Supplemental Analysis of the Effectiveness of the Personal Computer-Based Aircraft Training Device with That of an FAA-Approved Flight Training Device

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SUPPLEMENTAL ANALYSIS OF THE EFFECTIVENESS OF THE PERSONAL COMPUTER-BASED AIRCRAFT TRAINING DEVICE WITH THAT OF AN FAA-APPROVED FLIGHT TRAINING DEVICE

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The introduction of the personal computer-based aircraft training device, or PCATD, in the late 1990s stimulated the academic investigation of this technology for use in collegiate aviation education activities. Initially, FAA regulators dismissed this technology as gaming software and hardware, but the successful collegiate use of PCATD technology for training pilots convinced the FAA in 1997 (AC 61-126) to approve the use of PCATDs as an equivalency to actual flight time, but for only a portion of that equivalency allowed Flight Training Devices (FTDs). This study, a supplemental analysis of the effectiveness of a PCATD, found that there was no significant statistical difference between using the PCATD or the FAA approved FTD for maintaining an instrument pilot's ILS proficiency.

Introduction

Aviation educators have long sought economical ways to duplicate, or better described as simulate, the human processes necessary to safely operate an aircraft in flight and on the ground in a device other than an actual aircraft. The reasons for providing such simulations are many, but in particular represent a cost effective way to train and educate pilots as the costs associated with operating aircraft in flight lessons increase. The capability to simulate actual flight conditions began in 1934 as the C-3 Link Trainer, or "blue canoe" as it was called by the military pilots who used it, grew in popularity through the 1980s resulting in the construction of multimillion dollar, multifunctional simulation marvels that remain a flight training foundation for every branch of the military as well as the major airlines worldwide (Williams, 1994).

However, recent advances in software and hardware systems have allowed engineers to build much smaller, more cost effective devices that provide as accurate a simulation of flight conditions as those bulky, stand-alone facilities of the 1980s. In 1989, it was recognized that "within the next few years, low cost computers, simulators, visual systems . . . will be used to supplant most, if not all, training for . . . private, commercial and instrument-rated pilots as well as the various air traffic control positions" (Connolly & Lehrer, 1989, p. 443).

One of the newest devices is the personal computer-based aviation training device (PCATD). PCATDs are computer powered hardware and software devices that are small enough to fit on a large table, have the same flight controls, levers, and instrumentation as an actual aircraft, and even emulate on computer monitors the various weather phenomena pilots encounter when they actually fly aircraft in poor meteorological conditions. These types of flight simulation devices, usually costing less then $20,000, represent a new and cost effective way to educate aviation students to fulfill the Federal Aviation Administration (FAA) mandated flight experience requirements.

Expectedly, there has been an increase in the academic examination of PCATDs (Johnson & Stewart, 2002; Taylor et al., 2003; Taylor et al., 2001; Taylor, Talleur, Rantanen, & Emanuel, 2004). As computer software capabilities improve, and hardware configurations better represent the flight deck environment of actual aircraft, the PCATD has become a valuable tool for presenting realistic, high-quality representations of aircraft performance and instrumentation. Data from a study conducted by the Institute of Aviation at the University of Illinois (as cited in Taylor et al., 1997) indicates that the PCATD is as effective for teaching and retaining instrument flight skills as more traditional flight training devices (FTDs).

However, the FAA remains resistive to allowing the growth of PCATD use in FAA approved flight education curricula (Williams, 1994). According to Williams (1994), the FAA considers the scientific evaluation of PCATDs to lack a clear evaluation of the effective transfer of aircraft skills that has been validated for other FAA approved FTDs. However, due to continued lobbying by PCATD manufacturers, the FAA in 1997 did allow for the limited use of PCATDs in FAA approved flight training programs, albeit not to the same amount the FAA had previously approved for traditional FTDs.

Purpose of Study

The purpose of this study was to provide additional evidence to the FAA concerning the benefits PCATD and FTD simulations of instrument flight procedures to maintain instrument pilot proficiency as defined in the Federal Aviation Regulations (FARs). Such evidence is in the form of a comparison based on a statistical analysis of the effectiveness of a PCATD and FTD at improving pilot instrument proficiency on Instrument Landing System (ILS) approaches. Proficiency was based on the standards established by the FAA for an Airline Transport Pilot (ATP) Certificate. These standards, quantitative in nature, represent a positivist theoretical approach to this subject and a valid indication of the proficiency an instrument pilot may maintain by participating in terminal instrument simulation lessons in either a PCATD or an FTD.

Background

Simulation as a Learning Game

There is a significant amount of literature citing the effectiveness of students learning from games. In 1971, Fletcher (as cited in Roberts, 1976) found that "games were successful teaching devices" (p. 5). Also in 1971, Fletcher (as cited in Roberts, 1976) demonstrated that a student's learning of companion factual knowledge increased because of the increased motivation of gaming.

To compare aviation simulation with the research into the effectiveness of computer gaming, one must focus on literature validating the effectiveness of non-role-playing computer games. In particular, Roberts (1976) suggested that non-role-playing computer games focus on learning objectives that improve decision-making and problem-solving skills. There is also a link, according to Pillay (2003), that the closer the computer-based game task matches the target task, the more likely it is that a positive learning effect will occur. Specifically, Pillay (2003) found that one particular gaming activity showed significant difference between groups that used computer gaming and those that did not, $F\ (2, 33) = 5.798$, $p < .05$. Therefore, she suggested that playing computer games increases the efficiency in accomplishing a set of educational tasks and obtains correct solutions, suggesting the match between the learning and the target task is the positive effect of this learning activity. Additionally, Amory, Naicker, Vincent, and Adams (1999) suggested that the most important element of computer gaming is how logic, memory, and visualization combine to improve student problem-solving abilities.

Simulation as a Computer Game

The introduction of computer gaming that simulates the actual flight conditions a pilot can experience are a natural extension of computer game playing for educational purposes. The military, which began simulation, albeit in a rudimentary fashion with the "blue canoe" as earlier referenced, quickly adapted the efficiency, power, and flexibility of modern computer software and hardware for use in its flight education programs. This activity was quickly adopted by commercial airline education programs as this industry began to operate its own versions of high performance jet aircraft as well as general aviation, the population that operates less sophisticated propeller aircraft.

In 1971, Roscoe studied the degree to which a task learned in a simulator could be interpolated to other learning, to an aircraft for instance, specifically when comparing the rate of transfer of learning to a control group with no previous training. Roscoe also found that the transfer effectiveness of simulation differs for the types of training accomplished; simulation that may be ineffective for pre-solo training is effective for instrument and cross country training. In 1990, Lintern, Roscoe, and Sivier studied the use of simulators to transfer visual maneuvers, finding "skills learned in the simulator are relevant to real flight and that instructional procedures . . . are likely to . . . transfer to the control of an airplane" (p. 302).

Numerous researchers have studied the effectiveness of computer-based aviation training devices (Taylor et al., 1996; Taylor et al., 1997; Taylor et al., 2003). Such research efforts culminated with the investigation of PCATDs, FTDs, and airplanes at preparing a pilot to satisfy the requirements of an FAA Instrument Proficiency Check (Taylor et al., 2003; Taylor et al., 2004). The performance of subjects from the PCATD group was statistically indistinguishable from the FTD group: specifically for indicated airspeed control, $F(1, 160) = 8.77$, $p < .005$; specifically for glide slope control, $F(1, 162) = 86.45$, $p < .001$; specifically for course direction, $F(1, 161) = 48.92$, $p < .001$. The Taylor et al. (2003) study concluded that the FAA should permit instrument rated pilots to use either PCATDs or FTDs to maintain instrument proficiency. In addition, since the study found the effectiveness of training in a PCATD to be equivalent to that of an FTD for instrument tasks, the researchers also recommended that the FAA investigate the use of PCATDs and FTDs for administering Instrument Proficiency Check flight evaluations.

Significant literature also exists to attest to the effectiveness of simulation training in realistically representing actual aircraft operations. Koonce and Bramble in 1998 (as cited in Taylor et al., 2003) provided an overview study of the efficiency, cost benefits, and transfer of training benefits of flight simulation activities. Studies by Dennis in 1994, Ortiz in 1994, and Phillips, Hulin, and Lamermayer in 1993 found evidence of the positive transfer of training from desktop computers to the airplane, but these studies were limited in empirical scope (as cited in Taylor et al., 2003). Hampton, Moroney, Kirton, and Biers in 1994 reported that students trained on PCATDs performed as well on instrument procedures in the airplane as did students trained on traditional FTDs; however, no control group was used in this experimental design (as cited in Taylor et al., 2003). Taylor, Lintern, Hulin, Talleur, Emanuel, and Phillips conducted a study to determine the extent of PCATD transfer of training in instrument skills and found that the PCATD was effective for teaching instrument tasks (as cited in Taylor et al., 2003). A follow-up study in 2001 by this same group indicated the effectiveness of incremental training in a PCATD, showing it was effective in teaching basic instrument tasks to private pilots (as cited in Taylor et al., 2003).

Steven Hampton of Embry Riddle Aeronautical University studied PC-based simulation effectiveness in training private pilot candidates in 1991. He cited a study by Caro in 1972 that showed simulators were effective in transferring trained skills to the aircraft. He cited Gerhard's 1983 study that determined that simulators reduce training costs and provide an inherently safe learning environment for pilot training. Hampton's own study indicated that PC-based simulation was as effective as FTD training, $F(2, 27) = 3.27$, $p < .05$.

Finally, Johnson and Stewart (2002) of the U.S. Army Research Institute investigated the effectiveness of a PCATD at improving helicopter training processes. Their study of 16 aviators utilizing a utility method of inquiry found that the "micro-computer was valuable in supporting the training of navigation instruments and procedures" (p. 13); nonparametric: Sign test $N = 6$, $\chi = 0$, $p < .02$ for experienced aviators; nonparametric: Sign test, $N = 10$, $\chi = 0$, $p < .001$ for student aviators.

Participants

The participants of this investigation included 63 general aviation pilots who held at least an FAA Private Pilot Certificate with an instrument rating and who were randomly selected from an FAA database of pilots in the northwest Ohio region. As Taylor et al. (2003) used University of Illinois facilities to study the effectiveness of PCATDs and FTDs, a convenience sample was necessary because the PCATD and FTD simulations used in this study occurred on the Bowling Green State University (BGSU) campus. Although the selection process was primarily based on convenience, the researcher utilized suggestions by Watters and Biernacki (1989) to target this population. According to Watters and Biernacki, target sampling is a "purposeful, systematic method by which a controlled list of specific populations within a geographic area are recruited" (p. 420). They are not random samples but reflect "a strategy to obtain systematic information when true random sampling is not feasible" (p. 420). O'Connell (2000) added that a targeted sample selects participants with "specific attributes important to the subject under study" (p. 223), in this study pilots with instrument ratings. She concluded that such a sample represents "a useful methodology for constructing replicable samples . . . that maintains a strong congruence to the targeted population" (p. 224).

To increase the validity of this nonprobable sample, the researcher utilized random number generating software to identify the target sample from the FAA database. According to O'Connell (2000), the use of randomization can strengthen the validity of study results. Randomization also tends to "balance out the effects of extraneous factors evenly across groups and offers protections against threats to internal validity" (p. 228).

To increase the "causal inferences from extraneous assumptions" (Wilkinson, 1999, ¶ 13) of this sample, the researcher randomly assigned the simulation device each participant used during the study. Wilkinson noted that randomization assists in controlling for bias and extraneous variables.

Methodology

This study represents an experimental examination of pilot proficiency. The study utilized an "in simulator" evaluation process. Participants' ability to perform a task was evaluated during a pre-test, then participants were allowed to practice the task, and subsequently participants accomplished a posttest assessment as compared against a control group. Lintern, Roscoe, and Sivier (as cited in Bell & Waag, 1998) considered this type of study to be the only means to effectively analyze training effectiveness because it controls the costs and nature of the training tasks.

First, a pilot study was accomplished to validate the initial instrument procedures utilized to assess participant proficiency, test simulation devices for accuracy and reliability, and establish a research protocol for the study. The primary investigation continued by randomly assigning participants into two random groups. The types of maneuvers flown in this investigation were maneuvers commonly accomplished by instrument rated pilots flying an Instrument Landing System (ILS) terminal instrument approach. Ten specific variables that are accomplished during instrument approach procedures were assessed by the instructor and graded according to the FAA's ATP Practical Test Standards.

In this study, the first randomly assigned group of participants, Group A, accomplished a 15-minute practice session to familiarize themselves with the simulation device they were going to practice instrument procedures in, the FAA approved FTD. Participants from Group A were then given four 20-minute lessons of ILS instrument procedures practice in the FTD, consisting of the primary instrument flight maneuvers they would commonly perform during flight. Assessment of instrument proficiency to ATP standards occurred in Lesson 2 and then again in Lesson 5, utilizing a standardized grading profile.

The second randomly assigned group of participants, Group B, also accomplished the same 15-minute practice session to familiarize themselves with the simulation device they were going to practice instrument procedures in, for this group the PCATD. This group then accomplished the same set of 20-minute simulation lessons of instrument procedures as Group A, specifically Lessons 2, 3, 4, and 5. An assessment of initial instrument proficiency was accomplished during Lesson 2 and documented on the assessment profile. These participants were then asked to accomplish the same 20-minute final assessment of their instrument flight proficiency (Lesson 5) using the FTD. The study utilized the FTD for this final assessment in both groups because the FTD is the simulation device that is approved for practicing flight skills to maintain instrument proficiency by the FAA and represents the device to which the level of proficiency gained in the PCATD is to be compared.

Statistical analysis was performed to compare the level of proficiency improvement between the second lesson and fifth lesson for both participant groups. A statistical analysis compared the improvement of Group A with that of Group B, the participants who used the PCATD to practice instrument proficiency. This analysis identified if (a) both simulation devices were effective at improving the instrument proficiency of participants, and if so, (b) was one simulation device more effective in improving the instrument proficiency of pilots than the other.

Data Analysis

The pool of participants was very diverse, ranging from professional airline pilots who had numerous hours of multiengine simulated aircraft operations in very sophisticated aircraft simulation devices and who routinely flew commercial aircraft in instrument flight conditions to single engine aircraft, general aviation pilots who had never flown a simulation device before. Table 1 identifies pertinent demographic information concerning the participant pool. Nearly one fourth of the participants had significant flight experience, having logged more then 1,500 hours of total flight time. However, almost one third of the participant pool had very little actual instrument flight experience, less than 10 hours logged. Almost one half of the pool had very little simulated flight experience, which was expected from a pool of general aviation instrument pilots. Participants were evenly divided in flight experience in the last year, with participants having a good level of instrument approach experience in the last 12 months.

Table 1. *Demographics of Participants*

Flight Experience of Participants	% of Participants
Total flight experience <250 hours	17
Total flight experience >1500 hours	24
Actual instrument flight experience <10 hours	32
Actual instrument flight experience >250 hours	16
Simulator experience <10 hours	41
Simulator experience >250 hours	11
Flight experience (last year) <10 hours	14
Flight experience (last year) >250 hours	17
Instrument approaches (last 6 months) <3	24
Instrument approaches (last 6 months) >12	47

Table 2 summarizes the Kruskal-Wallis test comparing the effectiveness of each simulation device at maintaining instrument proficiency. Chi-square statistics indicate no significant difference between the control and treatment groups for any of the pilot instrument flight skills. Skills that showed the greatest group differences in mean ranks included the following: intercept glideslope, $\chi^2(1, N = 63) = 2.379$, $p = .123$; altitude, $\chi^2 (1, N = 63) = 1.879$, $p = .170$; and airspeed, $\chi^2 (1, N = 63) = 1.723$, $p = .189$.

Table 2. Results of the Kruskal-Wallis Test and Median Test

Skill	Control Group > Md Freq	Control Group Mn Rank	Treatment Group > Md Freq	Treatment Group Mn Rank	χ^2	*p*
Airspeed	16	34.7	11	29.1	1.72	.18
Altitude	11	29.0	15	35.0	1.87	.17
Attitude	0	30.5	5	33.4	0.47	.49
Nav track	16	33.9	11	30.0	0.94	.33
Pro Turn	11	31.5	13	32.5	0.05	.81
Inter Loc	12	30.8	13	33.1	0.27	.59
Inte Glid	14	35.2	10	28.6	2.37	.12
Acc ILS	3	33.9	3	30.0	0.84	.35
Mis Ap	16	33.7	10	30.1	0.71	.39
ATP Sd	15	32.3	12	31.6	0.03	.85
Tot gain	18	33.6	11	30.2	0.5	.46

Skills that showed the greatest group difference above the median for the control group were airspeed, navaid tracking, intercept glideslope, missed approach, performance to ATP standards, and total gain. The skills that showed the greatest group difference above the median for the treatment group were altitude, procedure turn, intercept localizer, and performance to ATP standards.

A *t* test of independent samples was conducted to identify differences in the groups by the overall gain in scores by flight simulation device. The gain in scores by median, mean, and standard deviation is summarized in Table 3. The test showed no statistical significance, $t(61) = 2.45$, $p = .807$, in the overall gain in flight skills.

Table 3. Gain in Skills—Median, Mean, and Standard Deviation

	Control Group			Treatment Group		
Skill	Md	Mn	*SD*	Md	Mn	*SD*
Airspeed	0.50	0.43	0.71	0.00	0.19	0.70
Altitude	0.00	0.09	0.77	0.00	0.35	0.83
Attitude	1.00	0.53	0.56	1.00	0.70	0.73
Nav track	0.50	0.53	0.56	0.00	0.41	0.62
Pro Turn	0.00	0.43	0.80	0.00	0.45	0.85
Inter loc	0.00	0.34	1.00	0.00	0.48	1.06
Inter Glid	0.00	0.31	0.73	0.00	0.03	1.01
Acc ILS	1.00	0.65	0.78	0.00	0.48	0.88
Mis Ap	0.50	0.40	0.66	0.00	0.35	0.95
ATP Sd	0.00	0.40	0.71	0.00	0.41	0.76
Tot gain	4.00	4.15	4.25	2.00	3.87	4.97

Conclusion

Feedback provided by participants indicated that 75% of participants *strongly agreed* that simulation is important in retaining instrument proficiency; another 21% *agreed* with that statement. Lintern et al. in 1990 reported that flight skills learned in a simulator are relevant to real flight in an aircraft and therefore are transferable to the aircraft. Again, participants appear to agree with Lintern et al. that learning took place in the simulator devices. Eighty-six percent of participants thought that their ability to fly an ILS approach improved. This improvement was closely followed by 84% of participants believing that their interception of a localizer course, a critical flight skill for accomplishing an ILS, improved. Other instrument skills that participants believed improved were navigation tracking, intercepting a glideslope, and accomplishing a procedure turn. Accomplishing a missed approach showed the lowest level of improvement, but still over one half of the participants in this study thought that their instrument flight skills improved on this task. Concurring with Lintern et al., participants responded that their flight skills improved and will be transferable to aircraft operations.

This study was accomplished to provide supplemental validation of the results Embry Riddle Aeronautical University, the University of Illinois, and others have provided to the FAA as evidence of PCATD effectiveness. In particular, this study assessed the effectiveness of a PCATD with that of an FAA approved FTD at maintaining a pilot's proficiency for accomplishing an ILS approach. Results indicated that there is no statistically significant difference in the devices. When considering whether one device is more effective at maintaining pilot instrument proficiency, again the study indicated that there is no statistical difference in either device.

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