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Transfer of Training Effectiveness of Personal Computer-Based Aviation Training Devices

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16. Abstract

The training effectiveness of Personal Computer-Based Aviation Training Devices (PCATDs) has received only limited testing. In the experiment reported here, a commercially available PCATD was evaluated in a transfer of training experiment for its effectiveness in supporting instrument flight training. The data show levels of savings in airplane flight time that varied from 15% to over 40% for certain training exercises. However, there were also cases in which savings were essentially zero or even showed decrements as high as 25%. In general, transfer savings were positive and substantial when new tasks were introduced. The data indicate that a PCATD can provide training benefit for certain tasks but, in addition, use of the PCATD in some areas is not expected to result in savings and will erode the overall potential to reduce costs.

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FOREWORD

This study tested the effectiveness of PC-based aviation training devices (PCATDs) in instrument training for the purpose of guiding regulation and certification considerations by the Federal Aviation Administration (FAA). Heretofore, only data of a subjective nature had been available.

The study was supported under FAA Grant No. 94-G-044 with the University of Illinois at Urbana-Champaign during fiscal years 1995 and 1996. Ms. Karen Ayers, Ms. Diana Christenson, and Ms. Sharon Allen assisted with the manuscript and Mr. Greg Morrison provided technical assistance during equipment set-up; Mr. Ricky Weinberg, chief pilot, and Mr. Richard Keir, instrument course supervisor, provided invaluable assistance with flight operations and with student management. Mr. Steve Owen, Mr. David Petersen, and Mr. Phillip Martin served as stage check pilots for the study. We thank the flight instructors and the students of Aviation 130 and Aviation 140 for participating in the study.

Sponsorship of the study was provided by Mr. Thomas C. Accardi, Director, Flight Standards Service, AFS-1. Project oversight was provided by Mr. Louis C. Cusimano, AFS-800, and Mr. Lauren Basham, AFS-840. Human factors program coordination was provided by Dr. Thomas McCloy and Mr. Ronald Simmons, Office of the Chief Scientist and Technical Advisor for Human Factors, AAR-100. Drs. Robert E. Blanchard and Kevin W. Williams served jointly in the role of contracting officer's technical representative for FAA Civil Aeromedical Institute.

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TRANSFER OF TRAINING EFFECTIVENESS OF PERSONAL COMPUTER-BASED AVIATION TRAINING DEVICES

INTRODUCTION

The resources required for flight training impose a substantial burden on the aviation community. The potential to reduce costs through the use of inexpensive but effective training devices has added an incentive for flight training departments to conduct more training with ground-based flight training devices. The cost of currently certified, generic flight training devices is out of reach of many flight students and flight schools, but personal computer-based aviation training devices (PCATDs) offer a low-cost alternative for instruction of flight tasks. Recently, there has been increased demand from developers, from industry, and from training organizations to use PCATDs in flight training. A summary of a joint industry-Federal Aviation Administration (FAA) conference concerned with the development and use of PCATDs documents this emphasis (Williams, 1994). An expense of less than $10,000 will provide a PCATD including software, computer hardware, and a flight-control system. This is within reach of most flight schools.

PCATDs have generated considerable enthusiasm within the aviation industry (Falun, 1992; Lert, 1990; Peterson, 1993). Hampton, Moroney, Kirton, and Biers (1994) reported that students trained in a PCATD performed as well on instrument procedures in the airplane as those students trained in a Frasca 141. Nevertheless, there is no clear evidence that PCATD training will transfer effectively to an airplane across a broad range of flight tasks. The fidelity of PCATDs is low in areas normally thought to be important: representation of displays, switches, and out-of-cockpit scenes; with control loading and flight dynamics being the most obvious. In addition, PCATDs accept control inputs from low-fidelity devices that range from computer keyboards, single joysticks, and yoke/pedal combinations of varying quality (Peterson, 1993).

There is evidence of positive transfer of PCATDs to the airplane (Phillips, Hulin, & Lamermayer, 1993; Ortiz, 1993, 1994; Dennis, 1994), although the empirical evaluations have been limited in scope. Experimental data bearing on issues of skill transfer are equivocal, and there is no means of ascertaining the training effectiveness of a PCATD without an empirical test of its impact on transfer of skills to flight performance. Specifically, it is necessary to determine the types of flight tasks that can be trained effectively in the PCATD and the level of proficiency obtained by practice with a PCATD. Analytical evaluation of PCATDs indicates that they provide many of the features required for standard instrument flight maneuvers. Instrument training in a PCATD may result in substantial transfer for instrument flight tasks.

To evaluate transfer of training, the performance of a group of subjects trained in a flight training device, and later trained to criterion in an aircraft, is compared with the performance of a control group of subjects who have been trained only in the airplane. A conventional measure of transfer of training has been percent transfer, which is known to be a negatively-accelerated function. Roscoe (1971) and Roscoe and Williges (1980) correctly pointed out that percent transfer fails to consider the amount of practice in the flight training device in determining the training effectiveness of the device. The transfer effectiveness ratio (TER), a negatively-decelerated function, has been used to determine the ratio of the trials/time in the airplane saved by the training device group, compared with the airplane group, as a function of the number of trials/time in the training device (Williams & Flexman, 1949; Roscoe, 1971).

Many of the applied research studies on flight training effectiveness have examined the effect of specific simulator features on specific tasks (e.g., Lintern, Roscoe, Koonce & Segal, 1990; Taylor, Lintern, Koonce, Kaiser, & Morrison, 1991). The first transfer of training evaluations of PCATDs (Phillips et al., 1993; Ortiz, 1993, 1994; Dennis, 1994) have followed that pattern. Only a few experiments have examined the impact of a single device on a whole course (e.g., Povenmire & Roscoe, 1971, 1973). Transfer studies conducted in 1949/50, but first reported by Flexman, Roscoe, Williams, and Williges (1972), used percent transfer and transfer effectiveness ratios in terms of errors, time to criterion, and trials to criterion to assess a comprehensive set of contact and instrument flight tasks. The Flexman et al. (1972) study remains the most definitive study of the effectiveness of flight training devices for a total flight course. It described a research plan that was implemented in the current evaluation of PCATDs.

Williams and Blanchard (1995), proposed that task analysis be used as a basis for predicting transfer effectiveness. The appropriate task analysis would identify the learning requirements for a particular flight task, and these requirements would then be organized in terms of common features. An analysis of the PCATD would determine which learning requirements could be supported by that device and, consequently, which flight tasks could be taught in the PCATD. They proposed that the initial validation of the guidelines would be accomplished through the collection of performance data from FAR Part 141 schools using PCATDs. The purpose of the present study is 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 measure transfer of these skills to the aircraft. The approach taken in this study is to use a representative PCATD to teach instrument tasks in the two-semester instrument training course at the University of Illinois Institute of Aviation.

Our training course outline for the PCATD emphasized instruction of specific maneuvers in order to determine if the PCATD was an effective training device for a variety of instrument tasks. For each flight lesson, which was programmed to be accomplished in one week, one or more instrument tasks were introduced and/or reviewed. Progression to the next flight lesson, however, required that the student meet the objectives in that flight lesson. Advancement to the next flight lesson, therefore, was based on demonstrated proficiency on the respective instrument tasks. For the PCATD group, proficiency had to be demonstrated in the PCATD prior to flying the flight lesson in the airplane. The PCATD group was required to demonstrate their proficiency in the airplane on a respective flight lesson prior to attempting the next flight lesson. The Airplane group received all of their instrument training in the airplane but also had to demonstrate proficiency in the airplane on each flight lesson prior to advancing to the next flight lesson. The effectiveness of the PCATD in teaching specific instrument tasks in a flight lesson was measured by comparing the trials required for the PCATD group and the Airplane group to reach proficiency in the airplane on specific instrument tasks. Subsequently, the percent transfer and TER for trials were computed for each instrument task. The effectiveness of using the PCATD to reach proficiency for a particular flight lesson was measured by comparing the time required for the PCATD group and the Airplane group to complete the objectives of the flight lesson in the airplane. Subsequently, the percent transfer and TER for time to complete the lesson were computed.

Early in training, the emphasis was on basic control skills with reference to instruments. Instruction then progressed through increasingly challenging exercises with emphasis on instrument holding patterns, instrument approaches, and preparation for cross-country flights. In each flight lesson, transfer on specific instrument tasks was evaluated; transfer relative to logged airplane time to satisfy the completion standards for that lesson was also assessed. In many lessons, the logged time to satisfy completion standards represents student progress on more than just the tasks tested in the lesson. Any discrepancy between trials to proficiency and time to proficiency may reflect differential progress with relation to the rated instrument tasks and those other lesson objectives.

An earlier interim report by Taylor, Lintern, and Hulin (1995) provided the results of the first year's work. This was also reported by Taylor, Lintern, Hulin, Emanuel, Phillips, and Talleur (1995), and Taylor, Lintern, Hulin, Talleur, Phillips, and Emanuel (1996).

METHOD

Subjects

One-hundred forty-four subjects were tested in a transfer of training design. These subjects were enrolled in instrument flight instruction at the University of Illinois. A total of 117 subjects were enrolled in basic instrument instruction (Aviation 130); 40 in the Fall, 1994 semester; 17 in the Spring, 1995 semester; 12 in the Summer, 1995 semester; 37 in the Fall, 1995 semester; and 11 in the Spring, 1996 semester. Ten of the subjects enrolled in Aviation 130 in the Fall 1995 received training in an integrated curriculum, which used both a PCATD and a Frasca 140 training device. The results of this preliminary study are reported by Taylor, Lintern, Hulin, Talleur, Emanuel, and Phillips (1996a). The remaining 27 students were enrolled in the advanced instruments course (Aviation 140) in the Fall, 1994 semester. Seventy-seven of the students who completed Aviation 130 completed the experiment as Aviation 140 students. The subjects were restricted to students between 18 and 30 years old who had taken their private pilot training at the University of Illinois or had completed a familiarization course and were recommended for Aviation 130.

Subjects were randomly assigned to the PCATD group and the Airplane group, with the constraint that male and female students were distributed evenly over the two groups. Students in the PCATD group were taught specific instrument tasks on the PCATD to a specified criterion and were then transferred to the aircraft, where they were required to perform these tasks again to the same criterion. Comparisons were made with a Control group that had received similar training only in an airplane. Students from both groups were required to achieve criterion on those tasks in the airplane prior to moving to the next flight lesson. The Fall 1994 Aviation 140 data set will be presented separately, since these students had no previous experience with PCATDs, while the remaining Aviation 140 students in the PCATD group had received basic instrument training in the PCATD. Of the 92 subjects who completed Aviation 130, 45 subjects were assigned to the Airplane group, and 47 subjects were assigned to the PCATD group. Of these 92 subjects, 74 subjects completed Aviation 140; 36 subjects were assigned the Airplane group, and 38 were assigned to the PCATD group.

Apparatus

A representative PCATD system that would be affordable for the majority of FAR Part 141- approved schools was assembled from commercially available, state-of-the-art but proven PCATD technology. The choice of PCATD components was established in a discussion with the Civil Aeromedical Institute's Human Factors Research group on July 22, 1994. Figure 1 shows the system, based on the criteria of representativeness, capability, and cost, which included MDM FS100 software, modified for Beechcraft Sundowner performance characteristics, an IBM-compatible Pentium, 60MHz computer, an instructor station map display, flight controls by Precision Flight Controls (see Figure 2), and a 20-inch monitor and hood. The 20-inch monitor permitted display of 6 standard 3.0-inch instruments. The system is described in more detail in Appendix 1 of the University of Illinois contract report (Taylor, Lintern, Hulin, Talleur, Emanuel & Phillips, 1996b). The training aircraft used were Beechcraft Sports/Sundowners, which have a single-engine, fixed-pitch propeller, and fixed landing gear.

Procedure

Instrument training at the University of Illinois is conducted in a two-semester sequence. Basic instrument procedures emphasizing aircraft control, instrument departure, enroute and approach procedures are taught during the first semester in Aviation 130; remaining instrument skills are taught during the second semester in Aviation 140 (Table 1). The objective of the courses is to develop the basic skills necessary for the control and accurate maneuvering of an airplane solely by reference to flight instruments; specifically, the skills necessary to perform IFR flight, including departure, enroute, and arrival procedures.

During each semester, the students are scheduled for 45 hours of lecture (ground school) and 15 flight lessons, each programmed for one week. An experimental

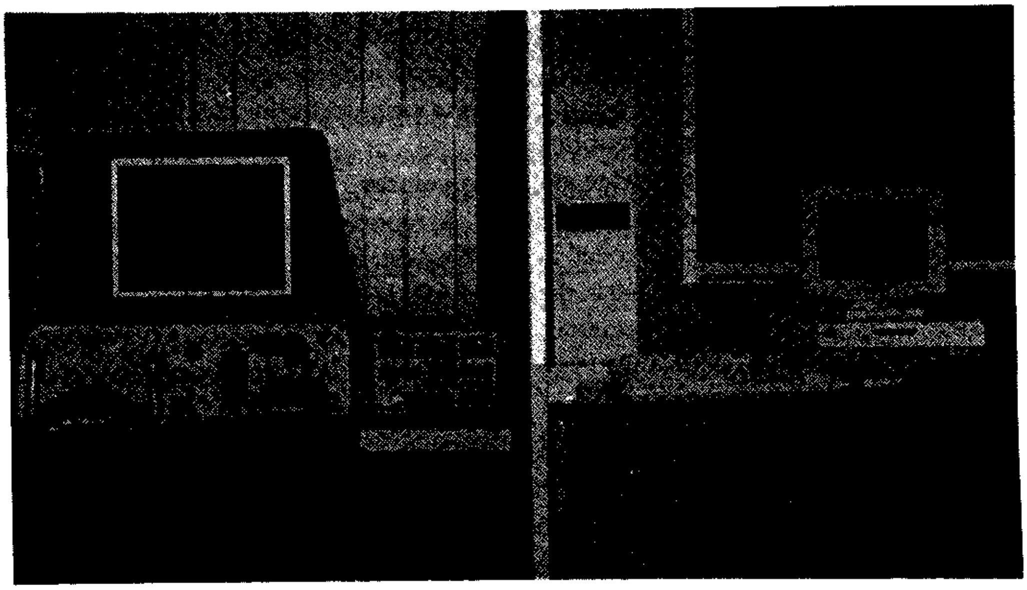

Figure 1. Student flight console on left with 20" screen. Avionics console to right of student console. Tower computer controls FS100 software for simulation. Computer on right of desk controls instructor's station.

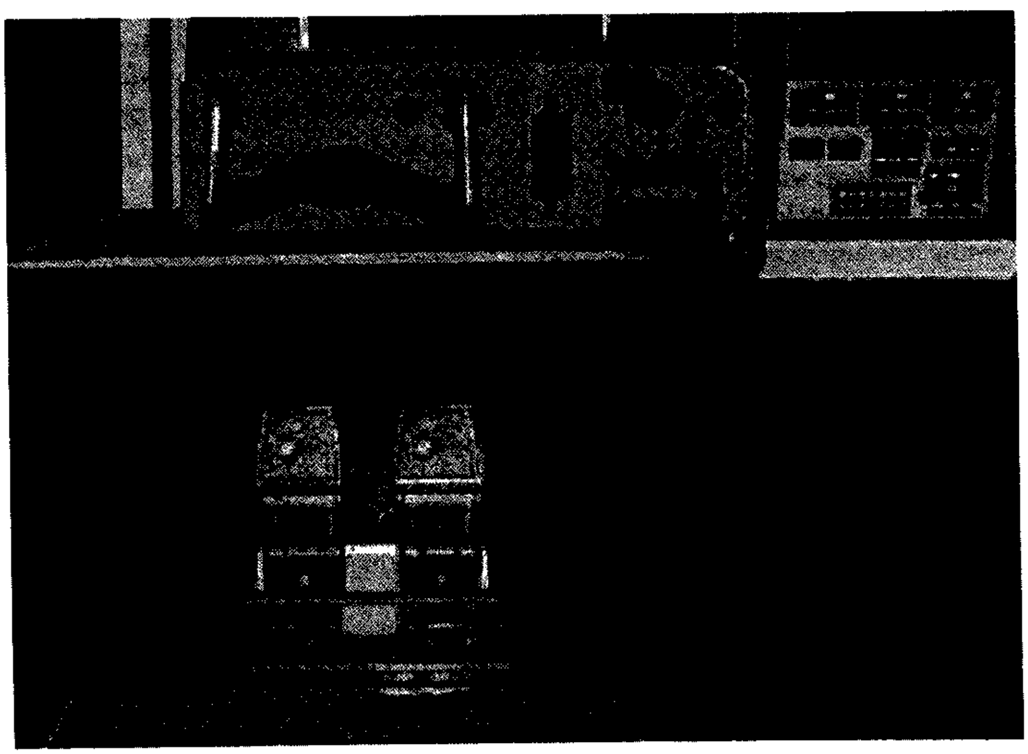

Figure 2. More detailed view of student flight console with rudder pedal assembly. Also shows avionics console to right.

Table 1. Summary of Training Course Outlines for Aviation 130, the First Semester Instrument Rating Course, and Aviation 140, the Second Semester Instrument Rating Course.

Lesson[1]	Content
31	Review private pilot maneuvers
32	VFR cross-country flight review
33	Two solo cross-country flights
34	Introduce basic instrument flight skills
35	Review basic instrument flight skills, Introduce attitude instrument flight with distractions
36	Introduce VOR use and orientation, VOR radial intersection holding patterns
37	Introduce ILS, VOR, and LOC BC instrument approach procedures, procedure turns, radar vectoring, review VOR tracking
38	Introduce DME Arcs, review holding patterns and instrument approaches
39	Introduce instrument cross-country flight procedures
40	Review holding patterns and instrument approach procedures
41	Review holding patterns and instrument approach procedures
42	Review instrument cross-country flight procedures
43	Review holding patterns and instrument approach procedures
44	Review all content areas, mock stage check with a different instructor
45	Review and stage check
46	Review private pilot maneuvers, review basic instrument flying skills, solo cross-country flight
47	Review basic instrument flying skills
48	Review DME Arcs, ILS, VOR, and LOC BC approaches
49	Introduce NDB tracking, NDB holding patterns, NDB instrument approaches
50	Introduce localizer and localizer back course holding patterns, review NDB skills
51	Introduce partial panel basic attitude instrument flying skills, review instrument approaches
52	Introduce partial panel instrument approaches and holding patterns
53	Review instrument cross-country flying skills and procedures
54	Review instrument cross-country flying skills and procedures
55	Review instrument cross-country flying skills and procedures, introduce night procedures
56	250 nm IFR cross-country flight, also a review flight
57	Review instrument cross-country flying skills and procedures
58	Mock stage check with a different instructor
59	Review for instrument stage check
60	Stage check

[1]Flight Lessons 1-30 are allocated to Aviation 101 and 120, which lead to Private Pilot Certification.

curriculum for both the PCATD group and the Airplane group (control) was developed (Emanuel, Taylor, Hulin, Lintern, Phillips, & Talleur, 1995).

For the PCATD group, all new maneuvers and procedures were introduced and trained to proficiency in a PCATD prior to training and skill validation in the aircraft. For the Airplane group, all new maneuvers were introduced and trained to proficiency in the airplane. Tasks within a flight lesson, trained in the PCATD, were trained or tested for proficiency in the airplane before proceeding to the next flight lesson. Subjects in the Airplane group were trained on the same tasks but in the airplane only.

Instructors rated student performances on designated flight tasks in both the PCATD and the aircraft. For performance assessment in the aircraft, each instructor used a rating scale developed for each flight lesson to record whether the student met the completion standards during the execution of the designated flight tasks. Instructors also recorded trials to criterion for specific tasks and flight time to complete flight lessons. The rating scales used in the project were modeled on those that have been used in previous flight research at the University of Illinois, and are described in detail in an earlier paper (Phillips, Taylor, Lintern, Hulin, Emanuel, & Talleur, 1995). Inter-rater reliabilities of 0.80 on these types of scales are typically achieved (Koonce, 1979). The rating scales were used for both the PCATD group and for the Airplane group. For the PCATD group, two identical rating scales were developed for each flight lesson (or a series of related flight lessons): one for training in the PCATD and one for training in the aircraft after reaching criterion in the PCATD. An identical rating scale was used for each flight lesson for the Airplane group. The rating scales can be found in Appendix 2 of Taylor et al. (1996b).

The guiding principles behind the development and scoring of these maneuver-assessment scales were to attempt to digitize the observing and scoring tasks of the instructor/observers. Maneuvers were divided into time segments, and the instructors were asked to record specific flight parameters, say, within ±100 feet of the assigned altitude or exceeding this range; within ±5° of assigned heading or outside this range. By breaking up the flight maneuvers into many parameters whose values define the quality of the maneuver, taking digitized assessments at specified times, and summing these digitized assessments across many flight parameters and times, the overall quality of the total maneuver and flight can be captured very accurately. In addition, the workload on the flight instructors was significantly reduced. They only had to glance at one or two instruments at specified times and note whether the student was within the range printed on their scoring sheets. By reducing the implicit analogue task from integrating a student's performance on all parameters throughout a maneuver and attempting to summarize the overall quality of their performance to recording a small number of digitized scores, we were able to maintain flight safety standards while recording performance levels.

Experienced flight instructors at the University of Illinois served as both flight instructors and experimenters in the project. The instructors were trained on delivery of the instructional curriculum and on the use of the rating scales. Three check pilots, who were uninformed as to the allocation of students to training conditions, were used for the stage checks.

Analyses

Percent transfer and transfer effectiveness ratios (TERs) were computed for each flight lesson using the following equations:

$$\frac{Y_c - Y_x}{Y_c} \times 100 = \text{Percent Transfer}$$

$$\frac{Y_c - Y_x}{X} = \text{Transfer Effectiveness Ratio}$$

Where: Y_c = Time/Trials in airplane by Airplane group
Y_x = Time/Trials in airplane by PCATD group
Y_x = Time/Trials in airplane by PCATD group

Percent Transfer measures the difference between the airplane and the PCATD groups in terms of trials/time to reach criterion in the airplane, expressed as a percent. A positive percent transfer favors the PCATD

Table 2. Instrument tasks in Aviation 130 and Aviation 140 for which percent transfer and TERs for mean trials to criterion and mean time to complete the flight lesson were calculated.

Task	Flight Lesson**
Aviation 130	
Steep Turns	34/35
Intersection Holds	36, 40-43, 42
Instrument Landing System (ILS) Approach	37, 38, 39, 40-43, 42
Localizer Back Course (LOC BC) Approach	37, 39, 40-43
Visual Omni Range (VOR) Approach*	38, 40-43, 42
Distance Measuring Equipment Arc Approach (DME Arc)	38
Aviation 140	
Intersection Holds	48
ILS Approaches	48, 51, 52, 53, 56, 57
VOR Approaches	48, 51, 52, 53, 56, 57
NDB Holds	49, 50
NDB Approaches	49, 50, 51, 52, 53, 54, 55, 56
LOC BC Holds	50
ILS Holds	50
LOC BC Approaches	52
Holding Patterns	52, 53, 54, 55, 56, 57

*VOR approaches were first introduced in Flight Lesson 37, but instructions for scoring this exercise were inadvertently omitted from the score sheet.
**See Table 1 for the lesson descriptions for the respective flight lessons.

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 group. Transfer effectiveness ratio (TER) measures 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, i.e., TER measures the effectiveness of the PCATD in training specific instrument tasks.

In all instrument tasks in Aviation 130 and Aviation 140, students were trained to proficiency in the PCATD and then trained and tested in the airplane. Table 2 shows the instrument tasks trained in Aviation 130 and Aviation 140, for which mean percent transfer and mean transfer effectiveness ratios (TERs) were computed from mean trials to criterion and from mean time to complete the flight lesson.

RESULTS

Mean percent transfer and mean transfer effectiveness ratios (TERs) are reported for two dependent measures: number of trials to criterion for selected instrument tasks (trials), and airplane time required in a flight lesson for students to reach the completion standards (time). In addition, means and variances of

Trials to Criterion

The mean trials used to compute percent transfer and TERs for trials on instrument tasks trained in Aviation 130 are shown in Table 3. It is evident from this table that the PCATD was more effective for introduction of tasks than for their review. For most tasks, positive transfer was found in the flight lesson during which the tasks were introduced. With steep turns, for example, the Airplane group (N=54) required a mean of 3.83 airplane trials to reach criterion, while the PCATD group (N=53) required a mean of 3.40 airplane trials after a mean of 3.28 prior trials in the PCATD. The percent transfer was 11.2%, and the transfer effectiveness ratio (TER) was 0.13. Therefore for this task, within the limit of the number of trials administered, each trial in the PCATD saved 0.13 trials in the airplane. The difference between the means of 0.43 trials as tested by a t-test (two tailed) was nonsignificant. For two tasks, ILS approach and VOR approach, the percent transfer was 33.3% (ILS, Flight Lesson 37) and 20.4% (VOR, Flight Lesson 38). The TERs for these two tasks were 0.28 (ILS, Flight Lesson 37) and 0.25 (VOR, Flight Lesson 38). For each of the tasks, each prior training trial in the PCATD saved one fourth or more trials in the airplane. For the ILS task (Flight Lesson 37), the PCATD group required 1.50 mean trials to reach criterion in the airplane, compared with 2.25 mean trials for the Airplane group. The difference between the means of 0.75 trials was significant: $t(86) = 4.18$, $p < 0.001$ (two-tailed).

For the VOR task (Flight Lesson 38), the PCATD group required 1.33 mean trials to reach criterion, compared with 1.67 for the Airplane group. The difference between the means of 0.34 trials was significant: $t(93) = 2.37$, $p < 0.02$ (two-tailed). For localizer, back course (LOC BC) (Flight Lesson 37) and the DME/Arc (Flight Lesson 38) approaches, the transfers were 17.5% and 18.1%, respectively. The TERs for these 2 tasks were 0.17 (LOC BC) and 0.20 (DME/Arc). For the LOC BC (Flight Lesson 37), the PCATD group required 1.46 mean trials to reach criterion compared with 1.77 for the Airplane group. The difference of 0.31 trials was not significant: $t(97) = 1.73$, $p < 0.09$ (two-tailed). Similarly, the mean trials to criterion on the DME/Arc task (Flight Lesson 38) was 1.58 for the PCATD group compared with 1.93 for the Airplane group. The difference between the means of 0.35 trials was not significant: $t(98) = 1.84$, $p < 0.07$ (two-tailed).

Additional training was given on each task after the flight lesson in which a task was introduced. For example, the ILS approach and the LOC BC approach were introduced in Flight Lesson 37. Additional training was conducted on the ILS in Flight Lesson 38 and on the LOC BC approach in Flight Lesson 39. As seen in Table 3, the mean number of trials to reach proficiency in the airplane for the Airplane group and the PCATD group was substantially smaller for Flight Lessons 38 and 39 compared with Flight Lesson 37, as was the mean number of trials to reach proficiency in the PCATD. For example, for the ILS task in Flight Lesson 37, the Airplane and the PCATD groups required 2.25 and 1.5 trials, respectively, to reach proficiency in the airplane after 2.70 prior trials in the PCATD by the PCATD group. Review of the ILS in Flight Lesson 38, however, indicates that the Airplane and PCATD groups required only 1.36 and 1.20 trials, respectively, to reach proficiency in the airplane after 1.33 prior trials in the PCATD by the PCATD group. The difference between the means was not significant. For Flight Lessons 38 and 39, the effectiveness of the prior training in the PCATD, as defined by percent transfer and the TER, was also reduced. For example, for the ILS task, the percent transfer was 33.3% in Flight lesson 37 and 11.8% in Flight Lesson 38; the TER was 0.28 in Flight Lesson 37 and 0.12 in Flight Lesson 38.

The means used to compute percent transfer and TERs for instrument tasks trained in Aviation 140 after the students had completed the experimental program in Aviation 130 are shown in Table 4. Flight Lesson 48 was a review of ILS and VOR tasks that had been introduced and reviewed extensively during the previous semester in Aviation 130. The percent transfer for ILS was 18.7% and the TER was 0.23. The mean trials to reach criterion for the ILS task in Flight Lesson 48 was 1.26 mean trials for the PCATD group and 1.55 mean trials for the Airplane group. The difference between the means of 0.29 trials was not significant: $t(57) = 1.60$, $p < 0.12$ (two-tailed). For the VOR, the percent transfer was 14.6% and the TER was 0.17. For the VOR task in Flight Lesson 48, the PCATD group required 1.05 mean trials to reach criterion compared with 1.23 trials for the Airplane group. The difference between the means of 0.18 trials was significant: $t(50) = 2.20$, $p < 0.03$ (two-tailed).

Non Directional Beacon (NDB) holds and approaches were introduced in Flight Lesson 49. Positive transfer was found for the mean trials to proficiency for the NDB holds and the NDB approaches in that lesson. The percent transfer for NDB holds and

Table 3. Mean trials in the airplane for the Airplane group (Y_c) and the PCATD group (Y_x), and the mean trials in the PCATD (X), percent transfer and training effectiveness ratios (TERs) for instrument tasks trained in Aviation 130. Levels of statistical significances of differences between Y_c and Y_x are shown.

Task	Group			p	Percent Transfer	TER
	Y_c	Y_x	X			
Steep Turns (Flt Lessons 34/35)	3.83	3.40	3.28	ns	11.2%	0.13
Int Hold (Flt Lesson 36)**						
ILS (Flt Lesson 37)	2.25	1.50	2.70	<0.001	33.3%	0.28
LOC BC (Flt Lesson 37)	1.77	1.46	1.81	<0.09	17.5%	0.17
VOR (Flt Lesson 38)	1.67	1.33	1.38	<0.02	20.4%	0.25
ILS (Flt Lesson 38)*	1.36	1.20	1.33	ns	11.8%	0.12
DME/Arc (Flt Lesson 38)	1.93	1.58	1.76	<0.07	18.1%	0.20
ILS (Flt Lesson 39)*	1.40	1.50	1.29	ns	7.9%	0.10
LOC BC (Flt Lesson 39)*	1.51	1.47	1.49	ns	2.7%	0.03
ILS (Flt Lessons 40,41,43)*	2.94	3.10	2.69	ns	5.4%	0.06
LOC BC (Flt Lessons 40,41,43)*	1.87	1.70	1.62	ns	4.9%	0.10
VOR (Flt Lessons 40,41,43)*	3.33	3.30	2.47	ns	1.0%	0.01
ILS (Flt Lesson 42)*	1.39	1.59	1.44	ns	-3.6%	-0.03
VOR (Flt Lesson 42)*	1.13	1.06	1.16	ns	-2.3%	-0.03

*Review tasks.
**An incorrect definition of a hold trial precluded meaningful data collection.

approach was 19.7% and 21.0%, respectively, and the TERs were 0.16 and 0.17, respectively. For the NDB holds task, the PCATD group required 1.18 mean trials; the Airplane group required 1.47 trials to reach criterion. The difference of 0.29 trials was not significant: $t(57) = 1.93, p < 0.06$ (two-tailed). The PCATD group required 1.54 NDB approach trials to reach criterion compared with 1.95 mean approach trials for the Airplane group. The difference between the means was significant: $t(67) = 2.29$, $p < 0.03$ (two-tailed). The review of NDB holds and approaches in the PCATD during Flight Lesson 50 also produced positive transfer. The percent transfer for NDB holds was 15.8%, and the TER was 0.16. These scores were about the same as the percent transfer and TER for holds when previously introduced in Flight Lesson 49. In Flight Lesson 50, the PCATD group required 1.12 hold trials to reach criterion compared with 1.33 trials for the Airplane group. The difference between the means was significant: $t(59) = 2.05, p < 0.05$ (two-tailed). For review of NDB Approaches in Flight Lesson 50, the percent transfer was 28.1% and the TER was 0.39, both of which were larger than the values found for Flight Lesson 49 when NDB approaches were introduced. For the NDB approach task in Flight Lesson 50, the PCATD group required 1.18 mean trials to reach criterion compared with 1.64 mean trials for the Airplane group. The difference between the means of 0.46 was significant, $t(54) = 2.70$, $p < 0.01$ (two-tailed). The LOC BC holds in Flight Lesson 50 also showed a significant amount of transfer. Percent transfer was 26.5% and the TER was

Table 4. Mean trials in the airplane for the Airplane group (Y_c) and the PCATD group (Y_x), mean trials in the PCATD (X), percent transfer and training effectiveness ratios (TERs), for selected instrument tasks trained in Aviation 140 after the students completed experimental training in Aviation 130. Levels of statistical significances of differences between Y_c and Y_x are shown.

Task	Group			p	Percent Transfer	TER
	Y_c	Y_x	X			
ILS (Flt Lesson 48)	1.55	1.26	1.26	ns	18.7%	0.23
VOR (Flt Lesson 48)	1.23	1.05	1.05	<0.03	14.6%	0.17
NDB Holds (Flt Lesson 49)	1.47	1.18	1.87	<0.06	19.7%	0.16
NDB Approach (Flt Lesson 49)	1.95	1.54	2.36	<0.03	21.0%	0.17
NDB Holds (Flt Lesson 50)	1.33	1.12	1.33	<0.05	15.8%	0.16
NDB Approach (Flt Lesson 50)	1.64	1.18	1.18	<0.01	28.1%	0.39
LOC BC Holds (Flt Lesson 50)	1.47	1.08	1.29	<0.03	26.5%	0.30
ILS Holds (Flt Lesson 50)	1.14	1.11	1.14	ns	2.6%	0.03
ILS (Flt Lesson 51)*	1.10	1.03	1.20	ns	6.4%	0.06
NDB (Flt Lesson 51)*	1.15	1.13	1.21	ns	1.7%	0.02
VOR (Flt Lesson 51)*	1.10	1.00	1.10	ns	9.1%	0.09
ILS (Flt Lesson 52)*	1.09	1.22	1.16	ns	-11.9%	-0.11
VOR (Flt Lesson 52)*	1.17	1.29	1.51	ns	-13.2%	-0.10
NDB (Flt Lesson 52)*	1.14	1.19	1.73	ns	-1.7%	-0.01
LOC BC (Flt Lesson 52)*	1.15	1.10	1.19	ns	4.4%	0.04
ILS (Flt Lesson 53)*	1.29	1.14	1.18	ns	11.6%	0.13
VOR (Flt Lesson 53)*	1.06	1.00	1.12	ns	5.1%	0.05
NDB (Flt Lesson 53)*	1.06	1.06	1.07	ns	0.0%	0.00
Holds (Flt Lesson 53)*	1.07	1.14	1.04	ns	-6.5%	-0.07
NDB (Flt Lesson 54)*	1.45	1.34	1.21	ns	7.6%	0.09
Holds (Flt Lesson 54)*	1.23	1.03	1.12	ns	16.3%	0.18
NDB (Flt Lesson 55)*	1.62	1.56	1.61	ns	3.7%	0.04
Holds (Flt Lesson 55)*	1.11	1.24	1.09	ns	-11.7%	-0.12
ILS (Flt Lesson 56)*	1.14	1.11	1.17	ns	2.6%	0.03
VOR (Flt Lesson 56)*	1.22	1.06	1.16	ns	4.9%	0.06
Holds (Flt Lesson 56)*	1.22	1.11	1.20	ns	9.0%	0.09
ILS (Flt Lesson 57)*	1.14	1.14	1.03	ns	0.0%	0.00
VOR (Flt Lesson 57)*	1.14	1.14	1.03	ns	0.0%	0.00
Holds (Flt Lesson 57)*	1.04	1.18	1.12	ns	-13.5%	-0.13

*Review tasks.

0.30, which indicates that almost one-third of a trial was saved in the Airplane for the PCATD group for each prior trial in the PCATD. For the LOC BC task in Flight Lesson 50, the PCATD group required 1.08 mean trials to reach criterion, compared with 1.47 mean trials for the Airplane group. The difference between the means of 0.39 trials was significant: $t(40) = 2.19$, $p < 0.03$ (two-tailed). None of the tasks reviewed in the remaining fight lessons indicated significant transfer.

The means used to compute percent transfer and TERs for instrument tasks trained in Aviation 140 in the Fall 1994 are shown in Table 5. As in Aviation 130 and the combined Aviation 140 data in Table 4, the introduction of tasks generally resulted in better transfer than review of tasks. For example, non directional beacon (NDB) holds and approaches were introduced in Flight Lesson 49. High positive transfer was found for the mean trials to proficiency for NDB holds and NDB approaches in that lesson. The percent transfer was 32.5% and 42.8%, respectively, and the TERs were 0.35 (NDB holds) and 0.40 (NDB approach). Each NDB hold trial and each NDB approach trial in the PCATD saved over one-third of a hold or approach trial in the airplane. For the students in Aviation 140 trained in the Fall 1996, the transfer effectiveness for both NDB holds and NDB approaches for the PCATD group was lower in Flight Lesson 50 than for Flight Lesson 49, when NDB holds and approaches were introduced. An NDB hold trial in the PCATD saved approximately one-tenth of a trial in the airplane, while an NDB approach trial in the PCATD group produced no savings.

Time to Complete Flight Lesson

The mean times to complete the flight lessons in Aviation 130 are shown in Table 6, together with associated values of percent transfer and the TERs. Transfer of training was substantial for many lessons. Positive transfer observed ranged from 22.7% transfer for Flight Lesson 38 (review of VOR and ILS and introduction of DME Arc) to 37.5% transfer for Flight Lessons 34/35 (introduction of steep turns). Positive TERs ranged from 0.23 for Flight Lesson 36 (intersection holds) to 0.50 for Flight Lessons 34/35 (introduction to steep turns). For Flight Lessons 34/35, the PCATD group saved one-half hour in the airplane for each prior hour in the PCATD. For Flight Lessons 34/35 (introduction of steep turns), the mean time for the flight lesson for the PCATD group was 0.95 mean hours compared with 1.52 mean hours for the Airplane group; the difference between the mean of 0.57 hours was significant: $t(78) = 5.01$, $p < 0.001$ (two-tailed). For Flight Lesson 37 (ILS and LOC BC approaches), the percent transfer was 27.5 and the TER was 0.32, which indicated that the PCATD group saved almost one-third of an hour in the airplane for each prior hour in the PCATD. For Flight Lesson 37 (ILS and LOC BC approaches), the mean time for the PCATD group to complete the flight lesson was 1.74 mean hours compared with 2.40 mean hours for the Airplane group. The difference between the means of 0.68 hours was significant: $t(94) = 3.32$, $p < 0.001$ (two-tailed). For Flight Lesson 36, intersection holds, the PCATD group saved almost one-fourth hour in the airplane for each prior hour in the PCATD. The PCATD group required 1.34 mean hours to complete Flight Lesson 36 (intersection holds), compared with 1.81 hours for the Airplane group. The difference between the means of 0.47 hours was significant: $t(99) = 2.89$, $p < 0.001$ (two-tailed). For Flight Lesson 38 (review of VOR and ILS, and Introduction to DME Arc) the percent transfer was 22.7 and the TER was 0.30. The PCATD group required 1.53 mean hours to complete this flight lesson, compared with 1.98 mean hours for the Airplane group. The difference between the means of 0.45 was significant: $t(85) = 2.82$, $p < 0.01$ (two-tailed).

The times to complete Aviation 140 flight lessons for subjects who had completed the experimental curriculum in Aviation 130 are shown in Table 7, together with the associated percent-transfers and TERs. Transfer of training, as measured by the time to complete the flight lesson, was substantial for the introduction of NDB holds and approaches (Flight Lesson 49) and for their first review (Flight Lesson 50). The percent transfer was 26.4% and 19.2%, respectively, for Flight Lesson 49 and 50. The TERs were 0.22 and 0.24 respectively for Flight Lesson 49 and 50, which indicated for both of these lessons prior training on NDB holds and approaches in the PCATD saved almost one-fourth of an hour in the airplane.

Table 5. Mean trials in the airplane for the Airplane only group (Y_c) and the PCATD group (Y_x) and the mean trials in the PCATD (X), and percent transfer and training effectiveness ratios (TERs), for instrument tasks trained in Aviation 140 (Fall 1994 data).

Task	Group			Percent Transfer	TER
	Y_c	Y_x	X		
Holds (Flt Lesson 48)*	1.69	1.93	2.43	-14.2%	-0.10
ILS (Flt Lesson 48)*	2.23	2.00	2.64	10.3%	0.09
VOR (Flt Lesson 48)*	2.31	1.79	1.79	22.5%	0.29
NDB Holds (Flt Lesson 49)	1.69	1.14	1.57	32.5%	0.35
NDB Approach (Flt Lesson 49)	2.62	1.50	2.79	42.8%	0.40
NDB Holds (Flt Lesson 50)*	1.38	1.27	1.00	8.0%	0.11
NDB Approach (Flt Lesson 50)*	1.25	1.33	1.08	-6.4%	-0.07
LOC BC Holds (Flt Lesson 50)	1.38	1.31	1.07	5.1%	0.07
ILS Holds (Flt Lesson 50)	1.15	1.08	1.08	6.1%	0.06
ILS (Flt Lesson 51)*	1.00	1.22	1.79	-22.0%	-0.12
VOR (Flt Lesson 51)*	1.09	1.08	1.15	0.9%	0.01
NDB (Flt Lesson 51)*	1.50	1.00	2.00	33.3%	0.25
ILS (Flt Lesson 52)*	1.25	1.27	1.43	-1.6%	-0.01
VOR (Flt Lesson 52)*	1.17	1.14	1.42	2.6%	0.02
NDB (Flt Lesson 52)*	1.62	1.08	2.10	33.3%	0.26
LOC BC (Flt Lesson 52)*	1.25	1.00	1.29	20.0%	0.19
Holds (Flt Lesson 52)*	1.08	1.00	1.50	7.4%	0.05
ILS (Flt Lesson 53)*	1.31	1.21	1.50	7.6%	0.07
VOR (Flt Lesson 53)*	1.10	1.15	1.00	-4.6%	-0.05
NDB (Flt Lesson 53)*	1.00	1.14	1.20	-14.0%	-0.12
Holds (Flt Lesson 53)*	1.67	1.00	1.33	40.1%	0.50
NDB (Flt Lesson 54)*	1.17	1.29	1.50	-10.3%	-0.08
Holds (Flt Lesson 54)*	1.10	1.08	1.00	1.8%	0.02
NDB (Flt Lesson 55)*	1.75	1.50	1.93	14.3%	0.13
Holds (Flt Lesson 55)*	1.44	1.27	1.15	11.8%	0.15
ILS (Flt Lesson 56)*	1.00	1.14	1.07	-14.0%	-0.13
VOR (Flt Lesson 56)*	1.17	1.29	1.14	-12.0%	-0.11
NDB (Flt Lesson 56)*	-	-	1.07	-	-
Holds (Flt Lesson 56)*	1.00	1.25	1.29	-25.0%	-0.19
ILS (Flt Lesson 57)*	1.00	1.07	1.14	-7.0%	-0.06
VOR (Flt Lesson 57)*	1.25	1.29	1.17	-3.2%	-0.03
Holds (Flt Lesson 57)*	1.17	1.13	1.22	3.4%	-0.03

*Review tasks.

Table 6. Mean time (in hours) to complete the flight lesson for Y_c, Y_x, and X, and percent transfer and TERs for Aviation 130 (Combined data for study). Levels of statistical significances of differences between Y_c and Y_x are shown.

Flight Lesson	Group			p	Percent Transfer	TER
	Y_c	Y_x	X			
34/35 (Steep Turns, N=54 and 53)	1.52	0.95	1.13	<0.001	37.5%	0.50
36 (Intersection Holds, N=54 and 53)	1.81	1.34	2.07	<0.001	26.0%	0.23
37 (ILS, LOC BC, N=54 and 53)	2.40	1.74	2.05	<0.001	27.5%	0.32
38 (VOR, ILS, DME Arc, N=54 and 52)	1.98	1.53	1.51	<0.01	22.7%	0.30
39 (ILS, LOC BC, N=52 and 52)	2.12	2.24	1.20	ns	-5.7%	-0.10
40,41,43 (ILS, LOC BC, VOR, Holds, N=48 and 48)	4.75	4.72	3.49	ns	0.6%	0.01
42 (ILS, VOR, Holds, N=49 and 52)	2.25	2.38	1.19	ns	-5.8%	-0.11

Table 7. Mean time (in hours) to complete flight lesson for Y_c, Y_x, and X and percent transfer and TERs for Aviation 140 (After completing training in Aviation 130). Levels of statistical significances of differences between Y_c and Y_x are shown.

Flight Lesson	Group			p	Percent Transfer	TER
	Y_c	Y_x	X			
49 (NDB Holds, Approach, N=38 and 39)	1.63	1.20	1.98	<0.001	26.4%	0.22
50 (NDB Holds, Approach, ILS and LOC BC Holds, N=38 and 39)	1.88	1.52	1.51	<0.04	19.2%	0.24
51 (ILS, NDB, VOR, N=38 and 38)	1.60	1.58	1.47	ns	1.3%	0.01
52 (ILS, NDB, VOR, LOC BC, Holds, N=38 and 38)	2.05	2.02	1.92	ns	1.5%	0.02
53 (ILS, NDB, VOR, Holds, N=38 and 38)	2.13	2.15	1.32	ns	-0.9%	-0.02
54 (NDB, Holds, N=38 and 37)	2.02	2.02	0.83	ns	0.0%	0.00
55 (NDB, Holds, N=38 and 37)	2.47	2.52	1.00	ns	-2.0%	-0.05
56 (ILS, VOR, Holds, N=36 and 37)	3.94	3.99	1.49	ns	-1.3%	-0.03
57 (ILS, VOR, Holds, N=37 and 37)	2.14	2.49	1.12	ns	-16.4%	-0.31

For Flight Lesson 49 (introduction of NDB holds and approaches), the PCATD group required 1.20 mean hours to complete the flight lesson compared with 1.63 mean hours for the Airplane group. The difference between the means was significant: $t(57) = 2.96$, $p < 0.001$ (two-tailed). NDB holds and approaches, ILS and LOC BC holds were reviewed in Flight Lesson 50. The mean time to complete the flight lesson for the PCATD group was 1.52 mean hours compared with 1.88 mean hours for the Airplane group. The difference between the means of 0.36 hours was significant: $t(65) = 2.06$, $p < 0.04$ (two-tailed). There was no significant transfer, as measured by time, for the remaining flight lessons. The percent transfer was -16.4%, and the TER was -0.31 which means that for each hour in the PCATD it took the PCATD group almost one-third of an hour longer to complete the lesson in the airplane than the Airplane group. This difference was not significant.

The mean times to complete selected flight lessons in Aviation 140 are shown for the Fall 1994 data in Table 8, together with associated values of percent transfer and the TERs. As indicated in Table 8, for Flight Lesson 49 (the introduction of NDB holds and approaches) and for their review (Flight Lesson 50), the transfer effectiveness for the time to complete the flight lesson variable was positive and substantial. Transfer for Flight Lesson 49 was 31.6% and 23.2% for Flight Lesson 50. TERs for lessons 49 and 50 were 0.31 and 0.35, respectively. PCATD students saved about a third of an hour in the airplane for each hour in the PCATD.

Course Completion Time

The means and variances for total airplane time for the Airplane and the PCATD groups to complete the two courses are shown in Table 9. For Aviation 130, the PCATD group required a mean of 21.0 hours to complete the course, compared with 23.1 hours for the Airplane group. The difference between the means of 2.1 hours was significant: $t(90) = 3.53$, $p < 0.001$ (two tailed). The data for those Aviation 140 subjects who first completed the Aviation 130 experimental program indicated that the PCATD group required a mean of 26.37 hours to complete the course, compared with 28.18 hours for the Airplane group. The difference between the means of 1.81 hours was significant: $t(72) = 2.61$, $p < 0.01$ (two tailed).

Table 8. Mean time (in hours) to complete flight lesson for Y_c, Y_x, and X, and percent transfer and TERs for Aviation 140 (Fall 1994 Data).

Flight Lesson	Group			Percent Transfer	TER
	Y_c	Y_x	X		
49 (NDB Holds, Approaches, N=13 and 14)	1.90	1.30	1.92	31.6%	0.31
50 (NDB Holds, Approaches, ILS and LOC BC, N=13 and 14)	1.81	1.39	1.19	23.2%	0.35
51 (ILS, NDB, VOR, N=13 and 14)	1.54	1.61	2.20	-7.0%	-0.03
52 (ILS, NDB, VOR, LOC BC, Holds, N=13 and 14)	2.52	1.73	1.96	31.4%	0.40
53 (ILS, NDB, VOR, Holds, N=13 and 14)	2.18	2.08	1.06	4.6%	0.09
54 (NDB, Holds, N=12 and 14)	1.99	1.85	0.87	7.0%	0.07
55 (NDB, Holds, N=13 and 14)	2.74	2.50	1.05	8.8%	0.23
56 (ILS, VOR, Holds, N=12 and 14)	4.02	4.15	1.07	-3.2%	-0.12
57 (ILS, VOR, Holds, N=12 and 14)	2.13	2.16	1.02	-1.4%	-0.03

Table 9. Mean Airplane times (in hours) and variances to complete courses for Airplane and PCATD groups for Aviation 130 and Aviation 140.

		Mean	(Y_c-Y_x)	Variance	N	t	p
Aviation 130							
(Y_c)	Airplane	23.1		8.3	45		
(Y_x)	PCATD	21.0	2.1	8.3	47	3.5	< 0.001
Aviation 140							
	Airplane	28.2		8.41	36		
	PCATD	26.4	1.8	9.47	38	2.61	< 0.01
Aviation 140 (Fall 1994)							
	Airplane	29.8		9.85	13		
	PCATD	26.7	3.1	5.67	14	2.91	< 0.05

For the Aviation 140 Fall 1994 data, the PCATD group required a mean of 26.7 hours to complete the course, compared with 29.8 hours for the Airplane group. The difference between the means of 3.1 hours was significant: $t(25) = 2.91$, $p < 0.05$ (two tailed).

DISCUSSION

The data from the study indicate that the PCATD is an effective training device for teaching instrument tasks to private pilots. These data show a significant level of transfer savings for course hours overall. Approximately 4.0 hours were saved for Aviation 130 and Aviation 140 combined. This represents a worthwhile benefit because rental costs are $69/hour for the airplane used in this experiment and $5/hour for the PCATD. The savings may seem marginal in light of the fact that time spent in the PCATD to generate those savings exceeded 12.5 hours for Aviation 130 and 14 hours for Aviation 140. It should be noted, however, that the procedures developed to satisfy the goal of the experiment generated inefficiencies. In that the primary goal was to explore all possibilities of contributions of the PCATD, a considerable amount of the PCATD training was undertaken to review task areas that resulted in little or no transfer. Training PCATD flight lessons to proficiency also reduced the efficient use of the PCATD.

Some signs of negative transfer are also evident. None of these effects was statistically significant, and they probably reflect random fluctuations. The data that have been generated in this experiment offer a solid guide to development of an instrument syllabus that could maximize the efficiency of the PCATD. Indeed, further savings should be possible from targeting for PCATD training only those tasks that show worthwhile positive transfer. Specifically, the data suggest that the same savings of approximately four hours could be achieved by use of approximately 6.75 PCATD hours in Flight Lessons 34 to 38 and 4.5 PCATD hours in Flight Lessons 45 to 50.

Aviation 130

Flight Lessons 34 to 38 were used to develop proficiency in a number of basic instrument tasks and to introduce and review various instrument hold and approach procedures. Total lesson times for each of these lessons showed significant levels of transfer ranging from approximately 20 to 40%, with TERs ranging from approximately 0.20 to 0.50. Analyses of individual tasks revealed that, in almost all cases, this transfer resulted, at least in part, from the learning of specific instrument maneuvers when they were first introduced.

The single exception to this trend was in Flight Lessons 34 and 35, when the task of steep turns failed to reveal significant transfer, but there was significant transfer for the overall flight lesson. In that Flight Lessons 34 and 35 included a considerable amount of nonspecific flying beyond steep turns that were also practiced in the PCATD, we assume the enhancement was generated in these nonspecific flying activities. No single instrument procedure trained in Aviation 130 showed statistically significant transfer in any lesson in which it was reviewed. A few of the transfer indexes for reviews of instrument procedures were negative, but none approached statistical significance.

Flight Lessons 39 to 42 prepared students for Instrument Flight Rules (IFR) cross-country flight. It was difficult to develop a PCATD scenario that would assist the students with very much of this preparation. The exercise that was developed had students practice ILS, VOR, and LOC BC that would be flown in the cross-country flight, which provided an opportunity to rehearse these tasks in the PCATD prior to the cross-country flight. The percent transfer and TER were insensitive measures in terms of determining the potential benefit of approach rehearsal during those flight lessons. The specific objectives of the flight lessons prevented substantial transfer, as measured by the percent transfer and TER.

Flight Lesson 43 was a review of IFR procedures and cross-country skills with the completion standards to the Instrument Rating Practical Test Standards for the lesson content with no assistance from the instructor. It was required that the PCATD group fly the PCATD a minimum of one hour per lesson in Flight Lessons 40 and 41. The group could use the PCATD up to a maximum of five hours in Flight Lessons 40-43 combined. Additional PCATD time was available with prior permission. Since the means of airplane trials to completion standards show that most students required only one trial to achieve proficiency on each of these exercises, high levels of positive transfer were not expected. One approach trial would be expected in cross-country flight, since the students would typically perform only one ILS, VOR, and/or LOC BC approach in the airplane at any airport.

The final two lessons in Aviation 130 are devoted to a practice check flight and a check flight. These lessons may appear at first to offer a critical point for measuring training effectiveness. However, it was assumed at the outset that these measures would be insensitive to differences between the Airplane and the PCATD groups. By design of the experiment, students from both groups had been brought to the same proficiency standards lesson by lesson in the airplane. The only possibility that real differences would show up in the practice or the real check flight is that one or the other of the training conditions had provided some sort of learning experience that contributed substantially to overall flight competence, as evaluated in the check flight, but had not been taught explicitly. There is no evidence here that this occurred.

Aviation 140

As noted earlier, Aviation 140 students were not treated identically in this experiment. The first group of Aviation 140 subjects (Fall 1994) had not been involved in the experiment during their Aviation 130 training. The remaining Aviation 140 subjects had been in the experiment as Aviation 130 subjects prior to taking the experimental curriculum in Aviation 140. Their data are combined into a single data set and treated separately from the Aviation 140 data collected during in the Fall 1994. Some differences between the two sets of results are evident. Most noticeably, there was a difference in transfer, based on time required to complete Flight Lesson 52, for transfer based on trials to reach criterion for review of NDB and LOC BC approaches in Flight Lesson 52, and for transfer based on trials to reach criterion for review of holds in Flight Lesson 53. There are a number of possible reasons for changes of this type from semester to semester, two being variations in weather and a changing pool of instructors. The most likely explanation is that the small number of students in the Fall 1994, coupled with the fact that these review lessons required very few trials to criterion in the airplane, induced some instability in the data. Because of the limited resources available for this project, we could not investigate the cause of these differences. Given the possibility of unstable data for the Fall 1994 group of Aviation 140 students, we emphasize the Aviation 140 combined data set in this discussion.

As in Aviation 130, task introduction generally resulted in better transfer than task review but several exceptions were observed. Flight Lesson 48 was a review lesson for the ILS and VOR approaches. The subjects had received substantial practice on these tasks in Aviation 130 during the previous semester. The data indicate that, compared with the Airplane group, the PCATD group saved in the airplane approximately one-fifth of the trials on the VOR approaches, due to prior review in the PCATD. This is strong evidence that the PCATD is an effective tool for reviewing previously learned instrument tasks if some time has elapsed since the tasks were last practiced. Indeed, these data are in marked contrast to the review data obtained in Aviation 130 that indicated review of instrument tasks learned to proficiency during the previous lesson was not a productive use of the PCATD.

In other respects, the observations to be drawn on the data from the Aviation 140 closely follow those drawn on the data from Aviation 130. Again, it was the early lessons in which new material was introduced that there was significant positive transfer. Flight Lessons 49 and 50 showed transfer values of approximately 20 and 25%, with TERs of approximately 0.20 and 0.25. All tasks in these two lessons were introduced here for the first time; all, with the exception of NDB holds in Flight Lesson 49 and ILS holds in Flight Lesson 50, showed statistically significant positive transfer. These values ranged from approximately 15 to 30%, with TERs in the range of approximately 0.15 to 0.40. With the exception of VOR in Flight Lesson 48 and NDB holds and approaches in Flight Lesson 50, no reviewed tasks showed statistically significant positive transfer, and none of the negative transfer values was statistically significant. No times to complete the flight lessons in Aviation 140 showed statistically significant positive transfer, with the exception of Flight Lessons 49 and 50.

As in Aviation 130, the practice checkflight for Aviation 140 (Flight Lesson 58) and the checkflight (Flight Lesson 60) may appear at first to offer a critical point for measurement of training effectiveness. However, these two lessons were again unlikely to discriminate between the training conditions because in preceding lessons, instructors were required to bring students from both groups to the same standards of proficiency. Flight Lesson 59 was used to review instrument procedures for which individual students had not met instrument rating practical test standards. There were relatively few students providing data on any specific exercise. It is likely that instructors used this lesson to selectively reinforce a student's weakest areas. Some of the transfer ratios in this lesson are high and there is also one large negative value. Nevertheless, these ratios are difficult to interpret because of the selective nature of the data.

Substitution of the PCATD for Instrument Flight Hours

Current FAA regulations, FAR Part 141.41, permit the substitution of 15 hours of time in a certified ground trainer for aircraft time required for instrument certification (FAA, 1992). The FAA Flight Standards Office has drafted an Advisory Circular, which provides that some of those hours of the instrument time required by FAR Part 141 can be flown in a PCATD. The draft advisory circular, if approved, would permit a PCATD, that meets the requirements of FAR Part 141.41 (a) (1), to be used in lieu of some of the time afforded an authorized ground training device under FAR Part 141, Appendix C. As mentioned earlier, the PCATD group required a mean 47.4 hours in the airplane to complete the instrument rating, compared with 51.3 hours for the Airplane group. This represents a saving of approximately 4 hours. This finding supports the proposal to permit the substitution of PCATD time for instrument time. Indeed, the data presented here suggest that the PCATD is effective in teaching all instrument tasks.

This experiment is specific to evaluation of a PCATD. It is possible that a generic training device would be more effective and might not suffer from the occasional problems of negative transfer we have observed here. However, the available evidence does not support this belief (Hampton et al., 1994) and there is little evidence that a generic training device would offer any benefit in addition to that gained from the PCATD.

SUMMARY

The data show that training in a PCATD resulted in positive transfer for instrument flight tasks when measured in reference to trials to criterion or time to complete a flight lesson in the airplane. The benefit of training in the PCATD varied substantially among the instrument tasks tested (from 15% to over 40%). In general, savings were positive and substantial when new tasks were introduced. The data indicated that a PCATD can save a part of the aircraft time that would otherwise be needed. A comparison of course completion times for the two courses resulted in savings of about four hours for the PCATD group, compared with the Airplane group.

Time constraints and other organizational limitations prevented the full use of the PCATD in all flight lessons. One substantial constraint on savings is an FAA-mandated requirement of four hours of pilot-in-command cross-country time in Aviation 130 and 12.5 hours in Aviation 140. In the present experiment, the PCATD was not used to teach cross-country skills. It would, however, be possible to offer practice on cross-country scenarios. With development of an appropriate assessment tool, it may be possible to demonstrate that PCATD-trained students could achieve full competence with cross-country flight well before they had completed their mandated exercises. Adjustments in the way the PCATD has been used may extend its usefulness in relation to these tasks.

The data also reveal that some tasks do not benefit to a large extent from training in the PCATD, and that use of the PCATD is more beneficial for training of new tasks than it is for review of tasks trained earlier in the course. These results suggest principles that might be used to target a PCATD for maximum effectiveness within a flight training program. This was not done in the present study. Our objective was to investigate the instrument tasks that could be trained using a PCATD. In that the overall savings in each of the courses, although statistically significant, are relatively small, it may be desirable to ensure that a PCATD is focused specifically on areas that result in substantial transfer to the airplane.

REFERENCES

Dennis, K.A. (1994). Computer-based simulation as adjunct to the initial stages of private pilot device training. Cranfield, England: Cranfield University.

Emanuel, T.W., Jr., Taylor, H.L., Hulin, C.L., Lintern, G., Phillips, S.I., & Talleur, D.A. (1995). Development of an experimental flight syllabus for testing PC computer-based aviation training devices. In R.S. Jensen & L.A. Rakovan (Eds.), *Proceedings of the Eighth International Symposium on Aviation Psychology* (pp. 1198-203). Columbus, OH: The Ohio State University.

Falun, N. (1992, September). Azuresoft elite. *Flight Training*, 50-2.

FAA. (1992). *Flight schools* (14 CFR Part 141). Federal Aviation Administration, Department of Transportation.

Flexman, R.E., Roscoe, S.N., Williams, A.C., Jr., & Williges, B.H. (1972, June). *Studies in pilot training: The anatomy of transfer* (Aviation Research Monographs, vol. 2, no. 1). Savoy, IL: University of Illinois, Institute of Aviation, Aviation Research Laboratory.

Hampton, S., Moroney, W., Kirton, T., & Biers, D.W. (1994). *The use of personal computer-based training devices in teaching instrument flying: A comparative study* (Final Report). Daytona Beach, FL: Embry-Riddle Aeronautical University.

Koonce, J.M. (1979). Predictive validity of flight simulators as a function of simulator motion. *Human Factors*, *21*(2), 215-23.

Lert, P. (1990, April). Flight simulator programs. *Air Progress*, 20-68.

Lintern, G., Roscoe, S.N., Koonce, J.M., & Segal, L.D. (1990). Transfer of landing skill in beginning flight training. *Human Factors*, *32*, 319-27.

Ortiz, G.A. (1993). PC-based flight simulation effectiveness. In R.S. Jensen & D. Neumeister (Eds.), *Proceedings of the Seventh International Symposium on Aviation Psychology* (pp. 698-701). Columbus, OH: The Ohio State University.

Ortiz, G.A. (1994). Effectiveness of PC-based flight simulation. *The International Journal of Aviation Psychology*, *4*, 285-91.

Peterson, C., Jr. (1993, April). Controlling your simulator software. *Private Pilot*, 72-7.

Phillips, S.I., Hulin, C.L., & Lamermayer, P.J. (1993). Uses of part-task trainers in instrument flight training. In R.S. Jensen & D. Neumeister (Eds.), *Proceedings of the Seventh International Symposium on Aviation Psychology* (pp. 743-46). Columbus, OH: The Ohio State University.

Phillips, S.I., Taylor, H.L., Lintern, G., Hulin, C.L., Emanuel, T.W., Jr., & Talleur, D.A. (1995). Developing performance measures for evaluating personal computer-based aviation training devices within an FAR part 141 pilot training school. In R.S. Jensen & L.A. Rakovan (Eds.), *Proceedings of the Eighth International Symposium on Aviation Psychology* (pp. 1204-9). Columbus, OH: The Ohio State University.

Povenmire, H.K., & Roscoe, S.N. (1971). An evaluation of ground-based flight trainers in routine primary flight training. *Human Factors, 15*, 109-16.

Povenmire, H.K., & Roscoe, S.N. (1973). Incremental transfer effectiveness of a ground-based general aviation trainer. *Human Factors, 15*, 534-42.

Roscoe, S.N. (1971). Incremental transfer effectiveness. *Human Factors, 13*, 561-7.

Roscoe, S.N., & Williges, B.H. (1980). Measurement of transfer of training. In S.N. Roscoe (Ed.), *Aviation psychology* (pp. 182-93). Ames, IA: The Iowa State University Press.

Taylor, H.L., Lintern, G., & Hulin, C.L. (1995). *Transfer training effectiveness of personal computer-based aviation training devices* (Interim Report). Savoy, IL: University of Illinois, Institute of Aviation.

Taylor, H.L., Lintern, G., Hulin, C.L., Emanuel, T.W., Jr., Phillips, S.I., & Talleur, D.A. (1995). Transfer of training effectiveness of personal computer-based aviation training devices. In R.S. Jensen & L.A. Rakovan (Eds.), *Proceedings of the Eighth International Symposium on Aviation Psychology* (pp. 1210-5). Columbus, OH: The Ohio State University.

Taylor, H.L., Lintern, G., Hulin, C.L., Talleur, D.A., Emanuel, T.W., & Phillips, S.I. (1996a). *A preliminary study of an integrated syllabus using a personal computer aviation training device and a generic training device.* Savoy, IL: University of Illinois, Institute of Aviation.

Taylor, H.L., Lintern, G., Hulin, C.L., Talleur, D.A., Emanuel, T.W., & Phillips, S.I. (1996b). Transfer of training effectiveness of personal computer-based aviation training devices. Final Technical Report ARL-96-3/FAA-96-2. Savoy, IL: University of Illinois, Institute of Aviation.

Taylor, H.L., Lintern, G., Hulin, C.L., Talleur, D.A., Phillips, S.I., & Emanuel, T.W. (1996). Effectiveness of personal computer-based aviation training devices. *Poster session presented at the Eighth Annual Convention of the American Psychological Society*, San Francisco, CA.

Taylor, H.L., Lintern, G., Koonce, J.M., Kaiser, R.H., & Morrison, G.A. (1991). Transfer of training and quasi-transfer of scene detail and visual augmentation guidance in landing training. *Proceedings of training transfer - Can we trust flight simulation* (pp. 6.1-6.14). London: Royal Aeronautical Society.

Williams, A.C., Jr., & Flexman, R.E. (1949). Evaluation of the school link as an aid in primary flight instruction. *University of Illinois Aeronautics Bulletin, 46*(5), 71.

Williams, K.W. (Ed.). (1994). *Summary Proceedings of the Joint Industry-FAA Conference on the Development and Use of PC-Based Aviation Training Devices.* Washington, DC: Department of Transportation/Federal Aviation Administration. (DOT/FAA/AM-94/25. NTIS #N95-14917).

Williams, K.W., & Blanchard, R.E. (1995). *Development of qualification guidelines for personal computer-based aviation training devices.* Washington, DC: Department of Transportation/ Federal Aviation Administration. (DOT/FAA/AM-95/6. NTIS #ADA-292961).

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