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Incremental Training Effectiveness of Personal Computers Used for Instrument Training

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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 (Airplane Control group). In order to evaluate transfer of training effectiveness of the PCATD, to complete each flight lesson in the airplane and comparisons of trials to criterion in the airplane, time 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 Airplane 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. A PCATD meeting the description and the criteria established in AC No: 61-126 (FAA, 1997) can be used for not more than 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. FAR 61.4(c) allows PCATDs to be approved for specific purposes.

Roscoe (1971) and Provenmire and Roscoe (1973) demonstrated that the TER and the incremental transfer effectiveness ratio (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 cost-effectiveness of a PCATD and to determine the point at which additional training in a PCATD is no longer cost-effective. The purpose of this experiment was to determine the incremental transfer effectiveness of three amounts of training of instrument tasks using a PCATD.

METHOD

Subjects

A total of one hundred twenty-five subjects enrolled in AVI 130 have participated in this study. The subjects, enrolled in instrument flight instruction

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at the University of Illinois, were assigned randomly among three PCATD groups and the Airplane group with the constraint that the subjects from each semester were assigned equally to the four groups.

Apparatus

PCATD training was presented using FAA approved PCATDs from Aviation Teachware Technologies (ELITE) v 6.0.2, and flight controls by Precision Flight Controls. 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. The Piper Archer III aircraft; which has a single engine, fixed pitch propeller, and fixed under carriage; was used for airplane training.

Procedure

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, and advanced instrument procedures emphasized NDB holds and approaches and partial panel procedures. 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 were developed for the three PCATD groups and the Airplane group.

Using a transfer of training design, four groups of subjects are being tested in the airplane for proficiency on various instrument flying tasks. Three of the groups have 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. The Airplane group served as a control group and 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. Instrument tasks trained in AVI 130 were: basic instrument procedures; holding; ILS, VOR, LOC BC, and DME ARC approaches. Instrument tasks trained in AVI 140 were: review intersection hold, ILS approach and VOR approach; NDB holds and NDB approaches; ILS localizer hold; partial panel NDB and VOR approaches and intersection holds. The amount of time in the PCATD for the four flight lessons in AVI 130 is shown in Table 1 for the three PCATD groups. Dependent measures were trials in the airplane to proficiency, time to complete the flight lesson in the airplane and total course completion time.

Table 1. Time (hr.) in PCATD by Group for Flight Lessons in AVI 130.

FLIGHT LESSON	PCATD 5	PCATD 10	PCATD 15
	TIME (HR) IN PCATD AVI 130		
34/35	0.5	1.0	1.5
36	0.7	1.3	2.0
37	0.7	1.3	2.0
38	0.7	1.3	2.0

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, who were blind to allocation of students to training conditions, were used for the evaluation flight.

After flight lesson 40 in AVI 130, the flight instructor could schedule an evaluation flight when the student was judged to be able to meet the proficiency standards for the stage check. 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) were provided additional flight time to reach proficiency.

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

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

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

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

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

Percent transfer measures the difference, expressed as a percent, between the Airplane 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 Airplane group. Percent transfer does not consider the amount of prior training in the PCATD by the PCATD groups. TER compares the difference between the Airplane 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 by the PCATD group. The ITER measures the amount of transfer of successive increments of training in the PCATD (Flexman, Roscoe, Williams and Williges, 1972).

RESULTS

Trials to Criterion

This paper reports the results for AVI 130 only; the results for AVI 140 will be reported when more subjects complete the instrument rating.

The mean trials to reach criterion in the airplane on the instruments tasks in AVI 130 by the Airplane group and the three PCATD groups (PCATD 5, PCATD 10, and PCATD 15) were computed and are shown in Table 2. Table 2 also shows the trials in the PCATD for each PCATD group. The data indicate that 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 Airplane group. There was no systematic pattern which indicated that larger amounts of PCATD training saved more trials.

The data in Table 2 were used to compute percent transfer, TER and ITER which are presented in Table 3 for the instrument tasks. The largest percent transfer for the trials dependent variable was found for the PCATD 10 group for 5 of the 8 instrument tasks (steep turns, ILS and VOR for flight lessons 37 and 38). For the turns in hold trials, the PCATD 15 group had the largest percent transfer. The PCATD 5 group had the largest percent transfer for LOC BC and DME ARC trials, but the transfer was small for both of these instrument tasks.

Substantial TERs were found for the PCATD 5 and 10 groups for steep turns but not for PCATD 15 group. There was little transfer for ILS in flight lesson 37, but a substantial amount for ILS in flight lesson 38. For the VOR instrument task, substantial transfer effectiveness was found for both flight lessons 37 and 38. The TER for the PCATD 5 group was 0.40 and 0.51 respectively for these two flight lessons. The average transfer for the PCATD 10 was 0.23 and 0.35 respectively and for PCATD 15 the average transfer was 0.11 and 0.19 respectively. No other TER for other instrument tasks was above the 0.24 level.

The largest ITER for steep turn trials was found for the PCATD 10 group, but the largest ITER for turns in hold trials was found for the PCATD 5 group. For VOR trials in flight lesson 37 and for both ILS and VOR trials in flight lesson 38, the largest ITER was found for the PCATD 5 group and the smallest for the PCATD 15 group. 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.

Time to Complete Flight Lesson

The mean times to complete the flight lesson in AVI 130 are shown in Table 4. 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 three 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.

These times were used to compute percent transfer, TERs, and ITERs shown in Table 5. The TERs for each of the three PCATD groups for flight lesson 34/35, steep turns, were positive but they were

smaller 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 time to complete the flight lesson. The most substantial transfer for the time variable occurred for flight lesson 38 for all three PCATD groups. The pattern of the TERs for all PCATD groups shows the predicted negative decelerated function for increasing amounts of training time in the PCATD.

For the time to complete flight lesson variable, the largest ITER was found for PCATD 5 and the smallest ITER was found for PCATD 15 for all four flight lessons.

Time to Complete AVI 130

The total dual prior to the evaluation flight was computed for the Airplane 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 Airplane group. The Airplane group required 22.5 hours compared to 20.18, 19.40 and 21.14 hours for the PCATD 5, 10, and 15 groups respectively. The times for the PCATD 5 and 10 groups were significantly different from the Airplane group but the time for the PCATD 15 group was not significantly different.

DISCUSSION

The data from the study indicates that the PCATD is effective in teaching basic instrument tasks to private pilots. Prior training in the PCATD resulted in a smaller number of trials in the airplane for each of the PCATD groups when compared to the Airplane group. The prediction that an increased number of trials in the PCATD on the selected instrument tasks would save more trials in the airplane was not realized. For five of the eight instrument t asks, the PCATD 10 group had the least trials in the airplane, for two tasks the PCATD 5 group had the least trials in the airplane and the PCATD 15 group had one task with the least trials in the airplane.

The percent transfer for trials ranged from a high of 43.4 for the PCATD 10 group for ILS in flight lesson 38 to a low of 2.4 for ILS for PCATD 5 for ILS in flight lesson 37. The TERs for ILS trials for the flight lessons 37 and 38 showed a substantial difference. The TERs for ILS for flight lesson 37 were small 0.04, 0.10 and 0.05 for PCATD 5, 10, 15 respectively, but for flight lesson 38, the TERs for ILS were 0.93, 0.48 and 0.30 for PCATD 5, 10, 15 respectively. For the PCATD 5 group the TER of 0.93 indicates that for flight lesson 38 almost one trial in the aircraft was saved for each trial in the PCATD. About a half 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 in flight lesson 37 and training in the PCATD for flight lesson 38 was a review lesson. In the currently study the subjects received only 1, 2, 3 trials respectively for PCATD 5, 10, 15 groups in each of the two flight lessons.

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. The same result was found by Taylor et al. (1996) 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. The percent transfer for time in the current study ranged from 9.4 percent for flight lesson 34/35 (steep turns) for PCATD 5 to 40.6 percent for flight lesson 38 (ILS, VOR, DME ARC) for PCATD 10. The percent transfer for Taylor et al. (1996) ranged from 37.5 percent for steep turns (flight lesson 34/35) to 22.7 percent 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 Flexman et al. (1972). In terms of the TER, the largest amount of transfer was always found for PCATD 5 and the smallest for PCATD 15 for all four flight lessons. The TERs ranged from 1.29 for flight lesson 38 (ILS, VOR, DME ARC) for PCATD 5 to 0.10 for flight lesson 34/35 (steep turns) for PCATD 15. Taylor et al. (1996) reported TERs which ranged from 0.23 for flight lesson 36 (holds) to 0.50 for flight lesson 34/35 (steep turns). Table 6 shows that the largest amount of transfer occurred in flight lesson 38 for all three PCATD groups. For the PCATD 5 group, the TER was 1.29, which indicated that over 1 ¼ hours were saved in the airplane for each hour in the PCATD. The PCATD 10 group saved over ¾ of an hour and the PCATD 15 group saved almost ½ hour for each hour in the PCATD. Over ½ hour was saved for the PCATD 5 group for both flight lessons 36 and 37.

Of the five ITERs for the trial variable shown in Table 3, three (VOR for flight lessons 37 and VOR

and ILS for flight lesson 38) show the predicted pattern of a negatively decelerated function (Flexman et al., 1972). For steep turns, the ITER for PCATD 10 is greater than for PCATD 5 and for turns in hold, the ITER for PCATD 15 is slightly greater than PCATD 10. The negative ITERs found for the PCATD 15 group were found since the increased number of trials in the PCATD for the PCATD 15 group compared to the PCATD 10 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.

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 (Flexman, et al., 1972). While there are substantial time savings for three of the flight lessons (36, 37, 38) for PCATD 5, the incremental savings for the PCATD 10 group ranges from 0.24 to 0.17. There is little or no incremental time savings for PCATD 5. These relationships resulted in the negative ITERs for the PCATD 15 group.

The time to complete AVI 130 was less for all three PCATD groups compared to the Airplane group. The flight hours saved were 2.39 hours, 3.17 hours, and 1.43 hours respectively for the PCATD 5, 10, 15 groups. These savings were significantly different for the PCATD 5 and 10 groups but not for the PCATD 15 group.

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Table 2. Mean trials in the Airplane for the Airplane 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)	3.75	3.16	2.43	3.22	1	2	3
Turn in Hold (FL 36)	8.13	6.13	6.00	5.57	6	12	18
ILS (FL 37)	1.69	1.65	1.50	1.55	1	2	3
VOR (FL 37)	1.88	1.48	1.43	1.55	1	2	3
LOC BC (FL 37)	1.53	1.42	1.47	1.45	1	2	3
ILS (FL 38)	2.19	1.26	1.24	1.28	1	2	3
VOR (FL 38)	1.90	1.39	1.21	1.34	1	2	3
DME ARC (FL 38)	2.35	1.97	2.28	2.24	2	4	6

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}).

Task	Percent Transfer			TER			ITER		
	X_5	X_{10}	X_{15}	X_5	X_{10}	X_{15}	X_5	X_{10}	X_{15}
Steep Turns (FL 34/35)	15.7	35.2	14.1	0.59	0.66	0.18	0.59	0.73	-0.79
Turns in Hold (FL 36)	24.6	26.2	31.5	0.33	0.18	0.14	1.00	0.07	0.22
ILS (FL 37)	2.4	11.2	8.3	0.04	0.10	0.05			
VOR (FL 37)	21.3	23.9	17.6	0.40	0.23	0.11	0.40	0.05	-0.12
LOC BC (FL 37)	7.2	3.9	5.2	0.11	0.03	0.03			
ILS (FL 38)	42.5	43.4	41.6	0.93	0.48	0.30	0.93	0.02	-0.09
VOR (FL 38)	26.8	36.3	29.5	0.51	0.35	0.19	0.51	0.18	0.05
DME ARC (FL 38)	16.2	3.0	4.7	0.19	0.02	0.04			

Table 4. 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 130.

	Mean Times			
Flight Lesson	Y_c	Yx_5	Yx_{10}	Yx_{15}
34/35, Steep Turns	1.49	1.35	1.23	1.34
36, Intersection Holds	1.72	1.36	1.23	1.15
37, ILS, LOC BC, VOR	2.26	1.86	1.75	2.02
38, ILS, VOR, DME ARC	2.56	1.66	1.56	1.62

Table 5. 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	9.4	17.5	10.1	0.28	0.26	0.10	0.28	0.24	-0.22
36, Intersection Holds	20.9	28.5	33.1	0.51	0.38	0.29	0.51	0.22	0.11
37, ILS, LOC BC, VOR	17.7	22.6	10.6	0.57	0.39	0.12	0.57	0.18	-0.39
38, ILS, VOR, DME ARC	35.2	40.6	36.7	1.29	0.77	0.47	1.29	0.17	-0.09