-by-step strategy helps learners pass essential information from working memory to long-term memory during the training process. The shortcoming of part-task training is in the difficulty learners sometimes exhibit when they attempt to perform all the subtasks together during the final stages of practice (Stammers, 1982; Wightman & Lintern, 1985). However, some studies have shown that this problem may not be as serious as the learning deficits produced by whole-task training.

A group of studies compared several part- and whole-task training methods that taught adult male subjects how to play a simulation game ("space fortress"). The game was designed to imitate some of the tasks that are performed by pilots and aircrew members in aviation environments (Mané & Donchin, 1989). Subjects were taught how to control a simulated spaceship and its weapons which were displayed on a computer screen. The spaceship and the simulated space fortress that they attempted to destroy possessed some complex dynamic qualities that made the game extremely difficult to master. In these studies, subjects performed better under progressive part-task training than under whole-task training when given equal training time.

Four training methods were compared by Mané et al. (1989) that taught the space fortress game. In a whole-task treatment group, subjects were introduced to and practiced the criterion game. Two other whole-task groups practiced with a spaceship that was 25% and 50% slower than the spaceship in the criterion game. A part-task treatment group received instruction and practice on three game components. Making the whole task easier by slowing down the spaceship proved to be ineffective because it changed the strategies that were needed to score high on the criterion game. Part-task subjects achieved significantly higher scores on the criterion game than the other three groups. Also, whole-task subjects required significantly more training time to achieve the same level of performance as the part-task group.

Another part- and whole-task comparison was conducted by Frederiksen and White (1989) who administered a sequence of 15 part-task training games prior to whole-task practice. Subjects advanced from one game to the next after reaching a predetermined level of performance or a maximum number of trials on each game. Part-task subjects achieved significantly higher scores than those trained on the criterion game after equal training time. Also, there were significantly less differences between low- and high-ability learners in the part-task group. These findings were attributed to a careful cognitive task analysis that guided the design of part-task exercises. The exercises enabled subjects to build several important subskills that were essential to overall successful performance but were very difficult to develop by practicing the criterion game.

Two whole-task training strategies were compared by Gopher et al. (1989). In one group, subjects were presented with a score on two separate parts of the space fortress game. These subjects performed significantly better than those in a second group who were presented with an overall game score. The dual-score method evidently helped subjects focus on two separate aspects of their performance which proved to facilitate the acquisition of game skills more effectively than a single score that summarized overall game performance. This whole-task attention-focusing strategy provides learners with a similar advantage as that produced by part-task training in that it enables learners to focus on separate parts of the criterion task.

The best training methods may include characteristics of both part- and whole-task training. Fabiani et al. (1989) compared the whole-task, dual-score strategy developed by Gopher et al. (1989) with the part-task strategy developed by Frederiksen and White (1989). A third treatment group received whole-task practice on the criterion game with a single game score. Results indicated that the whole-task group that received two separate scores performed better than the whole-task group that received an overall game score. Part-task subjects exceeded whole-task subjects on most of the dependent measures of game skill, but they experienced greater deficits in their performance than whole-task subjects when distracter tasks were performed simultaneously with the space fortress game.

Another part/whole-task comparison was conducted using the same basic criterion task employed in the present experiment (Mattoon, 1992). In the part-task treatment, the task was divided into three subtasks that were practiced separately before being combined and practiced as a whole task via a progressive part-task strategy. Subjects in the whole-task group received the same part-task instruction but practiced the whole task. Both groups of subjects received cumulative performance feedback and controlled the number of exercises presented prior to an immediate posttest. Overall, males performed the task more quickly and with greater accuracy than females on the posttest. Female subjects performed the task significantly faster and chose to complete more practice prior to the posttest under part-task training compared to females who completed whole-task training.

Summary

The current review of the literature has indicated that the comparison of learner- and program-control strategies is a major issue for research on computer-based instruction. Some researchers have attempted to show that learners can effectively control instruction if they are provided with performance feedback and advisement on control decisions. Yet, most empirical evidence is in favor of program control. Instructional control strategies have not been thoroughly examined in the context of instructional simulation, but the findings of two studies (Mattoon & Klein, 1993; Munro, Fehling, and Town, 1985) indicate that instructional support must be carefully controlled to avoid interfering with learners' concentration on complex practice tasks.

Part-task training is probably better suited to teach some complex tasks than whole-task training, but the specific characteristics of these two types of training that are most influential on learning and performance have not been well defined. The fundamental differences between part- and whole-task training may interact with type of instructional control, but no studies were found that investigated the potential joint effects of these two variables.

EXPERIMENT

The present experiment examined part- and whole-task training under learner- and program-control conditions. The criterion task was chosen based on its relevance to aircrew training programs. In such programs, student pilots must develop a high degree of proficiency for interpreting the head-up display (HUD) and the radar-electric optical (REO) display to perform several types of flying missions. One function of these cockpit instruments is to display numeric and symbolic data that pilots interpret to monitor the location and heading of "target" aircraft (other aircraft which may be detected by the pilot's radar during a flying mission). The HUD and REO provide the same basic target information, but they use different symbology.

Four research questions were addressed:

1. Do learners achieve different levels of skill for the target-estimation task under program and learner control or under part- and whole-task training?
2. Does instructional control or part/whole-task training affect training time?
3. Does learner and program control or part- and whole-task training

differentially affect subjects' ability to perform the same task with the REO after being trained with the HUD?

4. Do instructional control and part/whole-task training interact, so that different combinations produce differential training effectiveness?

Method

Subjects

Subjects were 48 male ROTC undergraduates from a large public university in the southwestern United States.

Materials

The four treatments (program-control part-task, program-control whole-task, learner-control part-task, and learner-control whole-task) were delivered by an instructional simulation program developed with HyperCard software and delivered by Macintosh computers with 12-in. screens. Subjects executed en route tasks and the criterion task using a computer mouse. The first part of the program taught subjects how to use the mouse to manipulate a symbol to activate "buttons" (graphic objects displayed on the computer screen).

A pretest was administered to assess subjects' initial level of skill with the mouse. The pretest required the subject to "drag" a graphic object to the center of a small circle of numbers on the screen and rotate it to a designated number. The pretest involved the same motor tasks and the same graphic object used to perform the target-estimation task in the experiment.

Criterion Task

The instruction taught subjects how to interpret the information shown on a simulated HUD to estimate the location and heading of a target symbol relative to a symbol that represented the pilot's aircraft. Subjects estimated target location by positioning a symbol called the "locator" on a 180-deg arc and estimated its heading by rotating the locator to point in a particular direction. A target's location was designated on the HUD by azimuth, a whole number that ranged from zero to 60 and a horizontal arrow that pointed to the left or right. The number corresponded to the angular distance the target was positioned to the left or right of the pilot's aircraft. The REO displayed azimuth by the position of a pointer along a numerical scale.

Aspect designated a target's heading with respect to the pilot's aircraft (the direction that the target symbol pointed on the computer screen). Aspect was represented on the HUD by the position of a pointer along the circumference of a circle. Aspect was displayed on the REO as a whole number that ranged from zero to 180 deg, and the word "right" or "left" appeared below the aspect value to designate the side of the target that faced the pilot's aircraft.

When a target's azimuth was zero, it was located straight above the pilot's aircraft. In this situation, the target symbol pointed in the same direction as the aspect pointer on the HUD. However, when the azimuth was greater than zero, a target's heading consisted of the deg of the aspect (position of the aspect pointer on the HUD) plus the deg of the azimuth. Since most targets had an azimuth that was considerably greater than zero, subjects had to consider both azimuth and aspect together to accurately estimate heading. Figure 1 shows a reproduction of the arc, locator, pilot's aircraft, and a target with an azimuth of 45 deg right (located to the right of the pilot's aircraft) and an aspect of 90 deg left (left wing toward the pilot's aircraft.

Each target estimate was designated as correct or incorrect during practice based on response time and accuracy criteria. Accuracy criteria was met when a subject placed the locater within seven deg of the correct target location and rotated it within 30 deg of its correct heading. Response time criterion was set at a maximum of 10 s for each half of

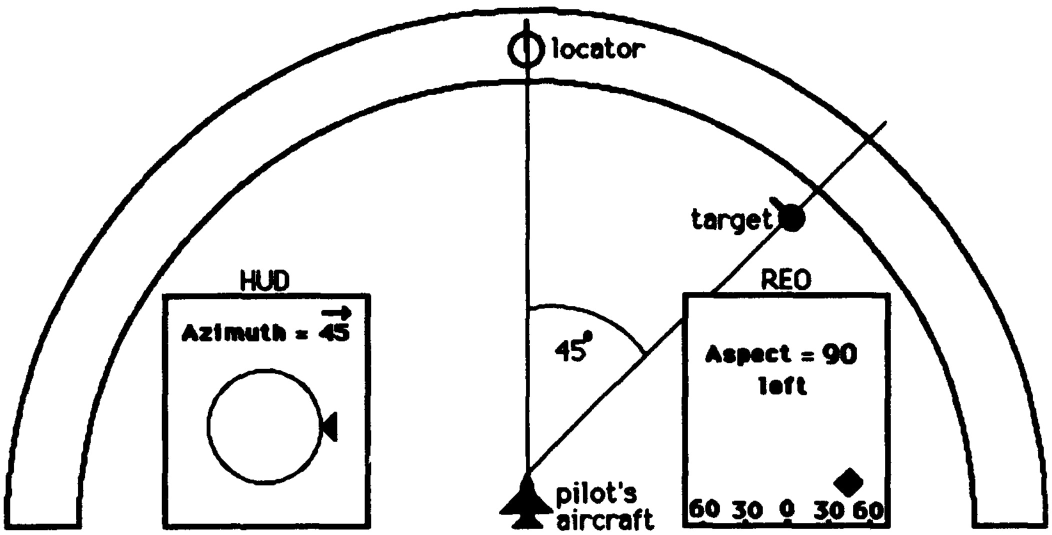

Figure 1. HUD, REO, arc, locator, pilot's aircraft, and a target with an azimuth of 45 deg right and an aspect of 90 deg left.

the target-estimation task (estimation of location and estimation of heading). The program provided feedback after each target estimate which consisted of the appearance of the target symbol at the correct location and heading.

Additional feedback was presented at the end of each of four practice activities that included the number of estimates that met response time criterion, the number of estimates that met accuracy criteria, and an advisement message. The advisement message--additional instruction may increase your accuracy and speed--was displayed if less than half of the subject's estimates met criteria. Otherwise, the message--your performance does not need improvement--encouraged the subject to bypass additional instruction.

Treatments

In the two program-control treatments, the program presented additional instruction to the subject each time less than 50% of the estimates in a practice activity met performance criteria. If 50% or more met criteria, the program bypassed additional instruction. The two learner-control treatments enabled subjects to complete or bypass additional instruction regardless of the number of estimates that met criteria. When 50% or more target estimates in a practice activity met criteria in either treatment, the feedback included a message which stated that no further performance improvement was needed.

In the part-task treatments, each of four different parts of the target-estimation task were taught by a separate lesson--estimation of target location without regard for heading, estimation of heading for targets with an azimuth of zero, estimation of location and heading for targets with a left azimuth, and estimation of location and heading for targets with a right azimuth. A practice activity was delivered after each part-task lesson that corresponded to the part of the task taught in the lesson. After the last part-task lesson, subjects practiced estimating location and heading of targets with a left or right azimuth (whole-task practice).

In the whole-task treatments, all four parts of the target-estimation task were taught in one lesson prior to a sequence of four whole-task practice activities. The targets were arranged in an easy-to-hard format, so that the easiest targets to estimate were presented in the first practice activity, and targets became increasingly difficult in subsequent activities.

The program delivered a HUD posttest with 30 targets to estimate following the last practice activity. After the HUD posttest, the program delivered an overview on the REO display that included an interactive simulation of the REO. The simulation enabled subjects to alter target parameters on the HUD while observing corresponding changes in target information on the REO. A posttest was then presented and required subjects to estimate 30 targets using the REO. Figure 2 illustrates the sequence of instructional events that were presented and the differences between the part- and whole-task treatments.

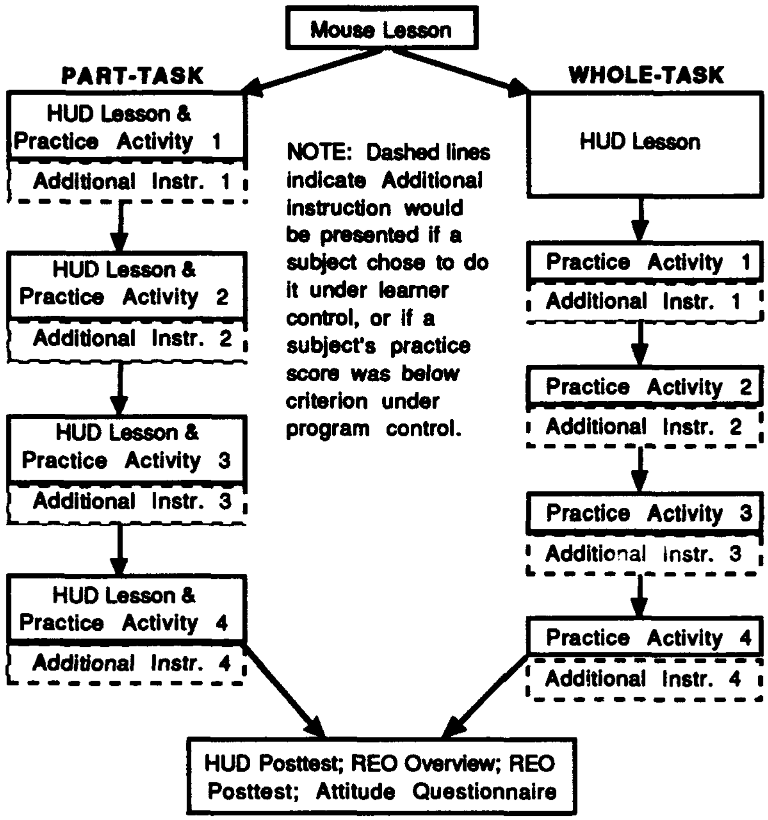

Figure 2. Sequence of Instructional Events.

Procedures

Each subject was paid $15 for participating in one of several equivalent experimental sessions that lasted about 90 minutes each. An equal number of subjects were assigned to each treatment group in the order they arrived at the computer site. They read a printed handout that described the conditions of receiving payment and the instructional simulation before starting the program. Subjects began by entering their name, identification number, and gender on the keyboard. They completed instruction that taught them how to use a computer mouse, HUD lesson material, HUD practice activities, HUD posttest, REO overview, and REO posttest, respectively.

Data Analyses

The two types of instructional control were completely crossed with the two types of training task and were manipulated between subjects to produce a factorial (2 x 2) design. Subjects' accuracy and response time were averaged across 10 pretest trials, 30 HUD posttest trials, and 30 REO posttest trials. These measures were analyzed using a multivariate analysis of variance (MANOVA) which was followed by a univariate analysis of variance (ANOVA) on response time and an ANOVA on accuracy. En route data were compared among treatments and included separate analyses for the time subjects spent on different parts of the program, scores on the practice activities, and option use by subjects under learner control. A significance level of $p<.05$ was used on statistical tests.

Results

Response time on the mouse test was significantly correlated with response time on the posttests ($p<.01$), so mouse response time was used as a covariate on subsequent analyses of posttest performance. Significant differences among treatment groups were detected for posttest response time, training time, and practice performance.

Posttests

The initial analysis of posttest performance indicated significant differences among the four treatment groups, multivariate $F(6,38) = 2.94$, $p < .05$. A follow-up ANOVA indicated that subjects who completed part-task training were significantly faster (M = 11.8 s) than those who completed whole-task training (M = 13.4 s), $F(1,43) = 7.97$, $p < .05$. Mean response times for the HUD posttest are reported in Table 1.

Table 1. HUD Posttest Response Times by Type of Control and Task

Task	Control: Learner Control	Control: Program Control	Total
Part-Task			
M	12.7	10.9	11.8
SD	2.02	2.19	2.25
Whole-Task			
M	12.3	14.6	13.4
SD	1.60	2.71	2.48
Total			
M	12.5	12.8	12.6
SD	1.79	3.05	2.48

Note. Time is reported in seconds; maximum possible response time was 20.

A significant control by task interaction effect on response time was detected for the HUD posttest, $F(1,43) = 12.65$, $p < .001$. Part-task subjects were faster under program control (M = 10.9 s) than under learner control (M = 12.7 s), whereas whole-task subjects were faster under learner control (M = 12.3 s) than under program control (M = 14.6 s). This control by training task interaction is shown in Figure 3.

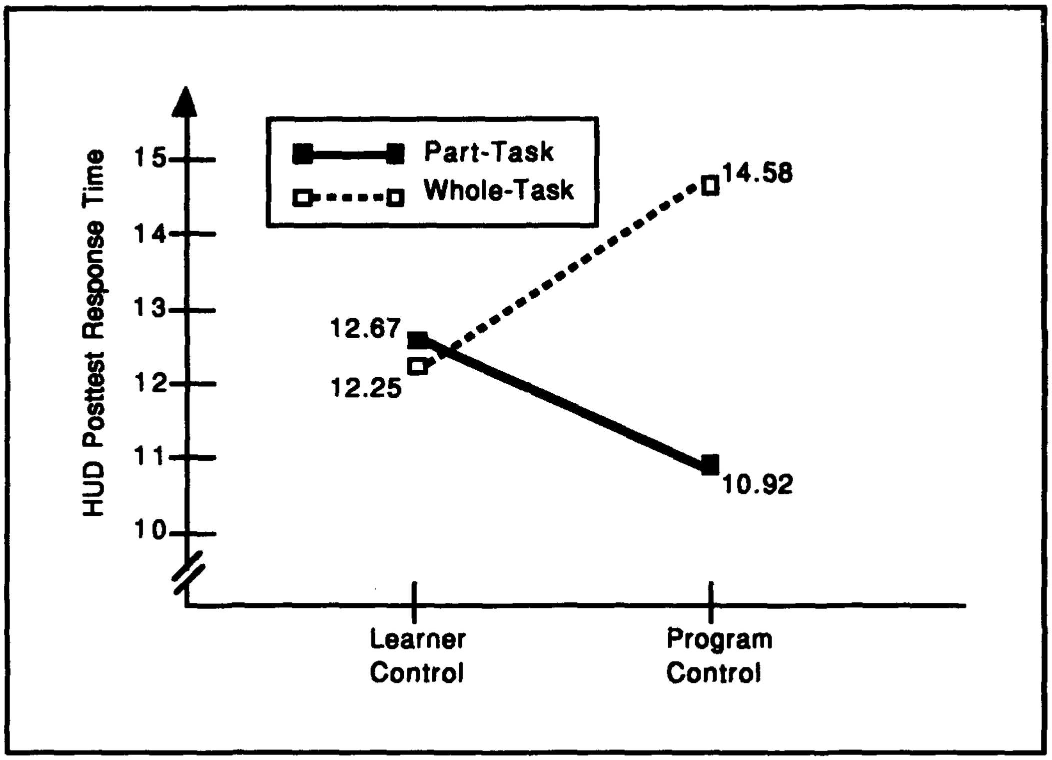

Figure 3. Type of control by task interaction for HUD posttest response time in seconds.

Mean response times for the REO posttest are reported in Table 2. The ANOVA showed that part-task subjects were also faster (M = 12.4 s) than whole-task subjects (M = 13.6 s) on the REO posttest, $F(1,43) = 5.03$, $p < .05$.

Practice Activities

Type of training task had a significant effect on the number of target estimates that met criteria on the four practice activities,

Table 2. REO Posttest Response Times by Type of Control and Task

Task	Control: Learner Control	Control: Program Control	Total
Part-Task			
M	12.8	12.1	12.4
SD	2.01	1.83	1.91
Whole-Task			
M	13.2	14.1	13.6
SD	1.53	2.07	1.84
Total			
M	13.0	13.1	13.0
SD	1.76	2.17	1.95

Note. Time is reported in seconds; maximum possible response time was 20.

multivariate $F(4,40) = 6.04$, $p < .001$. The proportion of scores in the part-task treatment that met criteria on the four practice activities was 92%, 83%, 67%, and 58%, respectively. The proportion of scores in the whole-task treatment that met criteria was 42%, 67%, 58%, and 50%, respectively.

The mean score for the part-task treatment ($M = 4.33$, $SD = 1.37$) was significantly greater than that of the whole-task treatment ($M = 2.67$, $SD = 1.58$) in the first practice activity, $F(1,43) = 15.63$, $p < .001$. Part-task scores were also significantly higher for the second activity (M = 4.38, SD = 1.71) than whole-task scores (M = 3.08, SD = 1.10), $F(1,43) = 10.10$, $p < .005$. The means for part-task subjects on the third (M = 3.04, SD = 1.43) and fourth (M = 2.75, SD = 1.67) practice activities were not significantly different from those of whole-task subjects' means for the third (M = 3.08, SD = 1.61) and fourth (M = 2.96, SD = 1.57) activities.

Part-task subjects also spent less time on feedback screens that showed the true target location and heading (M = 27.5, SD = 7.62 s) than whole-task subjects (M = 35.0, SD = 12.24 s) across the four practice activities, $F(1,43) = 21.67$, $p < .001$.

Training Time

Table 3 shows the average number of minutes subjects spent on the HUD lessons, practice, additional instruction, REO overview, and the complete lesson (time summed across all four parts of the program). Overall, subjects spent an average of 28.1 min on the complete lesson under learner control and an average of 30.8 min under program control. The means for training task were 30.2 min for part-task subjects and 28.7 min for whole-task subjects. The initial analysis indicated that training time differed significantly among treatment groups on different parts of the program, multivariate $F(4,41) = 19.23$, $p < .001$.

A follow-up ANOVA revealed a significant control by task interaction effect on the time subjects spent on the complete lesson, $F(1,44) = 4.70$, $p < .05$. Subjects under learner control spent substantially more time on the part-task instruction (M = 31.7) than on the whole-task instruction (M = 24.6), whereas those under program control spent more time on the whole-task instruction (M = 32.9) than on the part-task instruction (M = 28.8).

Follow-up ANOVAs were conducted to detect differences in time spent on each of the four parts of the complete lesson. Type of training

Table 3. Training Time by Type of Control and Task

Task	Learner Control	Program Control	Total
	HUD Lessons		
Part-Task			
M	13.7	12.6	13.1
SD	3.56	2.92	3.23
Whole-Task			
M	10.2	9.5	9.9
SD	3.30	2.21	2.77
Total			
M	11.9	11.1	11.5
SD	3.79	2.98	3.40
	Practice		
Part-Task			
M	6.9	7.1	7.0
SD	1.24	1.43	1.31
Whole-Task			
M	8.9	10.0	9.5
SD	2.05	1.98	2.05
Total			
M	7.9	8.6	8.2
SD	1.96	2.25	2.11
	Additional Instruction		
Part-Task			
M	8.3	6.6	7.5
SD	7.97	7.92	7.82

Table 3. Concluded

Whole-Task			
M	2.5	10.2	6.3
SD	4.06	7.79	7.25
Total			
M	5.4	8.4	6.9
SD	6.87	7.91	7.48
	REO Overview		
Part-Task			
M	2.8	2.5	2.7
SD	0.89	1.30	1.10
Whole-Task			
M	3.0	3.2	3.1
SD	1.14	1.21	1.15
Total			
M	2.9	2.8	2.9
SD	1.01	1.27	1.13
	Complete Lesson		
Part-Task			
M	31.7	28.8	30.2
SD	9.72	8.77	9.22
Whole-Task			
M	24.6	32.9	28.7
SD	7.80	9.28	9.40
Total			
M	28.1	30.8	29.5
SD	9.35	9.12	9.24

Note. Time is reported in minutes.

task produced a trade-off in the amount of time subjects spent on the HUD lesson material and the practice activities. Subjects spent more time on the four part-task HUD lessons (M = 13.1) than they spent on the whole-task lesson (M = 9.9), $F(1,44) = 13.88$, $p < .001$. However, they spent less time (M = 7.0) than whole-task subjects (M = 9.5) on the practice, $F(1,44) = 25.10$, $p < .001$.

A significant control by task interaction effect on the time subjects spent on additional instruction was also detected, $F(1,44) = 5.35$, $p < 05$. Subjects under learner control spent much more time on additional part-task instruction (M = 8.3) than on additional whole-task instruction (M = 2.5), whereas those under program control spent less time on additional part-task instruction (M = 6.6) than on additional whole-task instruction (M = 10.2). Figure 4 illustrates the fact that the control by training task interaction for time on the complete lesson was produced by the extreme differences in time on the additional instruction among the treatment groups.

Subjects spent about the same amount of time on the REO overview under learner control (M = 2.9) as they did under program control (M = 2.8). Part-task subjects spent an average of 2.7 min on the REO overview, while whole-task subjects spent an average of 3.1 min on this part of the program, but this difference was not significant.

Additional Instruction and Option Use

The significant interaction on time on additional instruction was produced by differences in the number of segments of additional instruction that were presented in each treatment group. A segment of additional instruction was available after each of the four practice activities, so the proportion of additional instruction that was presented to each subject was 0% (none of the segments), 25% (one of the segments), 50% (two segments), 75% (three segments), or 100% (all four

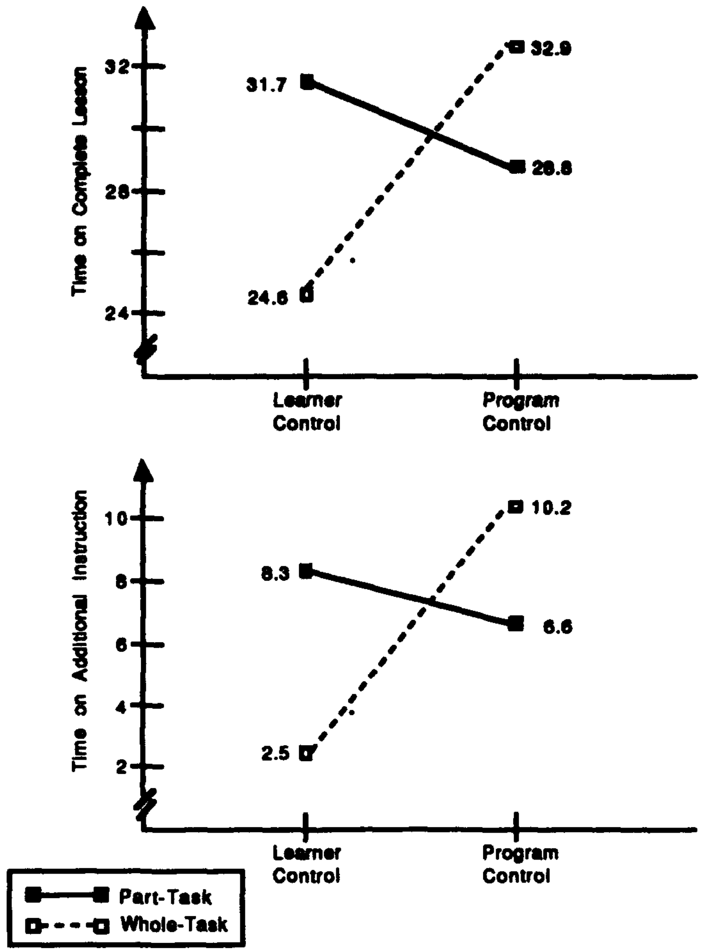

Figure 4. Time in minutes on complete lesson (top graph) and on additional instruction (bottom graph) by type of control and task.

segments). Table 4 shows the number of subjects, out of 12 in each treatment group, who received additional instruction after each practice activity.

Table 4. Segments of Additional Instruction and Time on Additional Instruction by Type of Control and Task

Segment	Learner Control	Program Control	Total
First			
Part-Task	7	1	8
Whole-Task	3	7	10
Second			
Part-Task	4	2	6
Whole-Task	1	4	5
Third			
Part-Task	8	4	12
Whole-Task	3	5	8
Fourth			
Part-Task	4	5	9
Whole-Task	0	6	6
Total Segments			
Part-Task	23	12	
Whole-Task	7	22	
Mean Time (minutes)			
Part-Task	8.3	6.6	
Whole-Task	2.5	10.2	

Subjects under learner control chose 23 segments of additional part-task instruction but only seven segments of additional whole-task instruction, resulting in the time differential of 8.3 versus 2.5 min. In contrast, subjects under program control were routed to 12 segments of additional part-task instruction (an average time of 6.6 min) and 22 segments of additional whole-task instruction (10.2 min).

Overall, subjects chose additional instruction on 19% of the occasions when their practice scores met criteria and chose to bypass additional instruction on 11% of the occasions when their scores were below criteria. Part-task subjects chose additional instruction 31% of the time when their scores met criteria, compared to only 6% in the whole-task treatment, and they bypassed additional instruction only 8% of the time when their scores were below criteria, compared to 15% in the whole-task treatment.

Discussion

The purpose of this experiment was to examine the effects of instructional control (learner control versus program control) and training task (part-task versus whole-task) in an instructional simulation program. In the part-task condition, each of four HUD lessons provided initial instruction on part of the target-estimation task, and each was followed by a part-task practice activity. In the whole-task condition, a single lesson covered all the initial instruction and was followed by four whole-task practice activities. Subjects under learner control had the option to complete a segment of additional instruction after each practice activity, while those under program control received or did not receive each segment of additional instruction as a function of their practice performance.

Results were generally in agreement with previous studies that found part-task training to be superior to whole-task training (Briggs &

Naylor, 1962; Fabiani et al., 1989; Frederiksen & White, 1989; Mané, Adams, & Donchin, 1989; Mattoon, 1992). Overall, part-task subjects performed the target-estimation task significantly faster than whole-task subjects on both posttests. However, the effect of training task on subjects' response time for estimating targets with the HUD was mediated by type of instructional control. In the program-control condition, part-task subjects estimated targets 34% faster with the HUD and 17% faster with the REO than whole-task subjects and spent 14% less time on instruction. This difference represents a considerable advantage for the program-control, part-task version of the program. Yet, under learner control, part- and whole-task subjects averaged about the same response time, and whole-task subjects spent 29% less time on instruction. This interaction was evidently produced by the differential amount of additional instruction received by the treatment groups.

The program-control, part-task treatment was evidently more effective in enabling subjects to understand the task or recall the rules needed to perform it than the other three treatments. Part- and whole-task subjects received the same information on the REO, and this was limited to a demonstration of its similarity to the HUD. Also, part-task subjects spent 15% less time (not statistically significant) on the REO overview than whole-task subjects. The fact that part-task subjects performed faster than whole-task subjects on the REO posttest indicates that they had more knowledge or skill associated with interpreting target information on the HUD than whole-task subjects.

Additional instruction appears to have had a negative effect on subjects' response speed. Part-task subjects under program control spent 26% less time on additional instruction but estimated targets 17% faster compared to part-task subjects under learner control. Whole-task subjects under learner control spent less than one fourth as much time on additional instruction but estimated targets 19% faster compared to whole-task subjects under program control.

Additional instruction increased the time lapse between practice activities, and this may have disrupted subjects' concentration and interfered with their learning. Munro et al. (1985) also found that learners, whose practice was interrupted by instructional information, performed less well on a complex task. They concluded that the processing demands associated with complex tasks calls for instruction that does not intrude on learners' attention on practice events. Results of the present experiment support this notion.

Part-task subjects spent significantly more time (32%) on initial HUD instruction but significantly less time (36%) on practice than whole-task subjects. Part-task HUD lessons contained about twice as many graphic examples, because the task was divided into two subtasks that were demonstrated separately. However, part-task examples contained half the graphic information and text that was presented in the whole-task examples, so it seems unlikely that the difference in time on the lesson material was due to the difference in number of examples.

Part-task subjects probably spent more time on initial instruction, because it was distributed across the practice activities instead of massed in one lesson as in the whole-task condition. Part-task subjects were given an opportunity to practice after each quarter of the initial HUD instruction, while whole-task subjects had to finish all the initial instruction before they could attempt the task. Whole-task subjects probably spent less time on initial instruction, because they became impatient and wanted to get to the first practice activity to see how well they were able to perform the task. Moving through the instruction more quickly may also have had a negative effect on whole-task subjects' understanding and retention of important information.

The difference for time on practice was clearly due to differences in the design of part- and whole-task materials. In the first two practice activities, the program encouraged part-task subjects to complete half of the target-estimation task in 10 s or less (estimation of target location on the first activity and estimation of heading on the second). Whole-task subjects were encouraged to estimate both location and heading in 20 s or less. This difference in response time criteria accounts for two min more time on the whole-task practice when summed across the 12 targets presented in the first two practice activities. Additionally, whole-task subjects spent an average of 27% more time than part-task subjects on each feedback screen during practice. These factors account for the greater time that whole-task subjects spent on practice.

Part- and whole-task subjects did not use learner-control options in the same manner. The program provided advisement messages that encouraged subjects to complete additional instruction or bypass it as a function of their practice scores. Part-task subjects chose to complete a segment of additional instruction on 31% of the occasions that their score was above *criterion*, while whole-task subjects chose additional instruction on only 6% of these occasions. Also, part-task subjects bypassed additional instruction on only 8% of the occasions that their score was below criteria compared to 15% of these occasions in the whole-task condition. In short, part-task subjects were more likely to choose additional instruction even when they were advised to bypass it, and whole-task subjects were more likely to bypass additional instruction when they were advised to complete it.

The differential use of learner-control options suggests that part- and whole-task subjects did not experience the same cognitive or affective states during training. Unlike the whole-task instruction that immediately described the criterion task in its entirety, part-task subjects did not receive a full description of the criterion task until the fourth quarter of the HUD instruction. The meaning of the option, labeled "additional instruction," may have been interpreted as "more complete information" by part-task subjects. This could have induced them to choose additional instruction more often in an attempt to gain a complete description of the criterion task. This *en route* behavior indicates that part-task subjects may not have fully understood the purpose of the learner-control options.

Whole-task subjects' tendency to bypass and spend less time on additional instruction appears to be related to affective rather than cognitive factors. Forty-six percent of their practice scores were below criteria compared to only 13% below-criteria scores received by part-task subjects. Evidently, having received poor scores during initial practice, whole-task subjects became discouraged with the program and were unwilling to spend much additional time on instruction. Students will bypass more review and remediation options in a learner-controlled lesson when they do poorly on instructional material (Carrier, 1984; Carrier et al., 1985; Gay, 1986). Clark (1984) explains that learners avoid the extra effort associated with choosing additional support options when they expect to fail anyway. Hicken (1991) found that undergraduate subjects bypassed more learner-control options for additional instruction during the most difficult parts of a CAI lesson. The present results indicate that learners under whole-task training may be less motivated to seek instructional support than those under part-task training due to the level of difficulty and potential frustration associated with whole-task practice.

Subjects apparently did not receive enough practice to master the criterion task in the present experiment, because their posttest performance was low in all four treatment groups. Only 57% of subjects' target estimates met speed and accuracy criteria on the HUD posttest, and only 29% met criteria on the REO posttest. Gagné and Briggs (1979) state that learners' speed and accuracy on tasks that have motor and perceptual components often improve slowly. Logan (1985) and Schneider (1985) explain that good performance on such tasks may require many hours of practice, because learners need to develop automatic motor responses to perceptual stimuli. If subjects had received enough practice in the present experiment to master the target-estimation task, the differences in performance among treatment groups may have been more robust.

The results of the present experiment have several implications for the design of instructional simulations:

1. Progressive part-task training may be more effective than whole-task training for teaching display-interpretation that requires fast and accurate responses to visual symbology.
2. Instructional support that interrupts practice may produce negative effects on performance.
3. Instructional control and part/whole-task training strategies can jointly affect terminal performance and en route behavior.
4. Instructional support for part-task training should be controlled by the computer program, or learner-control options should be well defined to enable learners to make the best choices as a function of their progress on performance objectives.
5. Learners may be especially susceptible to frustration during initial stages of whole-task practice.
6. Learners under part- and whole-task training will probably spend different amounts of time on content and practice materials because of fundamental differences in the two training methods.

The use of multiple training sessions in future studies may enable researchers to determine the effects of massed versus distributed practice in instructional simulation. Also, more than one training session would provide an opportunity to give learners enough practice to master difficult complex tasks. For example, a part-task treatment could provide instruction and practice for one subtask in the first training session and instruction and practice for other subtasks or groups of subtasks in each subsequent session (distributed part-task practice). A whole-task treatment could initially provide whole-task instruction followed by whole-task practice, and whole-task review and practice could be presented in each subsequent session (distributed whole-task practice). These methods could be compared to part- and whole-task treatments that deliver practice after all initial instruction has been presented (massed practice).

Whole-task subjects were reluctant to choose additional instruction in the present experiment which was probably due to their initial poor performance. This indicates that frustration could be a recurring problem in whole-task training. One solution may be to allow learners to take as much time as they want on each initial attempt to perform the criterion task, then slowly increase the stringency of response time criteria as performance improves. This method may be a good alternative to part-task training on certain criterion tasks.

Monitoring learners' perceptions may be equally important to monitoring performance in computer-based training research. A wider range of responses by subjects during en route tasks could help determine the relationships among certain cognitive and affective states and behaviors exhibited during training. For example, the degree of agreement with descriptive statements--"task is too difficult," "need a better description of the task," "need more practice on this task," and "ready to advance to higher challenge levels"--may yield more information than dichotomous choices among learner-control options or analyses on training time. Such inquiries could help identify causal factors associated with learners' perceptions and on-task effort.

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