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Incremental Training Effectiveness of Personal Computer Aviation Training Devices (PCATD) Used for Instrument Training

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FOREWORD

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EXECUTIVE SUMMARY

Flight training is costly when conducted in an approved training device and even more expensive when conducted in an airplane. 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 savings 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. In the experiment reported here, three groups of students at the Institute of Aviation, University of Illinois, received 5, 10, or 15 hours of prior training on selected instrument tasks required for the instrument rating. After training on each instrument task the subjects were evaluated in the airplane using completion standards for each task and these results were compared to a control group trained only in the airplane.

A total of 157 students participated in the study. The instrument training program at the Institute of Aviation is divided into two courses: AVI 130, Basic Instruments and AVI 140, Advanced Instruments. Basic instrument procedures emphasized aircraft control and instrument departure, enroute and approach procedures, while advanced instrument procedures emphasized NDB holds and approaches and partial panel procedures. This report presents the results from both AVI 130 basic instruments, and AVI 140 advanced instruments courses.

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 in both AVI 130 and AVI 140. 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. Separate Analyses of Variance (ANOVAs) were performed to examine the difference between the four groups on the three dependent measures. To further identify the locus of any significant effects, post-hoc Tukey’s tests of significance were employed to make specific pairwise comparisons.

The data from the current study indicates that the PCATD is effective in teaching basic and advanced instrument tasks to private pilots. 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 was found for treatment effect for mean trials in AVI 130 for the four groups. Post-hoc tests found significant differences between the Control and the PCATD 5 and 15 groups. Significant differences were found for the ILS and the VOR task for Flight Lesson 38. Post-hoc comparisons found a significant difference between the PCATD 5 and 15 groups and the Control group. 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. Statistical analyses indicated no significant difference due to experimental treatment for the four

groups. 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.

In AVI 130 the mean times to complete the flight lesson in the airplane for the four flight lessons in which there was prior training in the PCATD were lower for all three PCATD groups than for the Control group. A significant treatment effect was found for the four groups. Post-hoc comparisons indicated a significant difference between the Control group and all three experimental groups. A significant treatment effect was found for Flight Lessons 36 and 38 when the mean time to complete the flight lesson was compared for the four groups. Post-hoc comparisons indicated a significant difference between the Control group and the PCATD 10 group and the Control group and the PCATD 15 group for Flight Lesson 36 and between the Control group and all three experimental groups for Flight Lesson 38. 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.

For AVI 140, the mean times for all three PCATD groups to complete each of the four flight lessons were less than the time for the Control group. An analysis of mean times for the four groups to complete the flight lesson indicated a significant treatment effect. Post-hoc tests, however, indicated no significant differences between the Control group and any of the experimental groups. Analyses of individual flight lessons comparing the time to complete the flight lesson among the four groups found a significant treatment effect for Flight Lesson 52, but not for the other three flight lessons in AVI 140. During Flight Lesson 52 the student performed ILS Holds, NDB and VOR approaches and holds using partial panel procedures.Post-hoc tests indicated significant differences between the Control group and the PCATD 5 group and between the Control group and the PCATD 10 group. 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. A significant treatment effect was found for the four groups for the time to a successful evaluation flight during the basic instrument course. Post-hoc comparisons 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. A significant treatment effect was found in AVI 140 for the four groups for the time to a successful evaluation flight during the advanced instrument course. Post-hoc comparisons, however, indicated no significant differences between the Control group and any of the PCATD groups.

This study replicated the findings of Taylor et al. (1996) 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 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 (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, Lintern, Hulin, Talleur, Emanuel, and Phillips (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 results of the current study we conclude that 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, but found that only 5 of the 10 hours permitted could be used in a cost-effective manner. 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. (1999) suggested the approach used in the current study of allocating the time to the training of the following instruments tasks: steep turns (Flight Lesson 35), intersection holds (Flight Lesson 37), ILS, VOR and LOC BC Approaches (Flight Lesson 37), VOR, ILS and DME ARC approaches (Flight Lesson 38), review approaches (Flight Lesson 48), NDB holds and

approaches (Flight Lesson 49), NDB holds and approaches review (Flight Lesson 50), and holds and approaches using partial panel (Flight Lesson 52). The results of the current study clearly indicate that the use of 5 hours of PCATD time in accordance with the suggestions of Taylor et al. (1999) was cost-effective based on the allocation of PCATD time for the PCATD 5 group, but the doubling and tripling of the trials/time in these flight lessons, which was done for experimental control, was not an effective use of the additional time for the 10 nor the 15 hour groups. 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. We also suggest that ten hours or perhaps 15 hours of PCATD time in an instrument curriculum could be cost-effective, as well as transfer 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. The flexibility inherent in the programming of PCATDs would permit manufactures to introduce adaptive augmentations applicable to instrument flight. When using adaptive augmentation, one must be careful to remove the “training wheels” when the trainee makes the correct response to avoid developing dependency on the augmented displays. Examples of the types of displays that could be introduced include predictor symbols that respond immediately to control inputs to show what the airplane is about to do. Roscoe and his colleagues (Roscoe, 1968, 1980, 1999; Roscoe, Corl, & Jensen, 1981; Simon & Roscoe, 1956; Lintern, 1980) have previously shown the effectiveness of predicted altitude based on present altitude plus 15 seconds worth of rate of climb (to teach anticipation of time to level off), predicted heading based on momentary heading plus 15 seconds worth of rate-of-turn (approximated by the sine of the bank angle, scaled appropriately). There are similar applications to other flight variables such as localizer and glideslope deviations. All of these examples follow the principle of inducing correct responses early 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.

We also believe that PCATDs have the potential of providing training on other advanced and demanding maneuvers such as stalls, spins, and the associated recoveries. The potential also exists of using PCATDs in the Private Pilot curriculum. With the additional display developments, additional research could demonstrate ways in which the improved PCATDs could be effective for instrument and contact flight training.

INTRODUCTION

To evaluate transfer of training effectiveness of a PCATD, the performance of subjects trained on instrument tasks in a PCATD and later trained to criterion in an airplane must be compared to the performance of subjects trained to criterion only in the airplane. Percent transfer is commonly used to determine the savings (trials/time) in an airplane as a result of prior training in a ground trainer. The percent transfer, however, does not account for the trials/time in the ground trainer to achieve those savings. Roscoe (1971) demonstrated that the transfer effective ratio (TER) accounts for the amount of prior training in ground trainers by specifying the trials/time saved in the airplane as a function of the prior trials/time in the ground trainer. The incremental transfer effectiveness ratio (ITER) determines the transfer effectiveness of successive increments of training in the ground trainer (Flexman, Roscoe, Williams & Williges, 1972).

A study to determine the extent to which a PCATD can be used to develop specific instrument skills that are taught in instrument flight training and to determine transfer of these skills to the aircraft was reported by Taylor, Lintern, Hulin, Talleur, Emanuel and Phillips (1996, 1999). Students in instrument training at the Institute of Aviation, University of Illinois were taught instrument tasks using a commercially available PCATD. The performance of one group of subjects trained to criterion on a number of instrument tasks in a PCATD and later trained to criterion in an aircraft (PCATD Group) was compared with a group of subjects who received no PCATD training but were trained to criterion on the same instrument tasks in the airplane (Control group). In order to evaluate transfer of training effectiveness of the PCATD to complete each flight lesson in the airplane and make comparisons of trials to criterion in the airplane, course completion times for the two groups were made. The findings of the study indicated that the PCATD was an effective training device for teaching instrument tasks. When new tasks were introduced transfer savings were generally positive and statistically significant. No significant transfer was found when tasks already learned in previous lessons were reviewed. The comparison of course completion times indicated a savings of about four hours in the airplane for the PCATD group compared to the Control group; the savings were statistically significant. The overall transfer effectiveness ratio was 0.15 or a savings of 1.5 flight hours for each ten hours of PCATD time.

Current FAA regulations permit the substitution of 15 hours of time in a certified ground trainer for aircraft time required for instrument certification. FAR 61.4(c) allows PCATDs to be approved for specific purposes.

A PCATD meeting the description and the criteria established in AC No: 61-126 (FAA, 1997) can be used for up to 10 hours of flight instruction time allowed by Part 141 in lieu of 10 hours of the flight instruction in a flight simulator or other approved flight training device. Roscoe (1971) and Povenmire and Roscoe (1973) demonstrated that the TER and the ITER are negatively decelerated functions. Successive increments of training in a PCATD are predicted to decrease the average TER and the ITER. Incremental transfer functions need to be determined in order to measure the effectiveness of a PCATD and to determine the point at which additional training in a PCATD is no longer effective. The purpose of this experiment was to determine the incremental transfer effectiveness of three amounts of training instrument tasks using a PCATD.

Taylor, Talleur, Emanuel, Rantanen, Bradshaw, and Phillips (2001, 2002) reported the results of AVI 130.

METHOD

Subjects

A total of 157 subjects enrolled in the instrument training program at the University of Illinois, participated in this study. The subjects were assigned randomly among three PCATD groups and the Control group with the constraint that the subjects from 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 (Figure 1). 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.

Figure 1. PCATD from Aviation Teachware Technologies (ELITE) v 6.0.2, and flight controls by Precision Flight Controls.

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 receive 45 hours of lecture during the semester for both courses. For both courses, the students also receive 15 flight lessons, each of which are 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. The amount of time in the PCATD for the four flight lessons in AVI 130 and AVI 140 is shown in Table 1 for the three PCATD groups.

Table 1.

Time (hours) in PCATD by group and by flight lesson in the AVI 130 and AVI 140 courses.

Flight Lesson	PCATD 5	PCATD 10	PCATD 15
AVI 130			
34/35: Steep Turns	0.5	1.0	1.5
36: Holds	0.7	1.3	2.0
37: Approaches	0.7	1.3	2.0
38: Approaches	0.7	1.3	2.0
AVI 140			
48: Review Approaches	0.5	1.0	1.5
49: NDB Holds and App.	0.7	1.0	1.5
50: NDB Holds and App.	0.7	1.0	1.5
52: Holds/Approaches	0.7	1.0	1.5

All flight instructors were standardized on the use of the PCATDs, changes in the training course outlines (TCOs), and experimental procedures prior to the start of each semester. 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 allocation of students to training conditions, were used for the evaluation flight.

The 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 subjects who 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 to a successful evaluation flight or course completion time for both courses.

Analyses. Mean trials to reach criterion on the airplane for selected instrument tasks and mean time to complete the flight lesson were computed for all groups for both courses. Separate 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 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

Percent transfer, transfer effectiveness ratios, and incremental transfer effective ratios were computed for each flight lesson using the following equations:

$$\frac{Y_c - Y_x}{Y_c} = Percent \quad Transfer \tag{1}$$

$$\frac{Y_c - Y_x}{X} = TER \tag{2}$$

$$\frac{(Yx - \Delta x) - Yx}{\Delta X} = ITER \tag{3}$$

where Y_c = Time/Trials in airplane by Control group, Y_x = Time/Trials in airplane by PCATD group, X = Time/Trials in PCATD, ΔX = Incremental unit in Time/Trials, for PCATD group, and $Yx-\Delta x$ = Time/Trials, required by PCATD group to reach a performance criterion in an aircraft after $x - \Delta x$ trials in a PCATD

Percent transfer measures the difference, expressed as a percent, between the Control and the PCATD groups in terms of trials/time to reach criterion in the airplane. A positive percent transfer favors the PCATD group and a negative percent transfer favors the Control group. Percent transfer does not consider the amount of prior training in the PCATD by the PCATD groups. The TER is a ratio that compares the difference between the Control and the PCATD groups in terms of trials/time to reach criterion in the airplane as a function of the amount of prior training in the PCATD for the PCATD group. The TER is a measure of the average transfer for each group as a function of prior training. The ITER measures the amount of transfer of successive increments of training in the PCATD (Roscoe, 1971; Flexman, Roscoe, Williams, & Williges, 1972).

RESULTS

Trials to Criterion

AVI 130. 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) were computed and are shown in Table 2, which also shows the trials in the PCATD for each PCATD group. The data indicate that, with three exceptions, the mean trials in the airplane were less for all three PCATD groups for all instrument tasks when compared with the trials in the airplane by the control group. The exceptions are: 1) ILS (Flight Lesson 37), where the mean trials for the Control group were 1.60 compared to 1.61 for the PCATD 5 group; 2) LOC BC where the mean trials for the Control group were 1.48 compared to 1.58 for the PCATD 10 group; and 3) DME ARC where the mean trials for the Control group were 2.31 compared to 2.37 for the PCATD 10 group.

Table 2.
Mean trials in the airplane for the Control group (Y_c) and the three PCATD groups (Yx_5, Yx_{10}, Yx_{15}) and trials in the PCATD (X_5, X_{10}, X_{15}) for instrument tasks trained in AVI 130.

	Mean Trials in Airplane				Trials in PCATD		
Task	Yc	Yx_5	Yx_{10}	Yx_{15}	X_5	X_{10}	X_{15}
Steep Turns (FL 34/35)	3.70	2.92	2.61	3.22	1	2	3
Turn in Hold (FL 36)	7.40	6.18	6.34	5.92	6	12	18
ILS (FL 37)	1.60	1.61	1.58	1.47	1	2	3
VOR (FL 37)	1.80	1.47	1.47	1.47	1	2	3
LOC BC (FL 37)	1.48	1.34	1.58	1.39	1	2	3
ILS (FL 38)	2.05	1.21	1.32	1.21	1	2	3
VOR (FL 38)	1.82	1.32	1.24	1.29	1	2	3
DME ARC (FL 38)	2.31	1.92	2.37	2.11	2	4	6

These data are presented graphically in Figure 2. The Control group generally required more trials to reach criterion in the airplane for most of the basic instrument tasks than the three experimental groups. An ANOVA was computed which compared the results in Table 2 of mean trials for all instrument tasks to criterion in the airplane of the four groups. The results indicated a significant difference due to experimental treatment; $F(3,153) = 4.09$, $p =. 0.008$. 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 difference between the Control group and the PCATD 10 group was not significance. Individual ANOVAs comparing trials to criterion in the airplane for the four groups were performed for each instrument task in Table 2. 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 but no significant differences were found for the Control group and the PCATD 10 nor for the individual comparisons for the VOR 38 task. No other significant differences between the combined three experimental groups and the Control group were found for trials for any other basic instrument task.

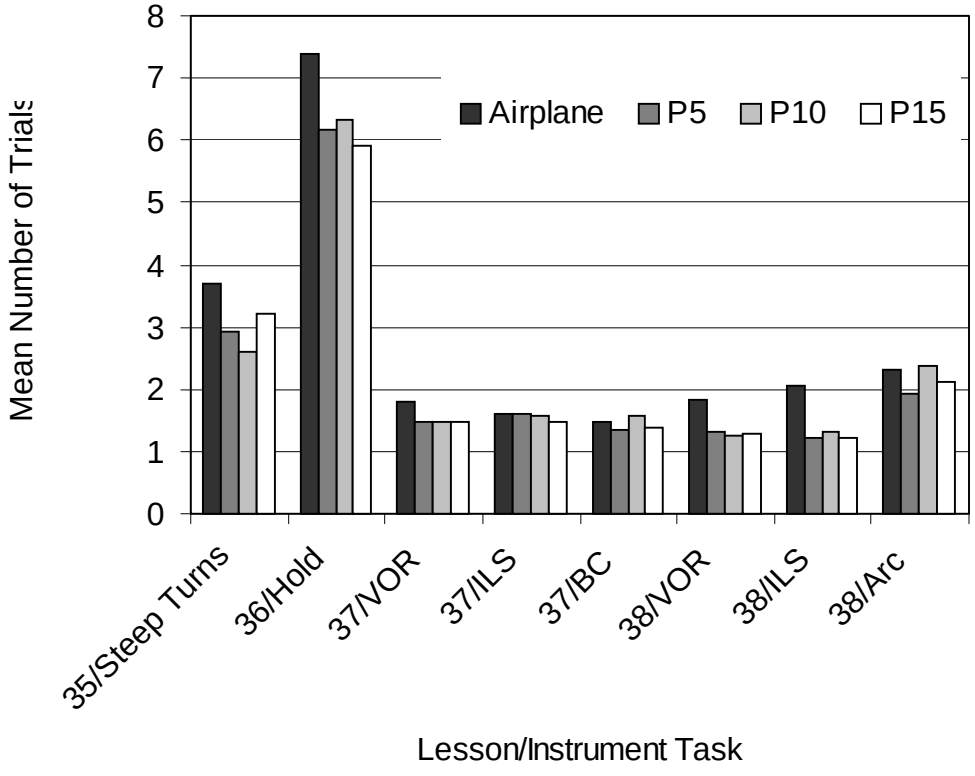

Figure 2. Mean trials in the airplane for the Control group and the three PCATD groups for the instrument tasks trained in AVI 130.

There was no systematic pattern indicating that additional PCATD training consistently led to an improvement in skill as measured by the number of trials saved. Indeed, for 2 of 8 tasks, the PCATD 5 group had the highest transfer rate: LOC BC and. DME ARC for the PCATD 5. Similarly, for the steep turns and VOR (Flight Lesson 37) tasks the PCATD 10 group had the best transfer, while for turns in hold and ILS (Flight Lesson 37) the PCATD 15 group achieved the greatest transfer. For VOR (Flight Lesson 37) the three PCATD groups saved the same number of trials compared to the Control group; and for ILS (38) the PCATD 5 and 15 groups saved the same number of trials compared to the Control group.

The data in Table 2 were used to compute percent transfer, TER and ITER, which are presented in Table 3. All percent transfers for all instrument tasks were positive with the exception of three: ILS (Flight Lesson 37) for the PCATD 5 group (-0.6%); LOC BC for the PCATD 10 group (-6.8%); and DME ARC for the PCATD 10 group (-2.6%). The largest percent transfer found for the trials dependent variable was for the ILS (Flight Lesson 38): 41.0% for both the PCATD 5 and 15 groups and 35.6% for the PCATD 10 group. Substantial percent transfers were also found for VOR (Flight Lesson 38); 27.5%, 31.9% and 29.1% for the PCATD 5, 10 and 15 groups respectively, and for the Steep Turns; 21.1 and 29.5 for the PCATD 5 and 10 groups respectively. No other percent transfers above 20.0 % were found for any instrument task for any of the three PCATD groups.

Table 3.

Percent transfer, transfer effectiveness ratios (TERs), and incremental transfer effectiveness ratios (ITERs) for trials on selected instrument tasks in AVI 130 for PCATD groups (X_5, X_{10}, X_{15}).

	Percent Transfer			TER			ITER		
Task	$\underline{X}_5$	$\underline{X}_{10}$	$\underline{X}_{15}$	$\underline{X}_5$	$\underline{X}_{10}$	$\underline{X}_{15}$	$\underline{X}_5$	$\underline{X}_{10}$	$\underline{X}_{15}$
Steep Turns (FL 34/35)	21.08	29.46	12.97	0.78	0.55	0.16	0.76	0.31	-0.61
Turns in Hold (FL 36)	16.49	14.32	20.00	0.20	0.09	0.08	0.20	-0.03	0.07
ILS (FL 37)	-0.63	1.25	8.13	-0.01	0.01	0.04			
VOR (FL 37)	18.33	18.33	18.33	0.33	0.17	0.11	0.33	0.00	0.00
LOC BC (FL 37)	9.46	-6.75	6.08	0.14	-0.05	0.03			
ILS (FL 38)	40.98	35.61	40.98	0.84	0.37	0.28	0.84	-0.11	0.11
VOR (FL 38)	27.47	31.87	29.12	0.50	0.29	0.18	0.50	0.08	-0.05
DME ARC (FL 38)	16.88	-2.59	8.66	0.20	-0.02	0.03			

Substantial TERs were found for the PCATD 5 and 10 groups for steep turns (0.78 and 0.55 respectfully) but not for PCATD 15 group (0.16). There was little transfer for ILS in Flight Lesson 37, but a substantial amount for ILS in Flight Lesson 38 for the three PCATD groups (0.84, 0.37, and 0.28 for the PCATD 5, 10 and 15 groups respectively). For the VOR instrument task, substantial transfer effectiveness was found for PCATD 5 for both Flight Lessons 37 and 38. The TER for the PCATD 5 group was 0.33 and 0.50 respectively for these two flight lessons. The TER for the PCATD 10 was 0.17 and 0.29 respectively and for PCATD 15 the TER was 0.11 and 0.18 respectively. No other TER for other instrument tasks was above the 0.20 level. The TERs for steep turns, turns in the hold, for Flight Lessons 37 and 38 and ILS for Flight Lesson 38 showed the predicted negatively decelerated function for increased number of trials. These functions are evident in the bar graphs shown in Figures 3 respectively. Examination of the ITERs indicates that with the exception of steep turns for the PCATD 10 group (ITER= 0.31) additional training beyond trials for the PCATD 5 group provided little benefit. Since there was no substantial transfer for the trial variable for ILS in Flight Lesson 37, LOC BC nor DME ARC, ITERs were not computed for these instrument tasks.

AVI 140. 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) were computed and are shown in Table 4, which also shows the trials in the PCATD for each group. 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. These exceptions are 1) Turns in the Hold (Flight Lesson 50) where the mean trials for the Control group were 4.17 compared to 4.69 for the PCATD 5 group; 2) ILS Turns in the Hold (Flight Lesson 50) for all three PCATD groups where the mean trials for the Control group were 3.43 compared to 3.84, 4.00, and 3.45 for the PCATD 5, 10, and 15 groups respectively; and 3) Turns in the Hold (Flight Lesson 52) for the PCATD 5 and 15 groups where the mean trials for the Control group were 4.16 compared to 4.16 and 4.33 for the PCATD 5 and 15 group respectively.

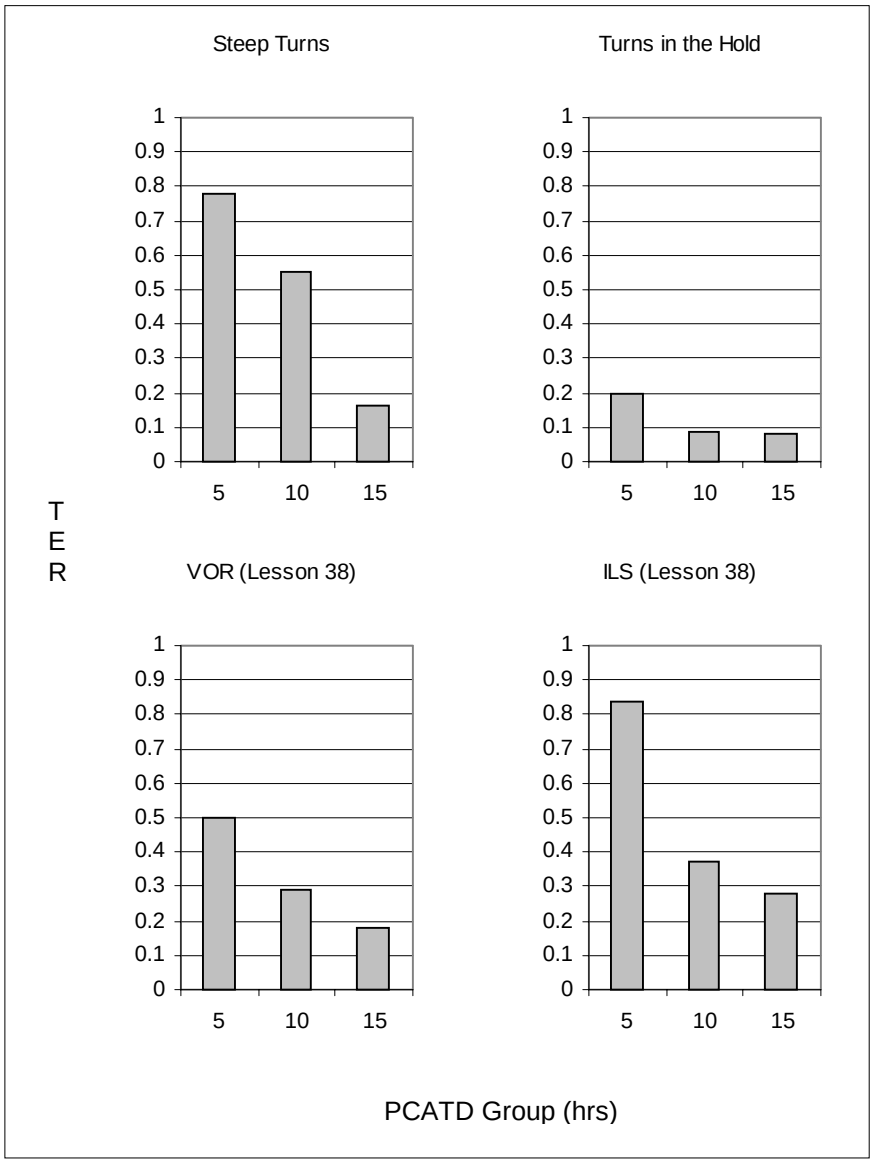

Figure 3. Transfer Effectiveness Ratios (TERs) for number of trials by maneuvers in AVI 130.

Table 4.

Mean trials in the Airplane for the Control group (Y_c) and the three PCATD groups (Yx_5, Yx_{10}, Yx_{15}) and trials in the PCATD (X_5, X_{10}, X_{15}) for instrument tasks trained in AVI 140.

	Mean Trials in Airplane				Trials in PCATD		
Task	Yc	Yx_5	Yx_{10}	Yx_{15}	X_5	X_{10}	X_{15}
Turns in Hold (FL 48)	3.94	3.85	3.72	3.22	3	6	9
ILS (FL 48)	1.35	1.24	1.22	1.22	1	2	3
VOR (FL 48)	1.28	1.15	1.16	1.13	1	2	3
NDB Turns in Hold (FL 49)	5.19	5.06	5.00	4.71	3	6	9
NDB (FL 49)	2.25	1.94	2.13	1.97	1	2	3
NDB Turns in Hold (FL 50)	4.17	4.69	4.09	3.65	3	6	9
NDB (FL 50)	1.51	1.38	1.34	1.32	1	2	3
ILS Turns in Hold (FL 50)	3.43	3.84	4.00	3.45	3	6	9
NDB (FL 52)	1.37	1.22	1.09	1.27	1	2	3
VOR (FL 52)	1.34	1.09	1.31	1.20	1	2	3
Turns in Hold (FL 52)	4.16	4.16	4.09	4.33	3	6	9

These data are presented graphically in Figure 4. The Control group generally required more trials to reach criterion in the airplane for most of the basic instrument tasks than the three experimental groups. An ANOVA was computed which compared the results in Table 4 of mean trials of the four groups for all instrument tasks to criterion in the airplane. The results indicated no significant difference due to experimental treatment; $F(3,129) = 1.07$, $p = 0.36$. Individual ANOVAs comparing trials to criterion in the airplane for the four groups were performed for each instrument task in Table 4. None of the ANOVAs were significant. 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.

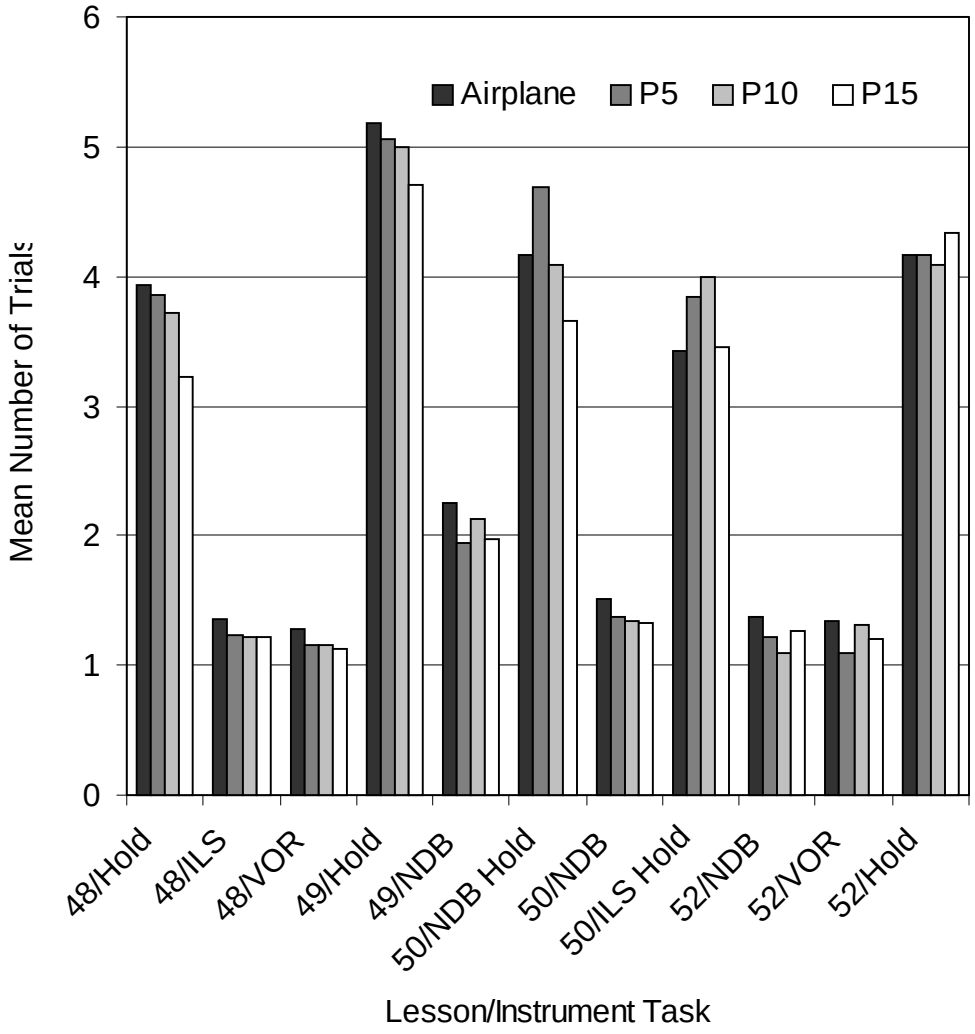

Figure 4. Mean number of trials for instrument tasks in AVI 140.

The data in Table 4 were used to compute percent transfer, TER and ITER, which are presented in Table 5. All percent transfers for all instrument tasks were positive with the exception of five percent transfers: NDB Turns in Hold (Flight Lesson 50) for the PCATD five group (-12.47%); ILS Turns in Hold for all three PCATD groups (-11.95, -16.62 and –0.58 respectively for the PCATD 5, 10,and 15 groups), Turns in the hold (Flight Lesson 52) for the PCATD 5 and 15 groups (0.00 and –4.09 for the PCATD 5 and 15 groups respectively). The percent transfer was generally small. The largest percent transfer found for the trials dependent variable for instrument tasks trained in AVI 140 was for the VOR (Flight Lesson 52); 18.66% for the PCATD 5 group. An 18.27 percent transfer was found for Turns in Hold (Flight Lesson 48) for the PCATD 15 group. No other percent transfers above 15.0%were found for any instrument task for any of the three PCATD groups.

Table 5.

Percent transfer, transfer effectiveness ratios (TERs), and incremental transfer effectiveness ratios (ITERs) for trials on selected instrument tasks in AVI 140 for PCATD groups (X_5, X_{10}, X_{15}).

	Percent Transfer			TER			ITER		
Task	X_5	X_{10}	X_{15}	X_5	X_{10}	X_{15}	X_5	X_{10}	X_{15}
Turns in Hold (FL 48)	2.28	5.58	18.27	0.03	0.04	0.08	0.03	0.04	0.17
ILS (FL 48)	8.15	9.63	9.63	0.11	0.07	0.04	0.11	0.02	0.00
VOR (FL 48)	10.16	9.38	11.72	0.13	0.06	0.05	0.13	-0.01	0.03
NDB Turns in Hold (FL 49)	2.50	3.66	9.25	0.04	0.03	0.05	0.04	0.02	0.10
NDB (FL 49)	13.78	5.33	12.44	0.31	0.06	0.09	0.31	-0.19	0.16
NDB Turns in Hold (FL 50)	-12.47	1.92	12.47	-0.17	0.01	0.06	-0.17	0.20	0.15
NDB (FL 50)	8.61	11.26	12.58	0.13	0.09	0.06	0.13	0.04	0.02
ILS Turns in Hold (FL 50)	-11.95	-16.62	-0.58	-0.14	-0.10	0.00	-0.14	-0.05	0.18
NDB (FL 52)	10.95	20.44	7.30	0.15	0.14	0.03	0.15	0.13	-0.18
VOR (FL 52)	18.66	2.24	10.45	0.25	0.15	0.05	0.25	-0.22	0.11
Turns in Hold (FL 52)	0.00	1.68	-4.09	0.00	0.01	-0.02	0.00	0.02	-0.08

Although the TERs were generally positive (four negative TERS were found), they were generally small and non substantial. With the exception of TERs of 0.31 for NDB (Flight Lesson 49) and 0.25 for VOR (Flight Lesson 52), none of other TERs were higher than 0.15 [e.g., VOR (Flight Lesson 52)]. The TERs for VOR (Flight Lesson 52) showed the predicted negatively decelerated function for increase number of trials. This function is evident in the bar graphs shown in Figure 5. Examination of the ITERs indicates that additional training beyond the PCATD 5 level provided no substantial benefit for trials for AVI 140.

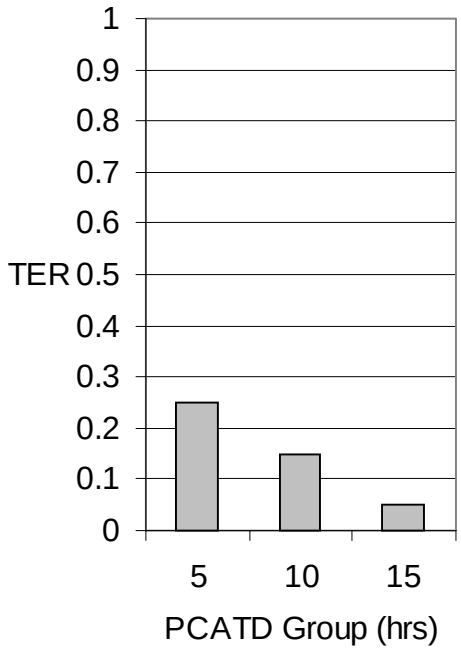

Figure 5. TER for mean trials in the airplane for VOR, Flight Lesson 52 in AVI 140.

Time to Complete Flight Lesson

AVI 130. The mean times to complete the flight lesson in AVI 130 are shown in Table 6. For all three PCATD groups, the mean times to complete each of the four flight lessons were less than the time for the Airplane group. For two of the four flight lessons the PCATD 10 group had the least time to complete the flight lesson. For Flight Lesson 36 the PCATD 15 group had the smallest time and for Flight Lesson 37 the PCATD 5 had the smallest time.

The data in Table 6 are presented graphically in Figure 6. The Control group consistently required more time to reach criterion for all four flight lessons in AVI 130 compared to the three experimental groups. An ANOVA was performed to compare the mean times to complete the flight lesson s among the four groups. The results indicated a significant effect among the groups for 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 were performed for each flight lesson in Table 4 comparing the time to complete the flight lesson among the four groups. The results of the individual ANOVAs 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 nor for Flight Lesson 37.

Table 6.

Mean time to complete the flight lesson in the airplane for the Control group (Y_c) and the three PCATD Groups (Yx_5, Yx_{10}, Yx_{15}) for AVI 130.

	Mean Times			
Flight Lesson	Y_c	Yx_5	Yx_{10}	Yx_{15}
34/35, Steep Turns	1.47	1.28	1.20	1.29
36, Intersection Holds	1.64	1.36	1.27	1.19
37, ILS, LOC BC, VOR	2.17	1.81	1.85	1.91
38, ILS, VOR, DME ARC	2.42	1.60	1.52	1.58

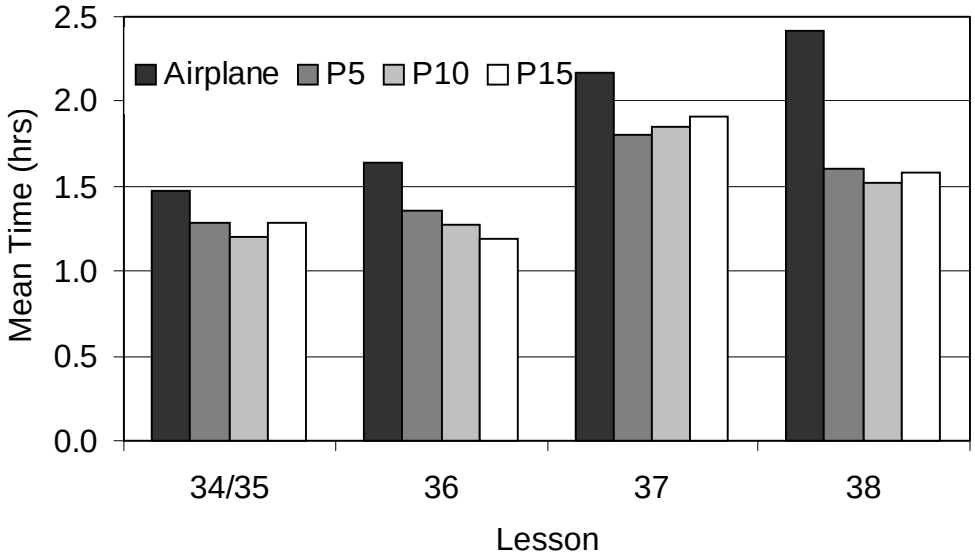

Figure 6. Mean time to complete the flight lessons in the airplane for the Control group and the three PCATD groups for AVI 130.

These times were used to compute percent transfer, TERs, and ITERs shown in Table 7. All percent transfers were positive but they were relatively small. The largest percent transfer occurred for Flight Lesson 38 for all 3 PCATD groups (33.9%, 37.2%, and 34.7% for the PCATD 5, 10, and 15 groups respectively). Substantial percent transfer was found for Flight Lesson 36 for PCATD 10 and 15 (22.6% and 27.4% respectfully). No other percent transfer exceeded 20%.

Table 7.

Percent transfer, transfer effectiveness ratios (TERs), and incremental transfer effectiveness ratios (ITERs) for mean time to complete flight lessons for PCATD groups (X_5, X_{10}, X_{15}) for AVI 130.

	Percent Transfer			TER			ITER		
Flight Lesson	X_5	X_{10}	X_{15}	X_5	X_{10}	X_{15}	X_5	X_{10}	X_{15}
34/35, Steep Turns	12.9	18.4	12.2	0.38	0.27	0.12	0.38	0.16	-0.18
36, Intersection Holds	17.1	22.6	27.4	0.40	0.28	0.23	0.40	0.15	0.11
37, ILS, LOC BC, VOR	16.6	14.8	12.0	0.51	0.25	0.13	0.51	-0.07	-0.09
38, ILS, VOR, DME ARC	33.9	37.2	34.7	1.17	0.68	0.42	1.17	0.13	-0.09

The TERs for each of the three PCATD groups for Flight Lesson 34/35, steep turns, were positive but they were generally smaller (0.38, 0.27, and 0.12 for the PCATD 5, 10 and 15 groups respectively) than the TERs for the other three flight lessons. Transfer of training was positive and substantial for Flight Lessons 36, 37 and 38 for the mean time to complete the flight lesson in AVI 130. The most substantial average transfer for the mean time to complete the flight lesson variable occurred for Flight Lesson 38 for all three PCATD groups (TERs were 1.17, 0.68 and 0.42 for the PCATD 5, 10, and 15 groups respectively). For the PCATD 5 group, the TERs ranged from 0.38 to 1.17. The pattern of the TERs for the mean time to complete the flight lesson variable for all PCATD groups showed the predicted negative decelerated function for each flight lesson for increased amounts of training time in the PCATD. These functions are evident in the bar graphs shown in Figure 7. For the time to complete flight lesson variable, the largest ITERs found were 0.16 and 0.15 for Flight Lesson 34/35 and 36 respectfully for the PCATD 10 group and 0.11.for the PCATD 15 group for Flight Lesson 36. The ITERs for time to complete each flight lesson showed the predicted negatively decelerated function. An example of the ITER is shown in Figure 8.

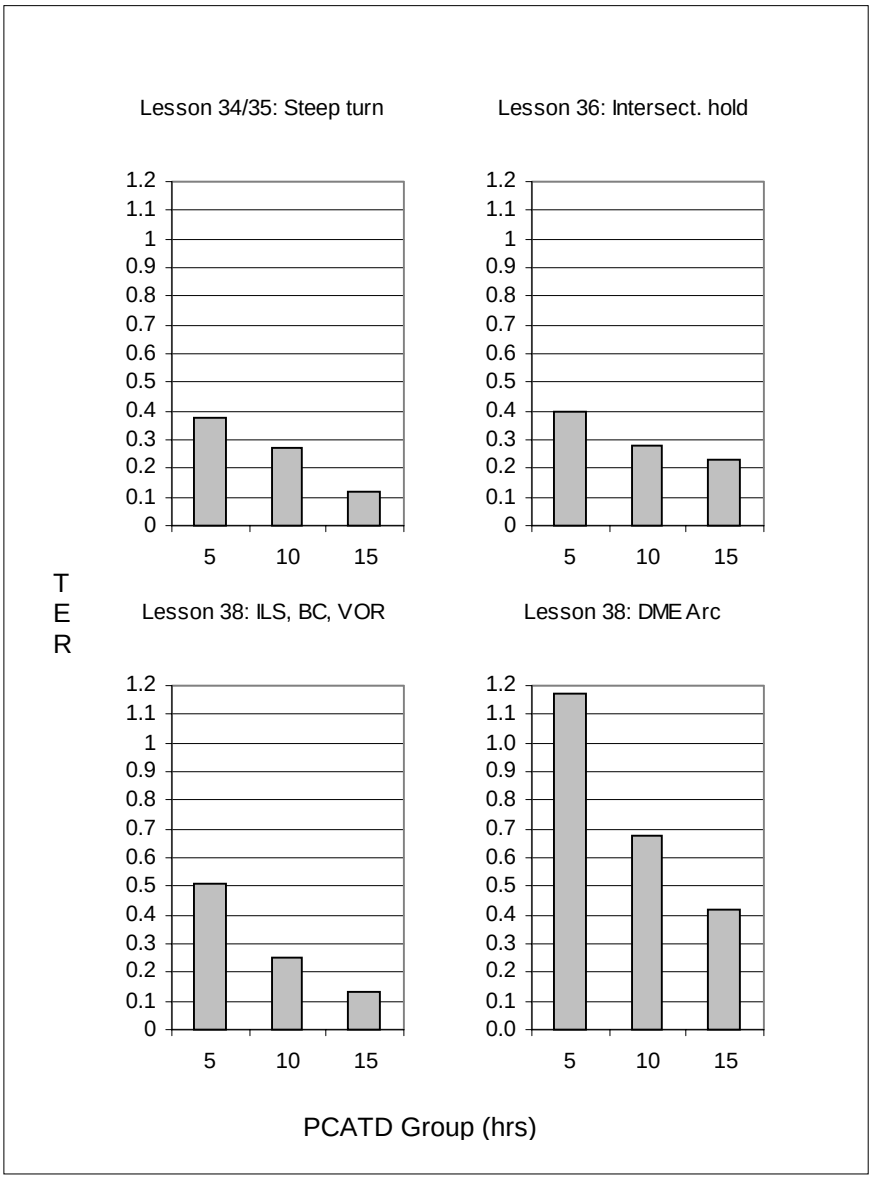

Figure 7. Transfer Effectiveness Ratios (TERs) for time to complete a flight lesson by flight lesson in AVI 130.

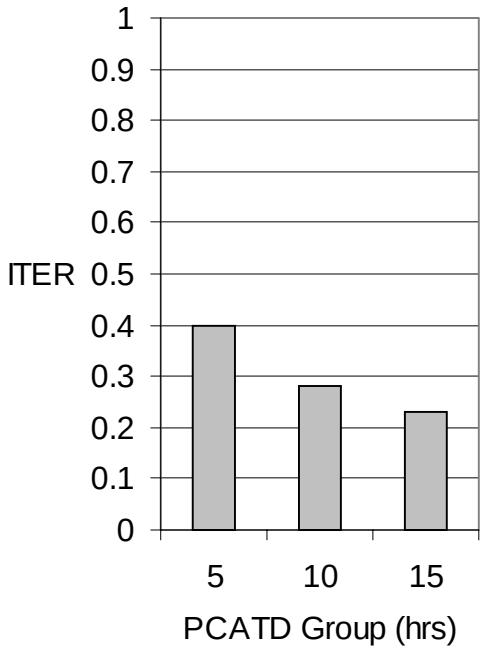

Figure 8. ITER for time to complete Flight Lesson 36, intersection holds in AVI 130.

AVI 140. The mean times to complete the flight lesson in AVI 140 are shown in Table 8. For all three PCATD groups, the mean times to complete each of the four flight lessons were less than the time for the Control group. For three of the four flight lessons, Flight Lessons 49, 50 and 52, the PCATD 10 group had the least time to complete the flight lesson. For Flight Lesson 48 the PCATD 15 group had the smallest time.

Table 8.
Mean time to complete the flight lesson in the airplane for the Airplane group (Y_c) and the three PCATD groups (Yx_5, Yx_{10}, Yx_{15}) for AVI 140.

	Mean Times			
Flight Lesson	Y_c	Yx_5	Yx_{10}	Yx_{15}
48, Holds, ILS, VOR	2.04	1.63	1.63	1.56
49, NDB Holds, NDB	1.63	1.33	1.32	1.43
50, NDB & ILS Holds, NDB	1.82	1.70	1.53	1.57
52, ILS Holds, NDB, VOR, Holds	2.27	1.62	1.60	1.89

The data in Table 8 are presented graphically in Figure 9. The Control group consistently required more time to reach criterion for all four flight lessons in AVI 140 compared to the three experimental groups. An ANOVA was performed to compare the mean times of the four groups to complete the four flight lessons. The results indicated a significant treatment effect for the four groups; $F(3,129) = 6.01$, $p = 0.0007$. Post-hoc Tukey tests for significance ($p<=0.05$) indicated significant differences between the Control group and each of the experimental groups. Individual ANOVAs were performed for each flight lesson in AVI 140 comparing the time for the four groups to complete the flight lesson. The results of the individual ANOVAs 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 flights lesson 48, 49, 50 although Flight Lesson 48 approached significance: $F(3,129)=2.37$,$p=0.07$.

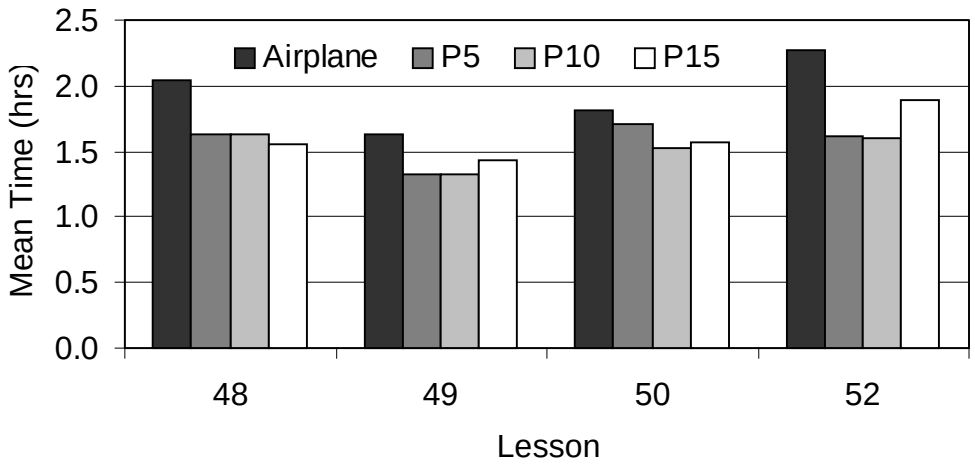

Figure 9. Mean time to complete flight lessons in the airplane for the Control and the three PCATD groups in AVI 140.

Times to complete the four Flight Lessons were used to compute percent transfer, TERs, and ITERs for AVI 140 which are shown in Table 9. All percent transfers were positive but they were relatively small; generally (three exceptions) the percent transfer were between 15.0% and 30.0%. The largest percent transfer occurred for Flight Lesson 52 for two of the three PCATD (28.63%, and 29.52% for the PCATD 5,and 10 groups respectively). The following percent transfers were also found for Flight Lesson 48 for all three PCATD groups (20.10%, 20.10% and 23.53% for the PCATD 5, 10 and 15 groups respectively), and for Flight Lesson 49 for PCATD groups 5 and 10 (18.40 and 19.02 for the PCATD 5 and 10 group respectively).

Table 9.

Percent transfer, transfer effectiveness ratios (TERs), and incremental transfer effectiveness ratios (ITERs) for mean time to complete flight lessons for PCATD groups (X_5, X_{10}, X_{15}) for AVI 140.

	Percent Transfer			TER			ITER		
Flight Lesson	X_5	X_{10}	X_{15}	X_5	X_{10}	X_{15}	X_5	X_{10}	X_{15}
48, Holds, ILS, VOR	20.10	20.10	23.53	0.59	0.32	0.24	0.59	0.00	0.10
49, NDB Holds, NDB	18.40	19.02	12.27	0.60	0.31	0.13	0.60	0.02	-0.22
50, NDB & ILS Holds, NDB	6.59	15.93	13.74	0.17	0.22	0.13	0.17	0.24	-0.06
52, ILS Holds, NDB, VOR, Holds	28.63	29.52	16.74	0.93	0.52	0.19	0.93	0.03	-0.41

The TERs for time to complete flight lesson in AVI 140 for each of the three PCATD groups for Flight Lesson 50, NDB & ILS holds and NDB approach, were positive but they were generally smaller (0.17, 0.22, and 0.13 for the PCATD 5, 10 and 15 groups respectively) than the TERs for the other three flight lessons. Transfer of training was positive 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 all PCATD groups showed the predicted negative decelerated function for three of the four flight lessons for increased amounts of training time in AVI 140 in the PCATD. These functions are evident in the bar graphs shown in Figures 10. For the time to complete flight lesson variable, the largest ITER found for PCATD 10 for Flight Lesson 50. Increased training time beyond PCATD 5 made little contribution to reducing the training time in the airplane.

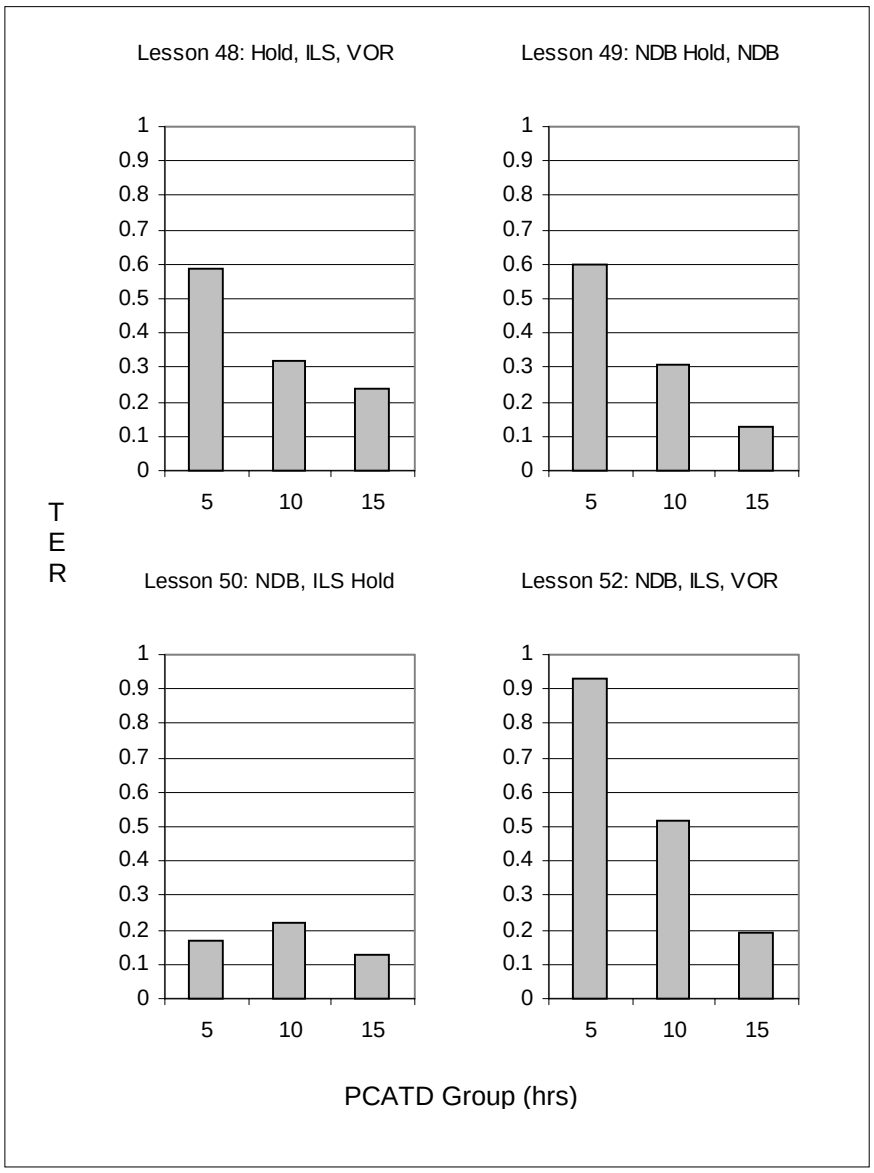

Figure 10. Transfer Effectiveness Ratios (TERs) for time to complete a flight lesson by flight lesson in AVI 140.

Time to Evaluation Flight

AVI 130. The total dual prior to a successful evaluation flight was computed for the Control group and for each of the three PCATD groups. The times to the evaluation flight were less for all three PCATD groups than for the Control group. The Control group required 22.16 hours compared to 20.13, 19.06 and 20.72 hours for the PCATD 5, 10, and 15 groups respectively. These times are presented in Figure 11. The flight hours saved were 2.03 hours, 3.10 hours, and 1.44 hours respectively for the PCATD 5, 10, 15 groups. An ANOVA was

computed to compare the time to a successful evaluation flight for the four groups. The result 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.

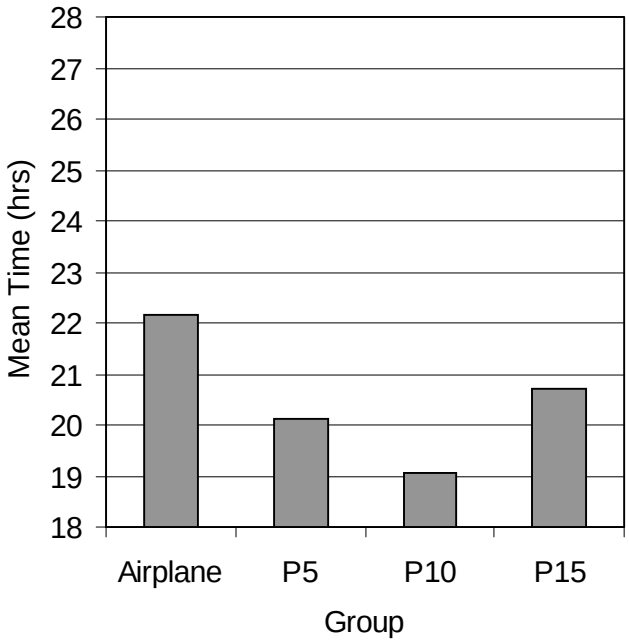

Figure 11. Mean time to successful evaluation flight for AVI 130.

AVI 140. The total dual prior to a successful evaluation flight for AVI 140 was computed for the Control group and for each of the three PCATD groups. The mean times to the evaluation flight were less for all three PCATD groups than for the Control group. The Control group required 27.13 hours compared to 25.08, 24.74, and 25.38 hours for the PCATD 5, 10, and 15 groups respectively. These times are presented in Figure 12. The flight hours saved were 2.05 hours, 2.39 hours, and 1.75 hours respectively for the PCATD 5, 10, 15 groups. An ANOVA was computed to compare the time to a successful evaluation flight for the four groups. The result 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.

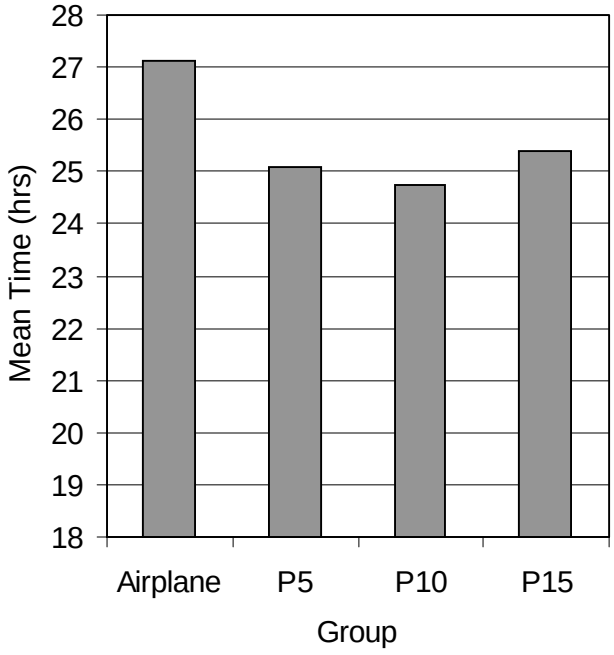

Figure 12. Mean time to a successful evaluation flight for AVI 140.

Overall time saved. The overall time saved for each of the PCATD groups compared to the Control group was: PCATD 5, 4.08 hours; PCATD 10, 5.49 hours; and PCATD 15, 3.19 hours. The overall TERs for the three groups for time saved in the instrument course were 0.82, 0.55 and 0.21 for the PCATD 5, 10 and 15 groups respectively.

DISCUSSION

Mean Trials

AVI 130. The data from the study indicates that the PCATD is effective in teaching basic instrument tasks in AVI 130 to private pilots. Prior training in the PCATD in AVI 130 resulted in a smaller number of trials in the airplane for each of the PCATD groups for 21 of the 24 instrument tasks tested. In previous research, Taylor et al. (1996) found significant differences for the ILS task for Flight Lesson 37 but not for Flight Lesson 38 when a PCATD group, trained to proficiency, was compared, using a t-test, with an airplane-only control group. These differences may be explained by differences in experimental design. Taylor et al. (1996) trained the experimental group to proficiency in the PCATD prior to training to proficiency in the airplane while the design in the current study calls for a fixed number of trials which varies from 1-3 for the three experimental groups. The data indicate that the mean number of trials in the

PCATD in the earlier study was 2.70 while the mean trials in the airplane for the PCATD group was 1.50. The Control group in the earlier study had a mean number of trials of 2.25 in the airplane compared to 1.60 in the current study. In Flight Lesson 38 the Control group had 2.05 mean trials in the airplane in the current study compared to 1.36 in the earlier study. One can infer that the flight instructors in the current study trained to a higher proficiency standard for the ILS task in Flight Lesson 38 compared to Flight Lesson 37. It should also be noted that the flight instructors in the current study had less teaching experience on average than the instructors in the earlier study.

The prediction that an increased number of trials in the PCATD on the selected instrument tasks would save more trials in the airplane was found in AVI 130 for only six of the sixteen instruments task comparisons. For two of the eight instrument tasks, the PCATD 5 group had the least trials in the airplane, for two tasks the PCATD 10 group had the least trials in the airplane and the PCATD 15 group had two tasks with the least trials in the airplane.

The percent transfer for trials ranged from a high of 41.0% for the PCATD 5 group for ILS in Flight Lesson 38 to a low of – 6.8% for LOC BC for PCATD 10 in Flight Lesson 37. For the PCATD 5 group the TER of 0.84 indicates that for Flight Lesson 38 almost one trial in the aircraft was saved for each trial in the PCATD. Over 1/3 of a trial was saved for the PCATD 10 group and about a third of a trial for the PCATD 15 group. The results of Taylor et al. (1996) showed the opposite effect. The percent transfer and TER for ILS were 33.3 percent and 0.28 respectively for Flight Lesson 37 but only 11.8 percent and 0.12 for Flight Lesson 38. It should be noted, however, that in the Taylor et al. (1996) study, the subjects were trained in the PCATD to a proficiency standard and trained to the same proficiency standard in the airplane in Flight Lesson 37. Training in the PCATD for Flight Lesson 38 was a review lesson. In the currently study the subjects received only 1, 2, or 3 trials respectively for the PCATD 5, 10, 15 groups in each of the two flight lessons and were trained in the airplane to a completion standard. This does not explain why the Control group took longer to reach completion standards in Flight Lesson 38 than in Flight Lesson 37 while all three PCATD groups continued to benefit from additional training in the PCATD. A reasonable explanation is that the flight instructors in all groups used a more difficult completion standard in Flight Lesson 38 than 37 and the PCATD groups all benefited from additional training in the PCATD before being tested in the airplane but the Control group was only trained/tested in the airplane.

AVI 140. Prior training in the PCATD in AVI 140, advanced instruments, resulted in a smaller number of trials in the airplane for each of the PCATD groups for 27 of the 33 instrument tasks tested, but these differences were small and none were significant. In previous research, Taylor et al. (1996) found significant differences for the VOR task for Flight Lesson 48, NDB holds for Flight Lesson 50, NDB approach in Flight Lesson 49 and 50, and for LOC BC holds for Flight Lesson 50, when a PCATD group, trained to proficiency, was compared using t-tests with an airplane-only control group**.** These differences may be explained by differences in experimental design. As discussed above, Taylor et al. (1996) trained the experimental group to proficiency in the PCATD prior to training to proficiency in the airplane while the design in the current study calls for a fixed number of trials which varies from 1-3 trials for the three experimental groups. The data indicate that the mean number of trials in the PCATD for VOR in Flight Lesson 48 in the earlier study was 1.05 while the mean trials in the airplane for the PCATD group was 1.05 compared to mean trials of 1.15, 1.16.and 1.13 for the

PCATD 5, 10 and 15 groups respectively, in the current study. The Control group in the earlier study had a mean number of trials of 1.23 in the airplane compared to 1.28 in the current study. For the NDB approach task for both Flight Lessons 49 and 50 in the current study all three experimental groups had a higher number of trials in the airplane than the PCATD group in the previous study (1.94, 2.13 and 1.97 trials respectfully for PCATD 5, 10 and 15 groups compared to 1.54) for Flight Lesson 49, and (1.38, 1.34 and 1.32 compared to 1.18) for Flight Lesson 50. Again, one can infer that the flight instructors in the current study trained to a higher proficiency standard in Flight Lessons 49 and 50 compared to the earlier study. It should also be noted that the flight instructors in the current study had less teaching experience on average than the instructors in the earlier study.

The percent transfer for trials in AVI 140 ranged from a high of 20.44 for PCATD 10 for NDB for Flight Lesson 52, 18.66% for the PCATD 5 group for VOR ILS in Flight Lesson 52, and 18.27% for turns in hold for PCATD 15 for Flight Lesson 48 to a low of –16.62% for ILS turns in hold for PCATD 10 in Flight Lesson 50. Substantial higher percent transfers were found for all instrument tasks for comparable instrument tasks for Flight Lessons 48, 49 and 50 for the previous study (Taylor et al, 1996). These ranged from 28.1% for NDB approach for Flight Lesson 50 to 14.6% for VOR for Flight Lesson 48. In addition, only two of seven of the previous percent transfers were below 20%. With the exception of the PCATD 5 group for NDB Flight Lesson 49 with a TER of 0.31, the TERS for trials in AVI 140 were smaller for the current study compared to the previous study (Taylor et al., 1996)

Mean Time to Complete the Flight Lesson

AVI 130. The mean times to complete the flight lesson in the airplane for the four flight lessons in which there was prior training in the PCATD were less for all three PCATD groups than for the Airplane group. Taylor et al. (1996) found the same result for these four flight lessons. Indeed, the previous results were used to select four flight lessons for PCATD training for AVI 130 for the present study. Significant differences were found for Flight Lessons 36 and 38 when the combined experimental groups were compared with the Control group for each of the four flight lessons. These results partially replicate the findings of Taylor et al. (1996) who found significant differences in the mean time to complete the flight lesson for all four of the flight lessons.

The percent transfer for time in the current study ranged from 12.9% for Flight Lesson 34/35 (steep turns) for PCATD 5 to 37.2% for Flight Lesson 38 (ILS, VOR, DME ARC) for PCATD 10. The percent transfer for Taylor et al. (1996) ranged from 37.5% for steep turns (Flight Lesson 34/35) to 22.7% for Flight Lesson 38.

For all four flight lessons the TERs for the time to complete the flight lesson variable showed the negatively decelerated function predicted by Roscoe (1971), and Flexman et al. (1972). In terms of the TER, the largest amount of average transfer was always found for PCATD 5 and the smallest for PCATD 15 as predicted for all four flight lessons. The TERs ranged from 1.17 for Flight Lesson 38 (ILS, VOR, DME ARC) for PCATD 5 to 0.12 for Flight Lesson 34/35 (steep turns) for PCATD 15. Taylor et al. (1996) reported TERs that ranged from 0.23 for Flight Lesson 36 (holds) to 0.50 for Flight Lesson 34/35 (steep turns). Table 5 shows that the largest amount of average transfer occurred in Flight Lesson 38 for all three PCATD

groups. For the PCATD 5 group, the TER was 1.17, which indicated that about 1¼ hours were saved in the airplane for each hour in the PCATD. The PCATD 10 group saved almost 7/10 of an hour and the PCATD 15 group saved almost ½ hour for each hour in the PCATD. Over ½ hour was also saved for the PCATD 5 group for flight lessons and 37 and about 4/10 of an hour for Flight Lessons 34/35 and 36.

Of the five ITERs for the trial variable shown in Table 3, two (steep turns and VOR for Flight Lesson 38) showed the predicted pattern of a negatively decelerated function (Roscoe, 1971 and Flexman et al., 1972). For turns in the hold, the ITER for PCATD 15 is greater than for PCATD 10 and for ILS for Flight Lesson 38, the ITER for PCATD 15 is slightly greater than PCATD 10. The negative ITERs found for the PCATD 10 group for turns in the hold and ILS in Flight Lesson 38 were found since the increased number of trials in the PCATD for the PCATD 10 group compared to the PCATD 5 group failed to save additional trials to criterion in the airplane. With the exception of PCATD 10 for steep turns, there is little ITER for either PCATD 10 nor PCATD 15, which indicated that additional training beyond the training for the PCATD 5 group saved few trials in the airplane.

For the four flight lessons shown in Table 5, the ITERs for time to complete flight lesson exhibited the predicted pattern of a negatively decelerated function (Roscoe, 1971 and Flexman et al., 1972). While there are substantial time savings for all four of the flight lessons for PCATD 5, the incremental savings for the PCATD 10 group ranges from 0.16 to 0.13 for three of the four flight lessons and is negative for the fourth, which indicated that the additional training time for PCATD 10 failed to substantially reduce the time to complete the flight lesson compared to the PCATD 5 group. There are little or no incremental time savings for the PCATD 15 group compared to the PCATD 10 group. These relationships resulted in the negative ITERs for three of the four flight lessons the PCATD 15 group.

AVI 140. For all four flight lessons in AVI 140 the Control group required more time to complete the flight lesson in the airplane when compared to the three experimental groups in which there was prior training in the PCATD. The same result was found by Taylor et al. (1996) for three of the four flight lessons (Flight Lessons 49, 50, and 52) in which there was prior training in the PCATD. Indeed, the previous results were used in part to select the four flight lessons for PCATD training for AVI 140 for the present study. In the current study, a significant effect was found for treatment effect among the four groups, but post-hoc tests found no significant differences between the Control group and any of the three experimental groups. Individual tests of significance for each flight lesson found a significant treatment effect for Flight Lesson 52. Post- hoc tests indicated significant differences between the Control group and the PCATD 5 group and the Control group and the PCATD 10 group. These findings were similar to those of Taylor et al. (1996) who found significant differences for Flight Lessons 49 and 50 between the Control group who trained only in the airplane and the PCATD group who had prior training in the PCATD.

The percent transfer for time in the current study ranged from 6.59% for Flight Lesson 50 (NDB holds and approaches and ILS holds) for PCATD 5 to 28.63% for Flight Lesson 52 (partial panel ILS, VOR, and holds) for PCATD 5. The percent transfer for Taylor et al. (1996) was similar ranging from 1.5% for Flight Lesson 52 to 26.4% for Flight Lesson 49.

For three of the four flight lessons in AVI 140 the TERs for the time to complete the flight lesson variable showed the negatively decelerated function predicted by Roscoe (1971), and Flexman et al. (1972); Flight Lesson 50 was the exception. In terms of the TER, the largest amount of average transfer was found for the PCATD 5 group for three of the flight lessons (Flight Lesson 50 was the exception), and as predicted the smallest TER was found for PCATD 15 for all four flight lessons. The TERs ranged from 0.93 for Flight Lesson 52 (partial panel for ILS, VOR, and holds) for the PCATD 5 group to 0.13 for Flight Lessons 49 and 50 for the PCATD 15 group. Taylor et al. (1996) reported TERs which ranged from 0.01 for Flight Lesson 52 to 0.24 for Flight Lesson 50. The results of the current study showed that the largest amount of average transfer occurred for the PCATD group in Flight Lessons 48, 49, and 52. For Flight Lesson 52, the TER was 0.93 for the PCATD 5 group which indicated that about one hour was saved in the airplane for each hour in the PCATD. For this flight lesson the PCATD 10 group saved over 1/2 of an hour (TER = 0.52) and the PCATD 15 group saved almost 1/5 hour (TER= 0.19) for each hour in the PCATD. Over ½ hour was also saved for the PCATD 5 group for Flight Lessons 48 and 49. Increased training time beyond the PCATD 5 level made no substantial contribution to reducing the training time in the airplane in AVI 140.

Time to a Successful Evaluation Flight

AVI 130. The time to a successful evaluation flight for AVI 130 was less for all three PCATD groups compared to the Control group. The flight hours saved were 2.03 hours, 3.10 hours, and 1.44 hours respectively for the PCATD 5, 10, 15 groups. A significant treatment effect was found for the time to a successful evaluation flight in AVI 130 for the four groups. Post-hoc tests indicated a significant difference between the PCATD 10 group and the Control group but not for the PCATD 5 and 15 groups. Taylor et al. (1996) found a time savings of 2.1 hours for the PCATD group. In the earlier study, the Institute of Aviation was approved to train to a proficiency standard not to the flight hours in FAR Part 141.

AVI 140. The time to a successful evaluation flight for AVI 140 was less for all three PCATD groups compared to the Control group. The flight hours saved were 2.05 hours, 2.39 hours, and 1.75 hours respectively for the PCATD 5, 10, 15 groups. A significant treatment effect was found for the time to complete the evaluation flight in AVI 140 for the four groups. However, post-hoc tests indicated no significant difference between any of the PCATD groups and the Control group. Taylor et al. (1996) found a significant treatment effect and a time savings of 1.8 hours for the PCATD group for AVI 140. As discussed above, in the earlier study, the Institute of Aviation was approved to train to a proficiency standard as opposed to the flight hours required by FAR Part 141. This exemption was not reissued when Part 141 was revised. In order to provide a way to determine flight savings due to prior training in the PCATD, the flight instructors were instructed to recommend an evaluation flight after Flight Lesson 40 in AVI 130 and Flight Lesson 55 in AVI 140 when the student was judged to be competent to meet the proficiency standards for the AVI 130 Lesson 45 stage check and the AVI 140 Lesson 60 instrument rating check respectively. In the earlier study, the flight instructor was able to train to a proficiency standard and if the student passed the check ride the student was refunded the remaining portion of the prior paid flight fee. In the current study the instructor and the student were required to complete the flight hours in the course outline for both AVI 130 and 140 even though the student had completed a successful evaluation flight. The differences between the

motivational aspects of the two studies are important and we recommend that future studies obtain an exemption in order to be able to train to proficiency standard.

Overall Effectiveness of PCATDs in Instrument Training

This study systematically 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 to a specific criterion, 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 transfer effect was found for the PCATD 5 group, which was predicted by the incremental transfer of training theory of Roscoe (1971). The predicted result that increased trials/ time in the PCATD would save trials/time in the airplane compared to the Control group, however, was not found. In some cases the results indicate a complex pattern of time savings in the airplane which failed to support the prediction that more training in the PCATD is better. The results 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. (1999) also found less transfer during AVI 140 than AVI 130. They noted that "the evident reason for this is that what is learned while mastering one task in a training device generalizes (i.e., transfers to some extent) to other tasks introduced later, thus reducing the remaining potential for transfer" (Taylor et al., 1999).

As discussed above time to a successful evaluation flight was less for the three PCATD groups when compared to the Control group for both AVI 130 and 140. For the PCATD 5 group the total time savings for both AVI 130 and 140 was 4.08 hours as a result of 5 hours of prior training in the PCATD. These findings systematically replicated the findings of Taylor et al. (1999) who found an overall savings of 3.9 hours. In the current study the TER for mean time to a successful evaluation flight was 0.82 for the PCATD 5 group compared to an overall TER of 0.15 for Taylor et al. (1999). As Taylor et al. (1999), indicated the procedure of training to a proficiency standard, even for review tasks, contributed to the inefficiency of their study. Clearly, the current study has indicated the effectiveness 5 hours in the PCATD when a fixed amount of training trials/time was used for specific flight lessons. The PCATD 10 group in the current study saved 5.49 hours of total time as a result of 10 hours of prior training in the PCATD which resulted in a TER of 0.55. The PCATD 15 group had a TER of 0.21.

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 results of the current study no appreciable benefit was found for more than 5 hours of PCATD training. These results provide support to the current FAA policy of permitting PCATD time to be used in lieu of time in an approved training device or airplane, but the results indicated that only 5 hours of training time in the PCATD was cost-effective. 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 an approved training device or the airplane.

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. (1999) suggested the approach used in the current study of allocating the time to the training of the following instruments tasks: steep turns (Flight Lesson 35), intersection holds (Flight Lesson 37), ILS, VOR and LOC BC Approaches (Flight Lesson 37), VOR, ILS and DME ARC approaches (Flight Lesson 38), review approaches (Flight Lesson 48), NDB holds and approaches (Flight Lesson 49), NDB holds and approaches review (Flight Lesson 50), and holds and approaches using partial panel (Flight Lesson 52). The results of the current study clearly indicate that the use of 5 hours of PCATD time in accordance with the suggestions of Taylor et al. (1999) was cost-effective based on the allocation of PCATD time for the PCATD 5 group, but the doubling and tripling of the trials/time in these flight lessons, which was done for experimental control, was not an effective use of the additional time for the 10 nor the 15 hour groups. 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. We also suggest that ten hours or perhaps 15 hours of PCATD time in an instrument curriculum could be cost-effective, as well as transfer 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. The flexibility inherent in the programming of PCATDs would permit manufactures to introduce adaptive augmentations applicable to instrument flight. When using adaptive augmentation, one must be careful to remove the “training wheels” when the trainee makes the correct response to avoid developing dependency on the augmented displays. Examples of the types of displays that could be introduced include predictor symbols that respond immediately to control inputs to show what the airplane is about to do. Roscoe and his colleagues (Roscoe, 1968, 1980, 1999; Roscoe, Corl, & Jensen, 1981; Simon & Roscoe, 1956; Lintern, 1980) have previously shown the effectiveness of predicted altitude based on present altitude plus 15 seconds worth of rate of climb (to teach anticipation of time to level off), predicted heading based on momentary heading plus 15 seconds worth of rate-of-turn (approximated by the sine of the bank angle, scaled appropriately). There are similar applications to other flight variables such as localizer and glideslope deviations. All of these examples follow the principle of inducing correct responses early 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.

We also believe that PCATDs have the potential of providing training on other advanced and demanding maneuvers such as stalls, spins, and the associated recoveries. The potential also exists of using PCATDs in the Private Pilot curriculum. With the additional display developments, additional research could demonstrate ways in which the improved PCATDs could be effective for instrument and contact flight training.

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