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EFFECTS OF PC-BASED PRETRAINING ON PILOTS' PERFORMANCE IN AN APPROVED FLIGHT-TRAINING DEVICE

Willem J. Homan and Kathleen D. Williams

PC-based multimedia learning tools are rapidly approaching a level of refinement that will allow them to become a viable and inexpensive option to the more traditional simulator training vital for instrument pilot certification. The purpose of this research was to investigate whether pretraining through the use of an inexpensive multimedia computer program, the ELITE, will lead to effective pilot performance compared with pretraining that is limited to an FAA-approved flight-training device. A standard instrument flight maneuver, the Distance Measuring Equipment Arc (DME ARC), was chosen for this experimental study. Scores on criterion-referenced tests were used to evaluate cognitive pilot performance. A computer scoring program was used to evaluate pilots' psycho-motor skills in the FAA-approved flight-training device (AST-300). A *t*-test statistical procedure was selected to analyze the resulting data. The results from the data analysis of pilots' performance indicated that there is no significant difference between the experimental group and the control group on: (a) cognitive performance in both the pre- and post- written evaluations, and (b) pre- and post-tracking skills as a function of the type of pretraining. This study identified PC-based flight trainers in aviation as an effective procedural learning tool that should be used in the overall flight-training environment.

INTRODUCTION

In the field of aviation, one of the most exciting recent developments is the personal computer (PC) flight-training device. PC-based multimedia is rapidly approaching a level of sophistication that will allow multimedia flight training to become an effective low-cost alternative to the more expensive conventional flight simulator training (Homan, 1996). In 1997, aspiring instrument pilots can acquire high-quality flight-training software for as little as $350. This software can be installed on a personal computer. Compare this cost with conventional simulator rates that often exceed $80 per hour. The availability and time limits associated with the use of a conventional simulator make these PC-based flight-training programs very attractive.

During the past four decades, various studies have investigated the effects of flight-training devices (FTDs) on subsequent performance in the aircraft. Most of these transfer-of-learning studies have the objective of evaluating the effectiveness of training techniques and equipment. This information is then used to design, develop, or upgrade training programs. Recently, multimedia have opened the door for all types of new and more elaborate training aids.

Historically, the debate in the aviation field has centered on the usefulness of simulators as a pretraining tool. The traditional format for pretraining usually consists of an integrated instructional sequence that includes instructional materials, actual instruction by a ground instructor, and practice in a flight-training device. Only after the FTD instruction does the student proceed to actual airplane training. Obviously, airplane performance is the ultimate goal of any form of flight pretraining. Therefore, both military and civilian researchers have focused on transfer of learning from simulator training to actual performance in the airplane.

Traditionally, the Federal Aviation Administration (FAA) recognizes practice on flight-training devices and simulators as time toward training and certification. According to federal regulations, 20 hours of a minimum of 40 hours of training time toward a pilot's instrument rating can be completed in an approved simulation device

(FAA, 1991). However, the FAA does not accept the use of traditional PC-based multimedia trainers to meet certification requirements or even to maintain flight competency. At present, there is no evidence to indicate a consistent positive transfer of instrument piloting skills from PC-based flight programs to that required for the actual control of an aircraft. Until it can be shown that there is a recognizable and significant transfer of instrument flight skills from PC-based multimedia programs to the actual cockpit, training hours on the PC will not be accepted by the FAA.

STATEMENT OF THE PROBLEM

The purpose of this study is to compare whether pretraining through the use of an inexpensive multimedia computer program will lead to pilot performance that is as effective as when pretraining is limited to an approved FTD. One practical test used by the FAA to determine whether a pilot meets the knowledge and skill standards for an instrument rating is to evaluate the execution of a circular maneuver flown at a specific distance from a ground facility. This instrument flight maneuver, called a DME ARC, requires the pilot to use both cognitive knowledge and psycho-motor skills to successfully complete the flight task. The FAA has established specific performance standards for the maneuver to assess pilots' ability (FAA, 1980). In normal operations, the DME ARC is used for aircraft guidance during low-visibility approaches to airports. Based on this information and that of the following literature, the researchers selected the DME ARC maneuver as the reference task for this experiment.

REVIEW OF RELEVANT LITERATURE

PC-Based Flight Trainers

Ortiz (1993) conducted research using the ELITE software program and actual airplane performance, indicating that one hour of practice on a standard PC loaded with ELITE multimedia software saves flight students approximately 29 minutes of training time in the actual airplane.

In 1994, Kuhlman conducted a comparative study of PC-based flight programs. In that study, four advanced-training software programs were evaluated and their capabilities and limitations determined. Although ELITE did not receive the highest overall score in this comparative study, the software did receive the highest marks on instrument-panel graphics and instrument pilots' preference. This and the close similarity between the instrument panel layout of the FAA-approved flight-training device (AST-300) and that of the ELITE prompted its selection. ELITE also uses a universal control interface that converts the flight-control signals to a digital format, making control smooth and very consistent. All navigation and aircraft control settings are controlled through a standard computer mouse. Because both the attitude indicator display and aircraft control through the flight controls form an essential part of the successful execution of the DME ARC maneuver, ELITE was selected as the multimedia software for this research.

A Virtual Pilot yoke with associated rudders, manufactured by CH Products in Vista, California, was chosen as the flight-control device. Alternative interface devices were considered, but only the Virtual Pilot yoke with the connected CH Pro rudders had a "feel" similar to that of the AST-300. Although a standard computer monitor was considered for this study, the researchers opted for a slightly larger 17-inch SVGA screen. This is in conformance with the equipment used during the Kuhlman research (1994) and also made the instrument panel similar in size to that of the AST-300 flight-training device. In this study, subjects were familiar with the use of all of the required instruments to execute a DME ARC. They were experienced in maintaining altitude and heading, or direction, and in changing heading by instrument reference while using a VOR indicator.

The training and evaluation tools used for this research are classified as either simulator, flight-training device, or training aid. Depending on the level of sophistication and the conformity to FAA guidelines, these training instruments can be used for acquiring or maintaining instrument flying competency.

Simulators

The FAA (1992) defines a true airplane simulator as an apparatus that is an exact duplication of the actual airplane, including a motion and visual system. Clearly, only the most sophisticated airline simulators meet these criteria.

On the other hand, an airplane FTD can be

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considerably less sophisticated and is defined by the FAA (1992) as an apparatus that includes a full-scale replica of an airplane's instruments, equipment, panels, and controls. It does not, however, have to duplicate the appearance and performance of a specific aircraft. The AST-300 apparatus used for this study is classified as an FTD. Training on this device can count as pilot proficiency time and can be used for the purpose of certification.

The FAA (1992) considers the ELITE instrument flight trainer a training aid. These training aids are not approved as flight-training devices at any level.

HYPOTHESES

This study was conducted to determine whether the use of PC-based pretraining would result in equally effective pilot performance on an instrument flight task (DME ARC) as when pretraining is exclusively done on an FAA-approved flight trainer. The concept of transfer of learning is defined in this study as any measurable effect of training in a prior task on performance in a subsequent task (Payne, 1982).

A value of $p < .05$ was used to determine significant difference for all test questions. To determine the effects on cognitive mastery, the following research question was evaluated: What is the effect of ELITE (PC) practice versus AST-300 simulation practice on criterion-referenced test performance? The difference in scores on the criterion-referenced test for subjects receiving ELITE (PC) practice versus those receiving AST-300 practice was compared to determine significance.

The effects on psycho-motor performance in the simulator were determined by evaluating the following research question: What is the effect of ELITE (PC) practice versus AST-300 simulation practice on altitude performance? Altitude performance for subjects receiving ELITE (PC) practice versus those receiving AST-300 practice was tracked and evaluated to note any significant difference.

To further determine the effects on psycho-motor performance in the FTD, the following research question was evaluated: What is the effect of ELITE (PC) practice versus AST-300 simulation practice on tracking performance? The difference in tracking performance for subjects receiving ELITE (PC) practice versus those receiving AST-300 practice was evaluated for significance.

METHOD

Subjects

This research study sampled 64 civilian pilots who held at least a private pilot license. The sample was drawn from a predefined population. Volunteers were obtained from advanced ground-school classes in an accredited flight program at Arizona State University. Also, flyers were posted at several airports in the Phoenix area and advertisements placed in local newspapers. The subjects were randomly assigned to two groups: an experimental group and a control group. A questionnaire (Homan, 1996) was administered to determine FAA certification, total and instrument flight experience, age, and sex of each subject.

Instrumentation and Apparatus

Aviation Simulation Technology (AST-300)

The AST-300 is a ground-based flight-training device manufactured by Aviation Simulation Technology in Bedford, Massachusetts. The device is approved for flight-training purposes by the FAA. The handling and performance characteristics of the trainer are similar to that of a typical light training airplane (Mann, 1979). A plotter device is standard equipment on Aviation Simulation Technology simulators. In this research, the plotter was used to record both altitude and flight track deviations from the model 15 DME ARC maneuver. The researchers had created a scaled map that displayed the target 15 DME ARC flight pattern.

DME ARC SOFT Program

DME ARC SOFT is a Qbasic program running on a PC with DOS 5.0 or higher that serves as a software interface to the AST-300 training device (Devarajan, 1995). DME ARC SOFT is a scoring program, specifically designed for this study, that can be used to evaluate a pilot's performance in the AST-300.

ELITE Program

Azuresoft's Electronic IFR Training Environment (ELITE) program allows practice and instant replay of all procedures required for an FAA instrument rating (Taylor, 1990). ELITE will plot both plan and profile views of flight patterns. A Virtual Pilot flight yoke and CH Pro rudders were used as interfaces with the ELITE program. The ELITE software was installed on a standard IBM 486 computer system with 66 megahertz speed. A 17-inch SVGA monitor was used for display of the ELITE program.

Instructional Materials

Instrument Flight Maneuver

An instrument flight maneuver (DME ARC) that is not often practiced by licensed pilots was selected. The procedure for flying a DME ARC in slow civilian aircraft requires a change in direction after each 10 degrees of arc around the navigation aid (VORTAC). The DME ARC procedure consists of: (a) straight-and-level flight, (b) shallow banked turns, (c) maintaining altitude, (d) maintaining predetermined heading, and (e) deciding the direction of a turn. Settings and indications on VOR, DME, and altimeter instruments also need to be considered. In short, instrument interpretations followed by appropriate corrections are the essence of a successful execution of a DME ARC maneuver.

Programmed Text

Pearce (1980) developed and validated a programmed text for the DME ARC maneuver, based on the procedures provided in Air Force Manual 50-2 (USAF, 1975). This booklet was designed to present the principles of executing and maintaining a DME ARC and furnishes the reader with a guided-learning module on how to perform the maneuver.

Criterion-Referenced Tests

Pre- and posttests were developed by both Pearce (1980) and the researchers of this study. The paper-pencil pretest was designed by the researchers to establish the participants' level of prior knowledge of the DME ARC concept. The development of this multiple-choice criterion-referenced test followed the working principles set forth by Haladyna (1994). The second paper-pencil test, designed by Pearce (1980), was developed during an experimental study that used the introductory programmed text. This multiple-choice posttest was administered as part of the final evaluation of the participating subjects.

RESEARCH DESIGN

Pretest/Posttest Control Group Design

A random assignment of the subjects as well as the use of a control group supports the design used for this study. Where true experimental designs are used, nearly all problems associated with internal and external validity are controlled. For this study, a pretest/posttest control-group design was adopted. The rigidity of this experimental process, as well as the combination of random assignment, the presence of a pretest, and the use of a control group, assisted in the control of the internal validity issues (Gay, 1992).

The FAA recommends three or four initial repetitions of new flight-training maneuvers to provide optimum learning. More extensive drills will result in a reduced learning rate and may adversely affect retention (FAA, 1977). A total of five DME ARC maneuvers were flown by each subject--three practice trials and one for each of the pre- and posttest evaluations.

Procedure

Volunteers were randomly assigned to one of two groups. All subjects were evaluated at the beginning and end of the experimental procedure on both cognitive and psycho-motor skills through multiple-choice tests and a performance evaluation on the FAA-approved trainer.

Subjects in both groups (X and Y) were given a paper-pencil pretest consisting of multiple-choice questions. All participants received a 5-minute warm-up and an introduction to the AST-300 approved trainer. The participants also received a fact sheet that identified the specific DME ARC maneuver used for this research. No instructions on how to perform the DME ARC were provided on the fact sheet. This information was followed by a performance evaluation trial scored by the DME ARC SOFT program. This limited instructor-participant interaction assisted in controlling researcher bias. The participants were not informed of the testing results.

The subjects of Group X received a treatment that consisted of the review of the DME ARC programmed text and three practice trials on the AST-300 approved flight trainer. No time limit was placed on the preview of the programmed text. After a 15-minute break, Group X subjects were given the posttest evaluation. This posttest consisted of two parts. First, a criterion-reference posttest was administered to determine the specific knowledge acquired by each subject after working through both the programmed text and the three practice trials. Part two of the posttest was the final motor-skill evaluation on the AST-300 flight trainer. The pilot's performance for this

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Table 1
Design of the Study

GROUP	ASSIGNMENT	PRETEST	TREATMENT	POSTTEST
X	Random	Criterion-reference test I	Programmed text	Criterion-reference test II
	30 subjects	Warm-up/Flight test in AST-300 trainer	AST-300 trainer practice	Flight test in AST-300 trainer
Y	Random	Criterion-reference test I	Programmed text	Criterion-reference test II
	34 subjects	Warm-up/Flight test in AST-300 trainer	Warm-up ELITE practice	Flight test in AST-300 trainer

final test was scored by the DME ARC SOFT program. Again, Group X was exposed to the experimental procedure that conformed to a traditional simulation-training sequence.

Group Y initially followed an identical format and proceeded through the experiment in the same sequence, similar to Group X. A 5-minute warm-up period and a DME ARC fact sheet were provided. At the treatment stage, the randomly assigned subjects reviewed the programmed text and were assigned three practice trials on the ELITE computer program. The posttests for the subjects in Group Y were identical to the posttests of Group X. The experimental design of this study is shown in **Table 1.**

In this research procedure the independent variables were the different forms of practice (AST-300 or ELITE) the subjects received during the treatment phase. The dependent variables were the scores on the criterion-referenced tests and the subjects' psycho-motor skill performance on the AST-300 approved flight-training device, as measured by the DME ARC SOFT program.

Flight Conditions

Atmospheric conditions were preset at smooth air with a slight westerly wind (5 knots), with a ceiling of 300 feet. Instrument flying conditions prevailed. The ELITE aircraft selection was the single-engine high-performance mode. Instrument panels on both the AST-300 and the ELITE were very similar in appearance. A one VOR setup with no HSI (Horizontal Situation Indicator) or auto-pilot function was used for this experiment. The AST-300 was operated using the combined throttle concept. Flight altitude was 2,500 feet with an airspeed of 135 knots.

DATA COLLECTION AND ANALYSIS

Data Collection

Training and data collection took place at the Department of Aeronautical Technology at Arizona State University during the summer of 1995. The DME ARC SOFT computer program was used for the instrument flying task data collection and evaluation in an attempt to control researcher testing bias. The raw data for the motor-skill evaluation was collected during both the pre- and posttest evaluations on the FAA-approved AST-300 trainer. A PC loaded with the DME ARC SOFT program and connected to the AST-300 automatically recorded data on airspeed, heading, altitude, angle of bank, pitch, positioning, and flight time. For the current research, only positioning and altitude were considered to be pertinent data.

For the final evaluation of the cognitive aspect of this study, a criterion-reference posttest, similar but not identical to the pretest, was used. Overall, participation in the DME ARC experiment averaged about 2.5 hours per subject.

Data Analysis

The cognitive pre- and posttests were scored on the basis of the number correct on the 15-item multiple-choice tests. Psycho-motor AST-300 performance was measured by the mean of the absolute deviations from the altitude and arc criterion (plus a constant) as a score for each subject. This criterion in each case was considered to be either the assigned altitude (2,500 feet) or the arc (15 DME). Each subject deviated plus or minus from this criterion as he or she attempted to maintain the altitude or the arc. These deviations were then expressed as a positive or negative number depending on whether the subject was above, below, left, right, or at criterion when the measurement was taken. For the purpose of this analysis, absolute values were used. The use of the absolute value of the deviation yielded the dimension of interest in this study: the magnitude of the deviation from the target line. The magnitude of the mean deviation (incremented by a positive constant to eliminate scores of zero) for each subject was then used as his or her score. Statistical tests were applied to determine whether the difference in the scores was significant. Independent t tests were used on pre- and posttest scores across the experimental and control group. Paired t tests were used on pre- and posttest within the experimental and the control group.

Some variations in subject characteristics that were not controlled, but which could possibly affect performance, were identified on the questionnaire. Both the cognitive and psycho-motor pretests provided a necessary baseline for each participant at the start of the training sequence.

RESULTS

Demographics

This research project covered a period of 11 weeks between June and August of 1995. Responses on the questionnaire revealed that all subjects in both the experimental and control groups had previous experience with the use of a personal computer equipped with a mouse. Randomization produced similar age and sex distributions between the experimental and the control groups. Total flying hours ranged from 72 hours to 813 hours in the control group, and from 67 hours to 1,354 hours in the experimental group. Instrument flight time varied from 5 hours to 207 hours in the control group, and from 7 hours to 135 hours in the experimental group. Age range for the experimental group was 21 to 39 years, and for the control group, 20 to 41 years. This distribution is comparable to an average age for active licensed pilots of 42 years in the United States (AOPA, 1995).

Of the 34 subjects in the experimental group and the 30 subjects in the control group, 29 in the experimental group and 25 in the control group had less than 400 hours total flight time. Of the total subjects in each group, 21 in the experimental group and 19 in the control group had less than 50 hours of total instrument time.

Of the 34 subjects in the experimental group, 17 did not have an FAA instrument rating. This finding compared with 18 out of the 30 subjects in the control group. Of the 34 subjects belonging to the experimental group, 19 had never performed a DME ARC maneuver. This variable compared with 18 out of 30 for the control group. None of the subjects in either group had ever received practice on the ELITE training system. Experience on the AST-300 flight-training device varied from 17 out of 34 participants in the experimental group to 13 out of 30 in the control group.

Cognitive Performance

Cognitive performance was evaluated by scores on both the pre- and posttest written tests. The written pretest was administered before the initial psycho-motor evaluation in the AST-300 trainer and before exposure to the programmed instructional materials. Subjects were not informed of their results on the written pretest. The written posttest was administered after the completion of the treatment but before the final psycho-motor evaluation in the AST-300 trainer. The participants were not informed of their results on the written posttest.

The criterion-reference tests for both the pre- and posttest written evaluation required a specific knowledge base to successfully execute the DME ARC maneuver. The programmed text developed by Pearce (1980) was adopted to provide the cognitive background for both the experimental and control groups.

Considering the nature of the research and the evaluation of the difference in the cognitive performance for both experimental and control groups, the researchers felt that hypothesis examination using independent t tests on pre- and posttest written scores across the experimental and control groups was appropriate. Paired t tests were adopted for comparisons of the written test results within the respective groups.

The statistical results for the written pretest scores across the experimental and control groups indicated a t value of .14084 with $df = 62$. This value fell clearly within the critical region with $\alpha = .05$. Similar statistical

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results ($t(62) = 1.647$; $p < .05$) were obtained for the cognitive posttests across the experimental and control groups. Therefore, the resulting conclusion is that there is no significant difference in the cognitive performance on the written tests between the two groups.

Paired t tests within the experimental group ($t(33) = -12.308$; $p < .05$) and the control group ($t(29) = -9.950$; $p < .05$), respectively, indicated a significant difference between the pre- and post- cognitive tests. Test scores showed significantly higher scores on the written posttests for both the experimental group (pretest mean = 11.11; posttest mean = 14) and the control group (pretest mean = 11.16; posttest mean = 13.63). Both groups had proceeded through the same programmed text as part of the experiment.

The lack of significant difference on the cognitive test scores indicated that both the experimental and control groups were very similar in knowledge of the principles of the DME ARC flight maneuver. This factor was observed for both the cognitive pretest and the posttest. Scores on the written tests ranged from 60% to 86.7% on the pretest, and from 80% to 100% on the posttest. The average positive change in cognitive performance for the experimental group (ELITE) was 19.2%, and the average positive change for the control group (AST-300) was 16.4%.

A score of 80% correct on the written pretest was achieved by 13 of the 34 subjects in the experimental group and 14 of the 30 subjects in the control group. No perfect scores on the written pretest were recorded.

All subjects in both experimental and control groups achieved a minimum score of 80% on the written posttest. Perfect scores on the cognitive posttest were achieved by 10 subjects in the experimental group and 6 subjects in the control group. The FAA requires a minimum score of 70% correct on written tests. One subject in the experimental group and three subjects in the control group showed no improvement in score.

As a result of this analysis, it was concluded that there is no significant difference in the scores on the criterion-reference tests between subjects who used interactive multimedia (ELITE) in combination with an approved flight-training device (AST-300) and subjects who used only the approved flight-training device (AST-300).

Psycho-Motor Performance

The observed difference in ability to maintain an assigned altitude and an assigned DME ARC distance between subjects using the ELITE and subjects who used the AST-300 for practice was examined for significance.

Altitude

Psycho-motor AST-300 performance on altitude was measured by the mean of the absolute deviations from the altitude criterion plus a constant of 1,000. Given the pre- and postcontrol group design for this experimental study, the researchers felt that hypothesis testing using independent t tests on pre- and posttest altitude variations across the experimental and control groups was appropriate. Paired t tests were adopted for comparisons of the altitude performance data within the respective groups.

The statistical results for the mean altitude data on the psycho-motor pretest across the experimental and control groups indicated a t value of -0.3391 with $df = 62$. This value fell clearly within the critical region with $\alpha = .05$. On the post altitude data, the means indicated a significant difference in altitude variability between both groups ($t(62) = -2.2912$; $p < .05$). Therefore, the results showed that there is significant difference in altitude performance between the two groups.

Paired t tests within the experimental group ($t(33) = 4.6835$; $p < .05$) and the control group ($t(20) = 6.2833$; $p < .05$), respectively, indicated a significant difference between the pre- and posttest on altitude performance. Three DME ARC practice trials were performed by each subject in both the experimental and control groups.

As a result of this analysis, it was concluded that there is significant difference in ability to maintain an assigned altitude between subjects using the ELITE and subjects who used the AST-300 for practice.

Distance

Psycho-motor AST-300 performance on distance was measured by the mean of the absolute deviations from the distance criterion (15 DME ARC) plus a constant of 10. Given the pre- and postcontrol group design for this experimental study, the researchers felt that hypothesis testing using independent t tests on pre- and posttest distance variations across the experimental and control groups was appropriate. Paired t tests were adopted for comparisons of the distance performance data within the respective groups.

The statistical results for the mean distance data on the psycho-motor pretest across the experimental and control groups indicated a t value of -9.7631 with $df = 62$. This value fell clearly within the critical region with $\alpha = .05$. On the post distance data, the means indicated no significant difference in distance control between both groups ($t(62) = 1.8178; p < .05$). Therefore, the resulting conclusion is that there is no significant difference in distance performance between both groups.

Paired t tests within the experimental group ($t(33) = 7.4316; p < .05$) and the control group ($t(29) = 5.5721; p < .05$), respectively, indicated a significant difference between the pre- and posttest on distance performance. Again, three DME ARC practice trials were performed by each subject in both the experimental and control groups.

This analysis shows that there is no significant difference in ability to maintain an assigned distance between subjects using the ELITE and subjects that used the AST-300 for practice.

DISCUSSION OF FINDINGS

Cognitive performance on both the pre- and post-written tests showed a significant improvement of the subject's knowledge within each group. In both cases, this result demonstrated the positive learning effect of the programmed text (Pearce, 1980). The baseline written pretest scores were virtually identical. Differences on the written posttest scores were observed, but these were determined to be statistically nonsignificant. As a result, both the experimental and the control groups had a similar cognitive base and learning curve with regard to the DME ARC maneuver. Influence of the different types of practice trials, if any, was not considered significant.

Distance performance on the DME ARC flight maneuver in the FAA-approved flight-training device did not show a statistically significant difference between the experimental and the control groups. Baseline data indicated distance performance that was practically identical for both groups. As implied by the paired t-test analysis within both groups, practice on both the AST-300 and the ELITE resulted in a very notable improvement of overall performance when the subjects were evaluated in the FAA-approved flight-training device after the required practice trials. Distance performance improvement for both groups also was very similar, as suggested by the statistical analysis across the two groups. From these results it appears that, at least for distance and heading control considerations on a DME ARC, the ELITE offers an acceptable training substitute to the more expensive flight-training devices.

Altitude performance on the DME ARC flight maneuver in the FAA-approved flight-training device did show a statistically significant difference between the experimental and the control groups on the posttest. Baseline data indicated altitude performance that was practically identical for both groups. As implied by the paired t-test analysis within both groups, practice on both the AST-300 and the ELITE resulted in very significant altitude performance improvements when the subjects were evaluated in the FAA-approved flight-training device after the required practice trials.

Nevertheless, an analysis across the two groups suggested that performance improvements on altitude were significantly greater for the control group (AST-300) than for the experimental group (ELITE). This finding implies that the computer interface, the CH Products' flight controls, may have a pitch sensitivity that differs significantly from the AST-300. Both the AST-300 and the ELITE were set to simulate smooth air. It was determined that no condition existed that would have required extensive altitude corrections.

As noted by Kuhlman (1994), ELITE offers very realistic instrument graphics that are essential for the successful execution of the DME ARC maneuver. However, this PC trainer has limited pitch stability through its control interface. As a result, ELITE is hard to trim. This factor could have contributed to the less significant improvement on altitude performance attained by the ELITE group. Overall, a significant improvement on altitude performance was noted within the ELITE group, but this improvement was significantly less than the performance improvements made by the subjects practicing solely on the AST-300.

To summarize, the results of this study concluded that PC multimedia training (ELITE vs. AST-300) does not have a statistically significant effect on cognitive

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performance on criterion-reference written tests or on distance performance during the execution of a DME ARC maneuver. However, this study shows that the type of training (ELITE vs. AST-300) does have a statistically significant effect on altitude performance during the execution of a DME ARC maneuver. The differences in total flight time and instrument time, among the participants of this study, were found to have no noticeable effect on the actual execution of the DME ARC maneuver.

The conclusions of this study are limited to the population of this experimental study. No attempts are made to extend these conclusions to other populations; however, these findings can be generalized to populations that are similar to the sample population. These conclusions also are limited to the specific equipment and software used in this study.

RECOMMENDATIONS AND IMPLICATIONS

It is recommended that further research be conducted to investigate the use of PC-based training for flight-training maneuvers other than the DME ARC. An attempt should be made to replicate the study with other types of PC-based flight trainers and FAA-approved flight-training devices. Furthermore, to extend generalizability, it is recommended that the study be replicated using a considerably larger population sample.

To ensure the maximum effectiveness with the use of PC-based multimedia trainers in aviation education, the researchers recommend the following:

1. The overall integration of PC-based training within the pretraining instructional sequence is essential.
2. A formalized approach with lesson plans should be implemented and study directions outlined.
3. Familiarization with the training software and the computer interface form a prerequisite to PC-based training.
4. An appropriately rated instructor should provide the student with feedback on performance.

Although this study indicates that PC-based flight trainers can be used effectively as a procedural learning tool and that systems such as the ELITE offer very significant cost advantages over the traditional flight-training devices and simulators, more research is required to determine the effects of PC-based trainers on actual performance in the aircraft. Until this important research link is made, it is doubtful that the FAA will consider PC-based trainers a valid substitute for actual training on approved flight-training devices. Nevertheless, it is possible that in the near future PC-based trainers will replace conventional flight-training devices for instrument flight training. In the meantime, the researchers recommend that PC-based trainers be considered a valuable and effective supplement to the simulation-training phase.

This research study has clearly demonstrated the usefulness of low-cost PC-based trainers in pilots' instrument training. The limitations identified in this study tend to be technical in nature, and, given the exponential growth of computer technology, it will be only a matter of time before high-resolution and high-quality PC-based flight-training programs are offered at reasonable prices. The same holds true for the somewhat problematic computer interface devices, such as the computer mouse and PC flight controls. Here again, the problems associated with these devices are only temporary. Therefore, PC-based flight simulations will likely gain more acceptance in the years to come.□

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