

**Aviation Research Lab
Institute of Aviation**

University of Illinois
at Urbana-Champaign
1 Airport Road
Savoy, Illinois 61874

**Incremental Training Effectiveness
of Personal Computers
Used for Instrument Training:
Basic Instruments**

**Henry L. Taylor, Donald A. Talleur,
Tom W. Emanuel, Jr., Esa M. Rantanen,
Gary L. Bradshaw, and Sybil I. Phillips**

**Interim Technical Report
ARL-02-4/NASA-02-2**

February 2002

Prepared for

**NASA Ames Research Center
Moffett Field, CA**

Contract NASA NAG 2-1282

TABLE OF CONTENTS

FOREWORD.....	ii
EXECUTIVE SUMMARY.....	iii
INTRODUCTION.....	1
METHOD.....	2
Subjects.....	2
Apparatus.....	2
Procedure.....	2
RESULTS.....	4
Trials to Criterion.....	4
Time to Complete Flight Lesson.....	8
Mean Time to Successful Evaluation Flight for AVI 130.....	12
DISCUSSION.....	13
Mean Trials.....	13
Mean Time to Complete the Flight Lesson.....	14
Mean Time to Successful Evaluation Flight for AVI 130.....	15
REFERENCES.....	16

FOREWORD

This work was supported under National Aeronautics and Space Administration (NASA) grant #NAG 2-1282. Dr. Immanuel Barshi, NASA Ames, CA served as the contracting officer's technical representative for NASA. Views expressed herein do not necessarily represent official NASA positions. Ms. Diana Christenson and Ms. Karen Ayers assisted with the manuscript and Mr. Ricky Weinberg; Chief Pilot and Head of the Institute of Aviation Professional Pilot Division, provided invaluable assistance with flight operations and with student management. Mr. Bill Jones, Mr. David Boyd and Mr. John Suppok served as stage check pilots for the study. We thank the flight instructors and the students of AVI 130 and AVI 140 for their participation in the study. Professor Gary Bradshaw is now at Mississippi State University, Department of Psychology, Mississippi State, MS 36762, 662-325-0550.

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 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 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 tasks trained were the following basic instrument tasks: aircraft control and instrument departure, enroute and approach procedures.

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 completion standards, time to complete a flight lesson and time to a successful evaluation flight. Percent transfer, transfer effectiveness ratios (TER) and incremental transfer effectiveness ratios (ITER) were computed for each instrument task and for the time to complete a flight lesson. 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 pairwise comparisons.

The data from the current study indicates that the PCATD is effective in teaching basic instrument tasks to private pilots. For all three PCATD groups 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 for the four groups for all instrument tasks. 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. All mean times to complete the flight lesson for the three PCATD groups were less than the mean times for the to the Airplane group. 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.

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 and all three experimental groups for Flight Lesson 38. 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. 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. The pattern of the TERs for mean time showed the predicted negatively decelerated function for each flight lesson for increased amounts of prior training in the PCATD. The ITERs for time to complete each flight lesson showed the predicted negatively decelerated function.

The 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. It was concluded that little additional benefit was found for training beyond the PCATD 5-hour level.

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, trials to criterion in the airplane, time to complete each flight lesson in the airplane, and comparisons of, of 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. 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 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 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 of basic instrument tasks using a PCATD.

METHOD

Subjects

A total of 157 subjects enrolled in AVI 130, the basic instrument training course 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. 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 AVI 130, basic instruments. 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 Control group.

Using a transfer of training design, four groups of subjects were tested in the airplane for proficiency on various instrument flying tasks. 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 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 course.

Flight Lesson	PCATD 5	PCATD 10	PCATD 15
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

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, could 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. 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.

Analyses. Mean trials to reach criterion on the airplane for selected instrument tasks and mean times to complete the flight lesson were computed for all groups. Separate ANOVAS were performed to analyze the difference between the four groups on the three dependent measures. One ANOVA explored variability that arose in the trial variable as a function of experimental treatment. A second ANOVA explored variability in flight lesson completion times. A third ANOVA explored variability in the time to complete the AVI 130 course. 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:

$$\frac{Y_c - Y_x}{Y_c} = \text{Percent Transfer} \quad (1)$$

$$\frac{Y_c - Y_x}{X} = \text{TER} \quad (2)$$

$$\frac{(Y_x - \Delta x) - Y_x}{\Delta X} = \text{ITER} \quad (3)$$

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, $Y_x - \Delta x$ = 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 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. The TER is a ratio that 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 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 et al., 1972).

RESULTS

Trials to Criterion

This interim report includes only the results for the AVI 130, basic instruments course. The final report will describe the findings of the full project. 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 Airplane group. These exceptions are: 1) ILS (Flight Lesson 37) where the mean trials for the Airplane group were 1.60 compared to 1.61 for the PCATD 5 group; 2) LOC BC where the mean trials for the Airplane group were 1.48 compared to 1.58 for the PCATD 10 group; 3) DME ARC where the mean trials for the Airplane 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 (Y_{x_5} , $Y_{x_{10}}$, $Y_{x_{15}}$) and trials in the PCATD (X_5 , X_{10} , X_{15}) for instrument tasks trained in AVI 130.

Task	Mean Trials in Airplane				Trials in PCATD		
	Y_c	Y_{x_5}	$Y_{x_{10}}$	$Y_{x_{15}}$	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 ($p \leq 0.05$) indicated significant differences between the Control group and the PCATD 5 group and between the Control group and the PCATD 15 group. The difference between the Control group and the PCATD 10 group was not significant. Individual ANOVAs comparing trials to criterion in the airplane for the four 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.

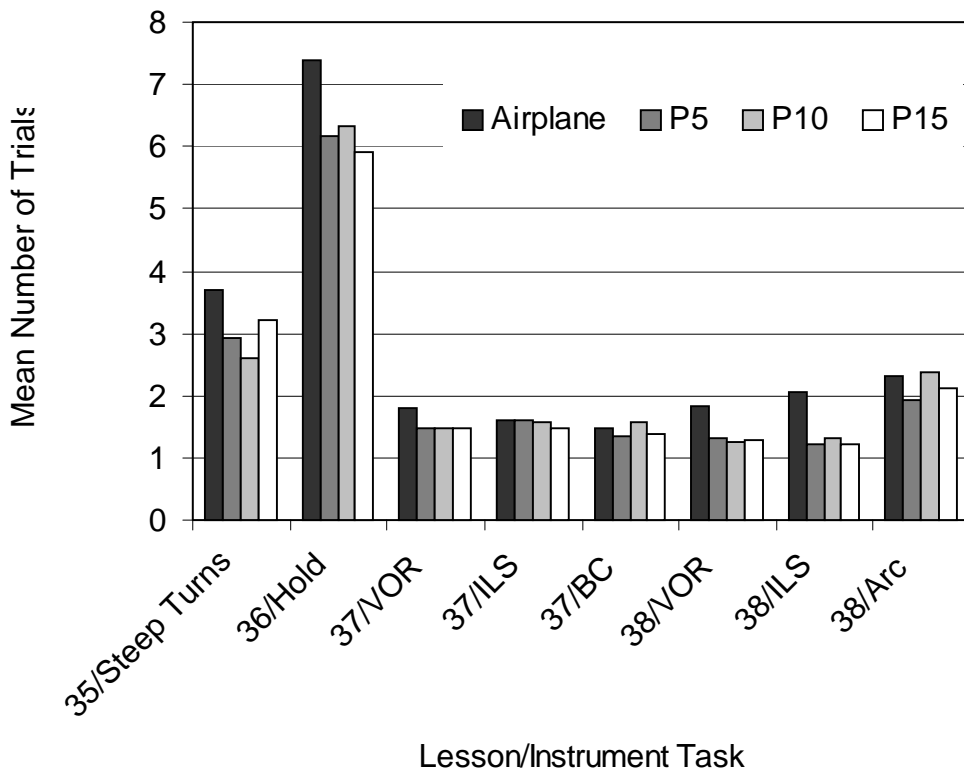


Figure 2. Mean trials in the airplane for the Control group and the three PCATD groups for the instrument tasks trained in AVI 130.

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 Airplane group; and for ILS (Flight Lesson 38) the PCATD 5 and 15 groups saved the same number of trials compared to the Airplane 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}).

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)	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 respectively) 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 Figure 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.

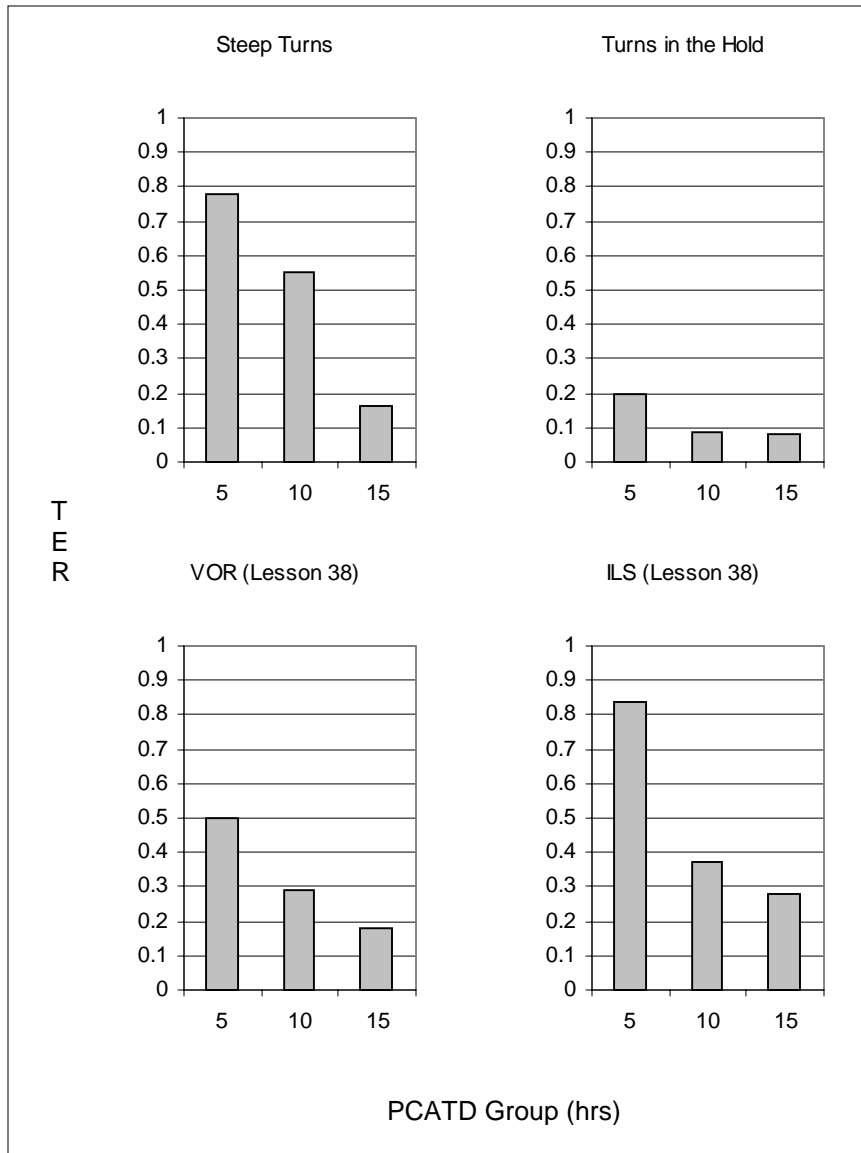


Figure 3. Transfer Effectiveness Ratios (TERs) for number of trials by maneuvers in AVI 130.

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 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.

Table 4.

Mean time to complete the flight lesson in the airplane for the Control group (Y_c) and the three PCATD Groups (Y_{x_5} , $Y_{x_{10}}$, $Y_{x_{15}}$) for AVI 130.

Mean Times				
<u>Flight Lesson</u>	<u>Y_c</u>	<u>Y_{x_5}</u>	<u>$Y_{x_{10}}$</u>	<u>$Y_{x_{15}}$</u>
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

The data in Table 4 are presented graphically in Figure 4. The Airplane group consistently required more time to reach criterion for all four flight lessons compared to the three experimental groups. An ANOVA was performed to compare the mean times to complete the flight lessons 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 ($p \leq 0.05$) 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 ($p \leq 0.05$) 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 Lessons 34/35 nor for Flight Lesson 37.

These times were used to compute percent transfer, TERs, and ITERs shown in Table 5. 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 transfers were also found for Flight Lesson 36 for PCATD 10 and 15 (22.6% and 27.4% respectively). No other percent transfer exceeded 20%.

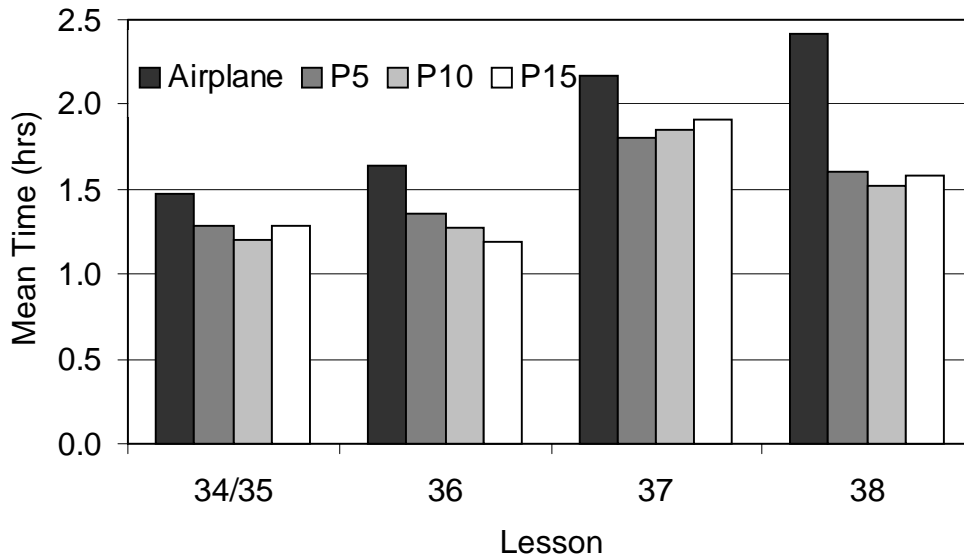


Figure 4. Mean time to complete the flight lesson in the airplane for the Control group and the three PCATD groups for AVI 130.

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.

Flight Lesson	Percent Transfer			TER			ITER		
	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 Lessons 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. 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). The largest TERs for one of the experimental groups (the PCATD 5 group), 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 negatively 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 Figures 5. For the time to complete flight lesson variable, the largest ITER found for the PCATD 10 group was 0.16 and for the PCATD 15 was 0.11.

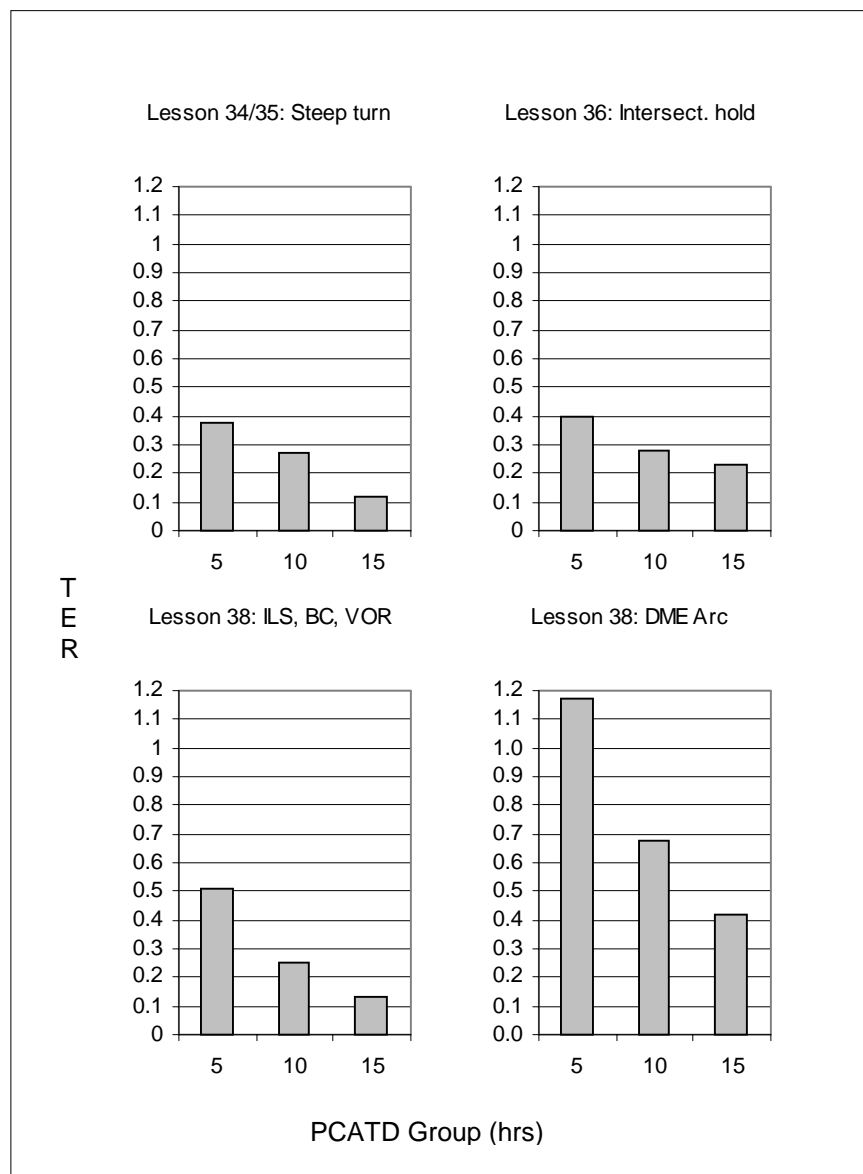


Figure 5. Transfer Effectiveness Ratios (TERs) for time to complete a flight lesson by flight lesson in AVI 130.

Mean Time to Successful Evaluation Flight for AVI 130

The total dual prior to a successful 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 22.16 hours compared to 20.13, 19.06 and 20.72 hours for the PCATD 5, 10, and 15 groups respectively. The flight hours saved were 2.03 hours, 3.1 hours, and 1.44 hours respectively for the PCATD 5, 10, 15 groups (Figure 6). 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 ($p \leq 0.05$) indicated a significant difference between the PCATD 10 and the Control group.

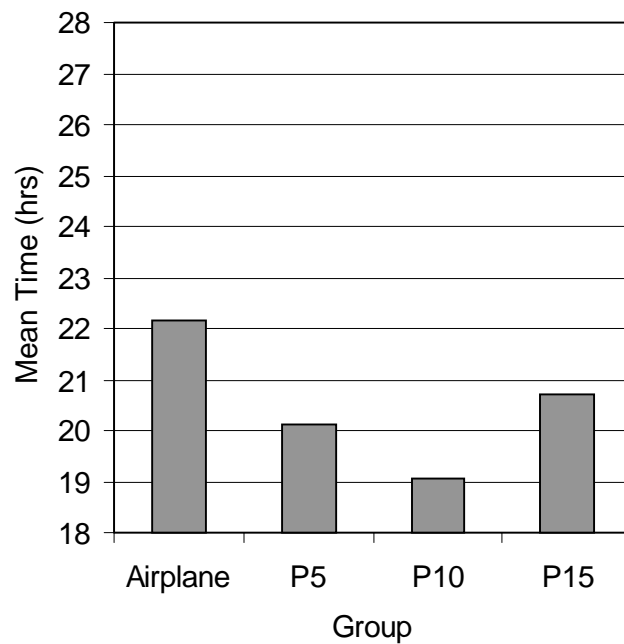


Figure 6. Mean time to successful evaluation flight for AVI 130.

DISCUSSION

Mean Trials

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 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 can 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 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 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, 3 trials respectively for 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 Airplane 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 Airplane group was only tested in the airplane.

Mean Time to Complete the Flight Lesson

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. 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.

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; 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 which 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 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; 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; 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.

Mean Time to Successful Evaluation Flight for AVI 130

The time to a successful evaluation flight for AVI 130 was less for all three PCATD groups compared to the Airplane group. The flight hours saved were 2.03 hours, 3.1 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 for AVI 130 for the four experimental groups. Post-hoc Tukey 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 compared to the 3.1 hours for the PCATD 10 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. 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 instructor was trained to recommend an evaluation flight after Flight Lesson 40 when the student was judged to be competent to meet the proficiency standards for the stage check which is normally scheduled for Flight Lesson 45. In the earlier study, the flight instructor was able to train to a proficiency standard and if the student passed the stage check the student was refunded the remaining portion of the flight fee and the instructor no longer had to fly with the student to complete the remaining course time. In the current study the instructor and the student were required to complete the flight hours in the course outline even though the student had completed a successful evaluation flight. The differences between the motivational aspects of the two studies adequately explain the differences in the time to a successful evaluation flight of the current study and the course completion time of the previous study.

This study replicated the findings of Taylor et al. (1996) that PCATDs are useful to teach basic 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 was 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. Generally 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. Additional research could point to ways in which the use of PCATDs could be improved for instrument training..

REFERENCES

- Federal Aviation Association. (1997) *Verification and approval of personal computer-based aviation training device* (Advisory Circular 61-126). Washington, DC: FAA, Dept. of Transportation.
- Flexman, R. E., Roscoe, S. N., Williams, A. C., Jr., & Williges, B. H. (1972, June). *Studies in pilot training* (Aviation Research Monographs, Vol. 2, #1). Savoy, IL: Univ. of Illinois, Inst. of Aviation.
- Phillips S. I., Taylor, H. L., Lintern, G., Hulin, C. L., Emanuel, T., & Talleur, D. (1995). Developing performance measures for evaluating personal computer-based aviation training devices within an FAR Part 141 pilot training school. *Proceedings of Aviation Psychology 8th International. Symposium*. Columbus, OH.
- Povenmire, H. K., & Roscoe, S. N. (1973). Incremental transfer effectiveness of a ground-based general aviation trainer. *Human Factors*, 15, 534-542.
- Roscoe, S. N. (1971). Incremental transfer effectiveness. *Human Factors*, 13, 561-567.
- Taylor, H. L., Lintern, G., Hulin, C. L., Talleur, D., Emanuel, T., & Phillips, S. (1996). *Transfer of training effectiveness of personal computer-based aviation training devices* (ARL-96-3/FAA-96-2). Savoy, IL: Aviation Research Lab.
- Taylor, H. L., Lintern, G, Hulin, C. L., Talleur, D. A., Emanuel, T., & Phillips, S. (1999). Transfer of training effectiveness of a personal computer aviation training device. *IJAP*, 9, 319-335.