To be presented at the 12th International Symposium on Aviation Psychology, Dayton, OH, 2003.

INCREMENTAL TRAINING EFFECTIVENESS OF PERSONAL COMPUTERS USED FOR INSTRUMENT TRAINING

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An incremental transfer of training research design was used to measure the effectiveness of a PCATD and to determine the point at which additional training in a PCATD was no longer effective. The dependent measures were trials to specific completion standards, time to complete a flight lesson and time to a successful evaluation flight. Percent transfer, transfer effectiveness ratios (TER) and incremental transfer effectiveness ratios (ITER) were computed for each instrument task and for the time to complete a flight lesson. The data indicate that the PCATD is effective in teaching basic and advanced instrument tasks to private pilots, which replicated the findings of an earlier study by Taylor and colleagues. As a result of prior training in a PCATD, trials, time to complete the flight lesson and time to a successful evaluation flight were less when compared to an airplane Control group. Overall, the greatest effect was found for the PCATD 5 group, which was predicted by the incremental transfer of training theory of Roscoe.

Introduction

In an earlier study by Taylor, Lintern, Hulin, Talleur, Emanuel and Phillips (1996), a commercially available Personal Computer Aviation Training Device (PCATD) was evaluated in a transfer of training experiment to determine its effectiveness for teaching instrument tasks. The data indicated that transfer savings for both the number of trials to reach a criterion performance for instrument tasks and time to complete a flight lesson were positive and substantial for new instrument tasks. A comparison of instrument rating course completion times resulted in a saving of about four hours in the airplane as a result of prior training in the PCATD. As a result of the Taylor et al. (1996) study, a Federal Aviation Administration advisory circular published in 1997 permits 10 hours of instrument training to be completed in an approved PCATD

Method

Subjects

A total of 157 students enrolled in the instrument training program at the University of Illinois participated in this study. The students were assigned randomly among three PCATD groups and the Control group with the constraint that the students during each semester were assigned equally to the four groups.

Apparatus

Training in the PCATD was presented using FAA approved PCATDs from Aviation Teachware Technologies (ELITE) v 6.0.2, and flight controls by Precision Flight Controls (Taylor, Talleur, Emanuel, Rantanen, Bradshaw, and Phillips, 2002). These PCATDs simulate the flight characteristics of the Piper Archer III. The system contained an instructor map display and a 20-inch monitor and hood. The 20-inch monitor permitted the display of eight flight instruments; avionics were contained in a separate unit positioned just to the side of the monitor. Airplane training was carried out in the Piper Archer III aircraft which is a single engine, fixed pitch propeller, fixed under carriage aircraft.

Procedure

The instrument training program at the Institute of Aviation is divided into two courses: AVI 130, Basic Instruments and AVI 140, Advanced Instruments. AVI 130 emphasized aircraft control and instrument departure, enroute and approach procedures, while AVI 140 emphasized NDB holds and approaches and partial panel procedures. This report presents the results from both AVI 130 and AVI 140. The students received 45 hours of lecture during the semester for both courses. For both courses, the students

also received 15 flight lessons, each of which were programmed for one lesson per week. Experimental curricula for both courses were developed for the three PCATD groups and the Control group.

Using a transfer of training design, four groups of subjects were tested in the airplane for proficiency on various instrument flying tasks in both courses. Three of the groups received the following amount of prior instrument training in a PCATD: 5 hours, 10 hours, 15 hours respectively. The PCATD training was distributed equally between AVI 130 and AVI 140. A Control group received all training in the airplane. Instrument training using the PCATD was administered to the three PCATD groups during four flight lessons for each semester.

Prior to the start of each semester, all flight instructors were standardized on the use of the PCATDs, changes in the training course outlines (TCOs), and experimental procedures. Flight instructors served as both instructors and data collectors. They rated student performances on designated flight tasks in the aircraft. For performance assessment in the aircraft, each instructor recorded if the student met the completion standards during the execution of the designated flight tasks. They also recorded trials to criterion for specific tasks and flight time to complete a flight lesson (Phillips, Taylor, Lintern, Hulin, Emanuel & Talleur, 1995). Three check pilots, blind to the allocation of students to training conditions, were used for the evaluation flight.

Each flight instructor was instructed to schedule an evaluation flight after Flight Lesson 40 in AVI 130, and Flight Lesson 55 in AVI 140 when the student was judged to be able to meet the proficiency standards for the stage check and the instrument proficiency check, respectively. The evaluation flight permitted the assessment of the differential time to complete the flight course as a function of the amount of PCATD training. Those students who failed the evaluation flight or failed to meet the proficiency standards by Flight Lesson 45 (stage check) and Flight Lesson 60 (instrument rating check flight) were provided additional flight time to reach proficiency. Dependent measures were trials in the airplane to proficiency, time to complete the flight lessons in the airplane, and total time in the airplane to a successful evaluation flight or course completion time for both courses.

Mean trials to reach criterion in the airplane for selected instrument tasks and mean time to complete the flight lesson in the airplane were computed for all groups for both courses. Separate Analyses of variance (ANOVAs) were performed to analyze the difference between the four groups on the three dependent measures for both AVI 130 and 140. ANOVAs determined the significance of the trial variable and flight lesson completion time variable as a function of experimental treatment for both AVI 130 and AVI 140. Finally, ANOVAs explored variability in the time to a successful evaluation flight for the AVI 130 and AVI 140 courses as a function of the experimental treatment. To further identify the locus of any significant effects, post – hoc tests were employed to make specific pairwise comparisons using Tukey's test of significance.

Results

The mean trials to reach criterion in the airplane on the instruments tasks in AVI 130 by the Control group and the three PCATD groups (PCATD 5, PCATD 10, and PCATD 15) are shown in Figure 1. For all three PCATD groups in AVI 130, prior training in the PCATD reduced the mean trials to completion standards in the airplane for 21 of the 24 instrument tasks tested when compared to the mean trials for the Control group. A significant difference due to treatment effect was found for mean trials in AVI 130 for the four groups; $F(3,153) = 4.09$, $p =. 0.008$. Post-hoc Tukey tests for significance ($p < = 0.05$) indicated significant differences between the Control group and the PCATD 5 group and between the Control group and the PCATD 15 group. The ILS task for Flight Lesson 38 and VOR task for Flight Lesson 38 were significant; $F(3,149)= 3.44$, $p=0.02$, and $F(3,149)= 2.83$, $p= 0.04$, respectively. Post- hoc Tukey tests for significance ($p \leq 0.05$) indicated significant differences between the Control group and the PCATD 5 group and between the Control group and the PCATD 15 group for the ILS 38 task.

The mean trials to reach criterion in the airplane on the instruments tasks in AVI 140 by the Control group and the three PCATD groups (PCATD 5, PCATD 10, and PCATD 15) are shown in Figure 2. For AVI 140, the data indicate that, with six exceptions out of 33 instrument task measures, the mean trials in the airplane were less for all three PCATD groups for all instrument tasks when compared with the mean trials in the airplane by the Control group.

An ANOVA of mean trials of the four groups for all instrument tasks to criterion in the airplane indicated no significant difference due to experimental treatment; F (3,129) = 1.07, p = 0.36. Analyses comparing trials to criterion in the airplane in AVI 140 for the four groups were performed for each instrument task, but there was no significant difference due to treatment effect for the four groups.

For AVI 130, the prediction that an increased number of prior trials in the PCATD on selected instrument tasks would save more trials in the airplane was found for only six of the sixteen-instrument task comparisons. For five of the eight instrument tasks the TERs for mean trials showed the predicted negatively decelerated function. For AVI 140, the prediction that increased numbers of prior trials in the PCATD would save more trials in the airplane was found for 13 of 22 instrument task comparisons. For five of the eleven instrument tasks the TERs for the mean trials showed the predicted negatively decelerated function.

The mean times to complete the flight lessons in the airplane for AVI 130 are shown in Figure 3. For all three PCATD groups, the mean times to complete each of the four flight lessons in which there was prior training in the PCATD were less than the time for the Airplane group. An ANOVA comparing the mean times to complete the flight lessons among the four groups indicated a significant difference due to treatment effect; F (3,153) = 7.53, p = 0.0001. Post-hoc Tukey tests for significance (p < = 0.05) indicated significant differences between the Control group and each of the experimental groups (PCATD 5, PCATD 10, and PCATD 15 groups). Individual ANOVAs for each flight lesson comparing the time to complete the flight lesson among the four groups indicated a significant treatment effect for Flight Lesson 36 and Flight Lesson 38; F (3,151)= 3.90, p=0.01, and F (3,149)= 4.07, p= 0.01 respectively. Post-hoc Tukey tests for significance (p < = 0.05) indicated significant differences between the Control group and the PCATD 10 group and between the Control group and the PCATD 15 group for Flight Lesson 36 and between all three experimental groups for Flight Lesson 38. No significant differences were found for treatment effect for Flight Lesson 34/35 or 37.

Three of the flight lessons showed the predicted decreased mean time with increased prior training in the PCATD when the PCATD 5 and 10 groups were compared, and one flight lesson showed this pattern when the PCATD 10 and 15 groups were compared. All TERs were positive and ranged from 1.17 to 0.38 for PCATD 5, from 0.68 to 0.25 for PCATD 10 and from 0.42 to 0.12 for PCATD 15. The pattern of the TERs for mean time showed the predicted negatively decelerated function for each flight lesson for increased amounts of prior training in the PCATD. The ITERs for time to complete each flight lesson showed the predicted negatively decelerated function.

The mean times to complete the flight lessons in AVI 140 are shown in Figure 4. The mean times for all three PCATD groups to complete each of the four flight lessons in which there was prior training in the PCATD were less than the time for the Control group. An ANOVA of mean times for the four groups to complete the flight lesson indicated a significant treatment effect; F (3,129) = 6.01, p = 0.0007. Post-hoc Tukey tests for significance (p<=0.05) indicated significant differences between the Control group and each of the experimental groups. ANOVAs for Individual flight lessons in AVI 140 of time for the four groups to complete the flight lesson. Indicated a significant treatment effect for Flight Lesson 52; F (3,126)=5.5, p=0.002. Post-hoc Tukey tests for significance (p<=0.05) indicated significant differences between the Control group and the PCATD 5 group and between the Control group and the PCATD 10 group. No significant differences were found for treatment effect for flight lessons 48, 49, 50 although Flight Lesson 48 approached significance; F (3,129)=2.37,p=0.07.

All percent transfers were positive but were relatively small; generally the percent transfer was between 15% and 30%. TER was positive for all flight lessons and substantial for Flight Lessons 48, 49 and 52 for the mean time to complete the flight lesson for AVI 140. The most substantial average transfer for the mean time to complete the flight lesson variable occurred for Flight Lesson 52 for two of the three PCATD groups (TERS were 0.93, and 0.52 for the PCATD 5, and 10, groups respectively). For the PCATD 5 group, the TERs ranged from 0.17 to 0.93. The pattern of the TERs for the mean time to complete the flight lesson variable for the PCATD groups showed the predicted negatively decelerated function for three of the four flight lesson for increased amounts of training time in the PCATD. For the time to complete flight lesson variable, the largest ITER found for PCATD 10 was for Flight Lesson 50. Increased

training time in AVI 140 beyond PCATD 5 did little to reduce the training time in the airplane.

In AVI 130, the mean time to a successful evaluation flight was less for all three PCATD groups compared to the Control group. An ANOVA which compared the time to a successful evaluation flight for the four groups indicated a significant treatment effect; $F(3,138) = 3.77$, $p = 0.01$. Post-hoc Tukey tests for significance ($p <= 0.05$) indicated a significant difference between the PCATD 10 group and the Control group.

For AVI 140, the mean time to a successful evaluation flight was less for all three PCATD groups than for the Control group. An ANOVA which compared the time to a successful evaluation flight for the four groups indicated a significant treatment effect; $F(3,107) = 2.65$, $p = 0.05$. Post-hoc Tukey tests for significance ($p <= 0.05$) indicated no significant differences between the Control and any of the PCATD groups.

Discussion

The data from the current study indicates that the PCATD is effective in teaching basic and advanced instrument tasks to private pilots. This study replicated the findings of Taylor et al. (1996,1999) that PCATDs are useful to teach instrument tasks to private pilots. As a result of prior training in a PCATD, trials, time to complete the flight lesson and time to a successful evaluation flight were less when compared to a Control group trained only in the airplane. Overall, the greatest effect was found for the PCATD 5 group, which was predicted by the incremental transfer of training theory of Roscoe (1971). In some cases the results indicate a complex pattern supporting the notion that more training is not necessarily better. That is, additional training in the PCATD did not always lead to more trials/ time saved in the airplane compared to the Control group. The results also indicated reduced trials/time saved for AVI 140 compared to AVI 130. The negatively decelerated function of the ITER predicts reduced transfer for instrument tasks introduced during later stages in the instructional sequence (Roscoe, 1971). Taylor et al. (1996,1999) also found less transfer during AVI 140 than AVI 130. They concluded that what is learned while mastering one task in a training device generalizes to other tasks introduced later, which reduces the remaining potential for transfer. Generally, in the current study, little additional time/trials were saved by the PCATD 10 group when compared to the PCATD 5 group and practically no incremental transfer was found for the additional hours of training by the PCATD 15 group compared to the PCATD 10 group.

One purpose for conducting an incremental transfer of training study is to determine at what point additional training in the PCATD in no longer effective. Based on the methodology used in the current study the results indicated no appreciable benefit is found for more than 5 hours of PCATD training. These results provide support for the current FAA policy of permitting PCATD time to be used in lieu of time in an approved training device or airplane. We found, however, that only 5 of the 10 hours permitted could be used in a cost-effective manner if the PCATD is only used to train specific instrument tasks. The results also clearly provide no support for increasing, from 10 to 15 hours, the amount of time using PCATDs as a substitute for time in the aircraft.

The question remains: how can flight schools most effectively use the 10 hours of instrument training time currently permitted by AC No: 61-126 (FAA, 1997)? Taylor et al. (1996,1999) suggested allocating the time to the training of the following instruments tasks: steep turns, intersection holds, ILS, VOR, DME ARC and LOC BC Approaches, NDB holds and approaches, and holds and approaches using partial panel. The current study clearly indicates that the use of 5 hours of PCATD time was cost-effective based on the allocation of PCATD time for these tasks for the PCATD 5 group, but the results of the 10 nor the 15 hour groups. Indicated that it was not an effective use of the additional five hours of time. Flight schools should examine their TCOs to determine where the additional 5 hours could be effectively used.

The current study treated each student the same in terms of the allocation of PCATD time for specific instrument tasks for specific flight lessons even though there is clear evidence that students learn different tasks at different rates. A more flexible approach may provide for more effective use of the additional 5 hours of PCATD time beyond the 5 hours used by the PCATD 5 group. There is also the probability that PCATDs can be used effectively for teaching cross-country procedures where there is the possibility of a one –to –one transfer of training for time. We are currently investigating the effectiveness of PCATDs for conducting cross-country flights.

We also suggest that ten hours or perhaps 15 hours of PCATD time in an instrument curriculum could be cost-effective, if better training strategies were incorporated in the PCATD software offered by manufacturers. Lintern, Roscoe, and Sivier (1990) found that adaptively augmented visual displays used in conjunction with standard flight instruments induced correct responses by trainees early in the training sequence. The students trained with the adaptively augmented displays performed significantly better on visual flight tasks when compared to control subjects. We suggest that display augmentations that induce correct responses early in the training sequence are not limited to visual flight training, but would also be relevant to instrument flight training. Examples of instrument flight variables that could be investigated include localizer and glide-slope deviations. The flexibility inherent in the programming of PCATDs would permit manufactures to introduce adaptive augmentations applicable to instrument flight These examples follow the principle of inducing correct responses early in the training sequence to minimize trial and error. We also suggest that by including predictor symbols and other display innovations, the incremental transfer of PCATDs during the first five hours could be even more effective than has been demonstrated in the current study.

Acknowledgments

This work was supported under National Aeronautics and Space Administration (NASA) grant # NAG 2-1282. Dr. Immanuel Barshi, NASA Ames, CA served as the contracting officer's technical representative for NASA. Views expressed herein do not necessarily represent official NASA positions. Ms. Diana Christenson assisted with the manuscript and Mr. Rick Weinberg provided invaluable assistance with flight operations and with student management. Mr. Bill Jones, Mr. David Boyd and Mr. John Suppok served as check pilots. We thank the flight instructors and students for their participation in the study. Professor Gary Bradshaw is now at Mississippi State University, Mississippi State, MS.

References

Federal Aviation Administration. (1997). *Verification and approval of personal computer-based aviation training device* (Advisory Circular 61-126). Washington, DC: FAA, Department of Transportation.

Lintern, G., Roscoe, S. N., & Sivier, J. E. (1990). Display principles, control dynamics, and environmental factors in pilot training and transfer. *Human Factors, 32*, 299-317.

Phillips S. I., Taylor, H. L., Lintern, G., Hulin, C. L., Emanuel, T., & Talleur, D. (1995). Developing performance measures for evaluating personal computer-based aviation training devices within a FAR Part 141 pilot training school. *Proceedings of Aviation Psychology 8th International Symposium*. Columbus, OH.

Roscoe, S. N. (1971). Incremental transfer effectiveness. *Human Factors, 13*, 561-567.

Taylor, H. L., Lintern, G., Hulin, C. L., Talleur, D., Emanuel, T., & Phillips, S. (1996). *Transfer of training effectiveness of personal computer-based aviation training devices* (ARL-96-3/FAA-96-2). Savoy, IL: Aviation Research Laboratory.

Taylor, H. L., Lintern, G, Hulin, C. L., Talleur, D. A., Emanuel, T., & Phillips, S. (1999). Transfer of training effectiveness of a personal computer aviation training device. *International Journal of Aviation Psychology, 9*, 319-335.

Taylor, H. L., Talleur, D. A., Emanuel, T. W., Jr., Rantanen, E. M., Bradshaw, G. L., & Phillips, S. I. (2002). *Incremental training effectiveness of personal computers used for instrument training* (Final Technical Report ARL-02-5/NASA-02-3). Savoy, IL: University of Illinois, Aviation Research Lab.

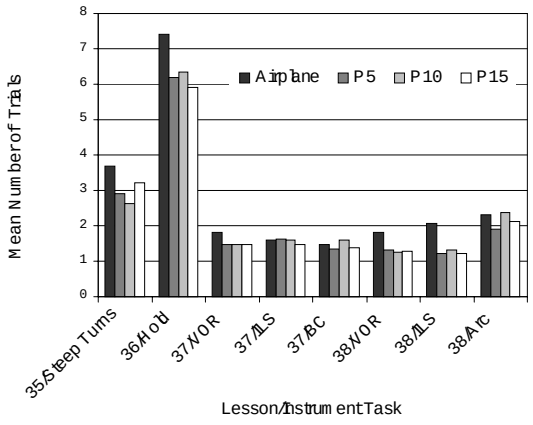

Figure 1. Mean number of trials in the airplane for the control group and the three PCATD groups for the instrument tasks trained in AVI 130

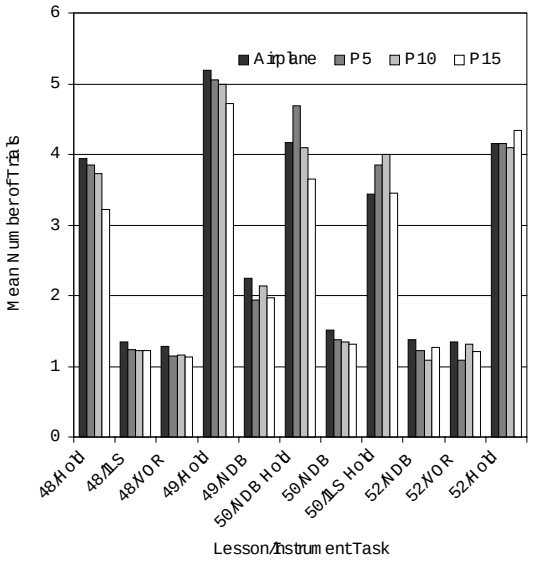

Figure 2. Mean number of trials for instrument tasks in AVI 140

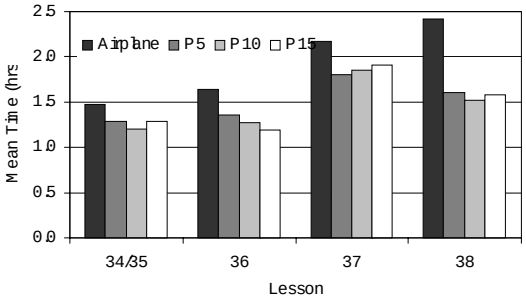

Figure 3. Mean time to complete the flight lessons in the airplane for the control group and the PCATD groups for AVI 130.

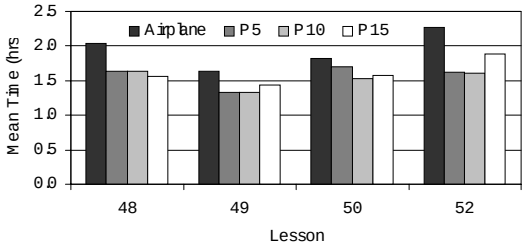

Figure 4. Mean time to complete the flight lessons in the airplane for the control group and the PCATD groups for AVI 140