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Winter 2005

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Ryan Olson

John Austin

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### Scholarly Commons Citation

Olson, R., & Austin, J. (2005). A Step Toward Early PC-Based Training That Reduces Risk: The Effects of Practicing an “Instrument Referenced” Skill Pattern on “Visually Referenced” Performance of Beginning Flight Students. *Journal of Aviation/Aerospace Education & Research*, 14(2). <https://doi.org/10.15394/jaaer.2005.1523>

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**A STEP TOWARD EARLY PC-BASED TRAINING THAT REDUCES RISK:  
THE EFFECTS OF PRACTICING AN "INSTRUMENT REFERENCED" SKILL PATTERN  
ON "VISUALLY REFERENCED" PERFORMANCE OF BEGINNING FLIGHT STUDENTS**

Ryan Olson and John Austin

**ABSTRACT**

A matched pairs design was used to evaluate the effects of instrument referenced skill pattern practice on a Personal Computer-Based Aviation Training Device (PCATD) on beginning flight student performance in the field ( $N = 28$ ). Approximately three hours of experimental training was administered by a certified flight instructor between students' first and ninth flight hours, with each student completing six skill pattern trials. The treatment group ( $n = 14$ ) performed better than the control group ( $n = 13$ ) on every dependent measure, with a mean effect size of .35. Statistical tests on mean differences were inconclusive, but the favorable effect sizes and absence of negative transfer should encourage scientists and practitioners to expand the use of PCATDs to improve learning and safety among beginning flight students.

Personal computer (PC) -based technology for teaching aviation-related skills is steadily growing in both quality and quantity. People interested in aviation can buy increasingly affordable and sophisticated aviation related software and control interfaces for PCs. Just a few examples include joysticks that provide "force feedback" by vibrating under certain conditions, the ability to "fly" multiple types of aircraft and select from multiple views of the flying experience, and the emergence of satellite-based geographical terrain imagery. However, PC-based aviation training devices (PCATDs) that meet Federal Aviation Administration (FAA) software and hardware standards for use in formal flight instruction may only be used for a maximum of four hours of instrument training applied toward earning an instrument flight rules (IFR) rating (Federal Aviation Administration, 1997).

Conservative policies regarding the use of PCATDs are appropriate while we experiment with such technologies and evaluate the effectiveness of potential applications. However, PC-aided and PC-based training should expand beyond instrument training as we discover areas of application that improve student learning, reduce cost, and increase safety. We will, no doubt, also discover limitations in the effectiveness of supplemental PC-based training for flight students. One possible type of limitation is that some skills learned on PCATDs could interfere with rather than enhance student performance in the field (i.e., negative or undesirable transfer of training). However, we should not let fears about the limits of PC-based technology prevent us from developing potentially life saving applications.

The guiding vision for the current study was to contribute to the eventual development of PC-based training modules that reduce the risk of accidents and incidents among beginning flight students. As an exploratory step toward this kind of training, we evaluated the effects of early supplemental PCATD training on student performance during the first semester of flight training. The training occurred between students' first and ninth flight hours, and involved practicing an instrument referenced "skill pattern." The skill pattern condition was a replication of a condition from a previous study conducted by Lintern, Taylor, Koonce, Kaiser, and Morrison (1997), where beginning students appeared to benefit from the treatment. The effects of the independent variable were assessed using a variety of measures of student performance in the field.

***Why Focus on Beginning Flight Students?***

An analysis of historical accidents and incidents at the organization participating in this study revealed that the majority of such occurrences happened during the landing stage of flight and involved solo student pilots with 30 or fewer hours of total flying experience (Olson, Rantz, & Dickinson, 2001). Most flight training professionals would not be surprised by these data, and other flight schools would likely observe similar patterns in their own historical records. The bottom line is that learning to fly is inherently risky, and students may be exposed to an elevated level of risk during their first several months in the air.

Teaching a student pilot an effective professional flying repertoire is a complicated process, and flight training professionals generally attend to each phase of flight

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instruction with care. However, the progress and performance of beginning flight students is not always given the extra special attention it deserves. From an empirical perspective, flight schools are likely to benefit from paying special attention to this phase of flight and to particular variables implicated as “hot spots” in historical accident, incident, and occurrence analyses (Rantz, Olson, & Dickinson, 2001). With regard to the occurrence pattern discussed above, maximally effective risk management practices would begin by ensuring that policies and procedures governing solo flights have been expertly designed and rigorously implemented. In addition, flight schools might (1) expand data collection on student landing performance, (2) conduct more problem-solving regarding instructional design and student learning, and (3) invest in research programs to explore the effectiveness of innovative training strategies for beginning students. While the organization participating in the current study has invested in all of these areas, the current project was most directly related to the third strategy.

**Why PCATDs?**

The previous section highlighted the challenge of helping novice pilots become experts as quickly as possible while simultaneously minimizing risk. One option for improving students' learning in this fashion is to provide them with early simulated landing practice in Flight Training Devices (FTDs). For example, there is evidence that simulated landing practice in FTDs can reduce the number of landings practiced by students prior to their first solo flights (e.g., Lintern, Roscoe, Koonce, & Segal, 1990). However, FTDs are expensive and not always available to students, and, even when they are available, training slots for beginning flight students can be limited.

The growing quality of PC-based technology offers opportunities to develop supplemental training for beginning flight students that is more affordable and widely available than FTD-based training, thereby enabling greater potential impact on the learning and safety of entire cohorts of students. For this reason, we believe it is important for scientists and practitioners to explore PC-based training applications that move beyond their typical use as supplemental IFR trainers.

**Development of the PCATD Training Condition for the Current Study**

While investigating the effects of various combinations of visual scene detail and augmentation in combination with various amounts of simulated landing practice for beginning flight students, Lintern Taylor, Koonce, Kaiser, and Morrison (1997) used a control group that practiced an instrument or non-visual skill pattern. It was reported that students in both the landing practice groups and the skill pattern group attempted essentially the same number of landings prior to their first solo flights [i.e., there was not a statistically significant difference between

groups  $F(3,66) = 1.371, p = .259$ ]. If the skill pattern condition was actually inert, this result would suggest that simulated landing practice did not benefit participants, which was contrary to evidence from previous research. However, in an earlier study, Lintern, Roscoe, Koonce, and Segal (1990) included a control group that had no simulation practice of any kind. Lintern, et al. (1997) found that the difference between pre-solo student attempted landings in the 1990 control group ( $n = 16, M = 73.44$ ) and the 1997 skill pattern group ( $n = 17, M = 52.35$ ) was statistically significant ( $t(31) = 4.21, p < .001$ ). The authors concluded, since the setting and general training environment for both studies were essentially the same, that the skill pattern practice must have taught skills that were generally beneficial for beginning flight students. Lintern, et al. (1997) recognized that this phenomenon had been observed before, citing studies by Ritchie and Hanes (1964) and Ritchie and Michael (1955) as early examples. While we were cautious about the validity of comparing groups from different studies, the possibility that the “instrument referenced” skill pattern improved so called “visually referenced” student performance in the field was intriguing, and, in our view, worthy of an empirical replication.

The skill pattern condition in Lintern, et al. (1997) was conducted with custom built FTDs rather than PCATDs. However, empirical evidence suggests that the skill pattern condition could be functionally replicated with a PCATD. In an FAA Advisory Circular approving PCATDs for instrument flight training, the author(s) wrote:

A study conducted by the University of Illinois, titled “Transfer of Training Effectiveness of Personal Computer-Based Aviation Training Devices: Final Report,” dated October 1996, examined each task addressed in this [Advisory Circular]. The director of the study affirmed that all instrument training tasks allowed by this [Advisory Circular] have a positive transfer effectiveness, or no statistically significant negative transfer effectiveness. Given this background, the FAA has determined that there is sufficient justification to allow the use of PCATD's meeting acceptable standards as creditable devices for meeting some of the training requirements for an instrument rating under the applicable provisions of part 61 or part 141. (p. 2)

Given the evidence for the effectiveness of PCATDs for teaching a range of instrument-related tasks, we believed that the FTD-based skill pattern practice provided in Lintern et al. (1997) could be functionally replicated with a PCATD. The primary purpose of the current study was to replicate the Lintern, et al. (1997) skill

pattern condition with a PCATD and evaluate its effects on the performance of beginning flight students. In addition, this experiment was viewed as a step toward intentionally designing supplemental PC-based instruction to improve learning and safety among cohorts of beginning flight students.

## METHOD

### *Hypotheses*

For the experimental manipulation in the current study, the null hypothesis was that skill pattern practice on a PCATD would have no effect on the performance of beginning flight students. In other words, this hypothesis stated that in the population from which the current sample was drawn, the mean difference between treatment and control groups on any given performance measure is actually zero ( $H_0: \mu_1 = \mu_2$ ). The alternative hypothesis was that skill pattern practice on a PCATD would have an effect on the performance of beginning flight students. In other words, this hypothesis stated that in the population from which the current sample was drawn, the mean difference between treatment and control groups on any given performance measure is not zero ( $H_1: \mu_1 \neq \mu_2$ ). This non-directional alternative hypothesis would allow us to reject the null hypothesis even if our treatment group happened to perform worse than the control group.

We felt that a conservative non-directional hypothesis was appropriate because Lintern, et al. (1997) had obtained their results using an FTD for training rather than a PCATD. However, the direction of the results observed by Lintern et al. in (1997) caused us to favor the prediction that the treatment group would perform better than the control group on one or more performance measures.

### *Participants and Setting*

The participating university-based flight school, referred to hereafter as the participating organization (PO), had nearly 900 students enrolled in its various training programs at the time of the study. These programs included four-year bachelor's degrees in Aviation Flight Science, Aviation Maintenance Technology, and Aviation Science and Administration. The Aviation Flight Science program operated as a Pilot Training School under Federal Aviation Regulations Part 141 (Federal Aviation Administration, 2001a). In addition to these degree programs, the PO operated an International Pilot Training Centre that trained cadets for employment as commercial pilots with major airlines using an accelerated 14 month training program (i.e., an "ab initio" or "from the beginning" style syllabus).

Participants were recruited from the Aviation Flight

Science bachelor's degree program on the first day of their first professional flight course using an informed consent process approved by the relevant Human Subjects Institutional Review Board<sup>1</sup>. Pre-solo students with ten or fewer officially logged flight hours were eligible to participate, and the majority of eligible students consented ( $N = 28$ , 24 Male, 4 Female, Mean age = 21.2 years). Background information was collected from participants at that time, including hours of previous flying experience and estimates of previous aviation related PC gaming experience.

### *Experimental Design*

A matched-pairs research design was used to maximize experimental power. The primary matching variable was average student rankings on scores contributing to the Speed and Working Memory (SWM) factor of the CogScreen Aeromedical Edition™ (CSAE) test, which is a computer administered and scored test of cognitive abilities that is related to aviation performance (Kay, 1995). The SWM factor of the CSAE was delineated by Taylor, O'Hara, Mumenthaler, and Yesavage (2000), who used principal components analysis to create a set of five factors from among the 65 raw scores produced by the test. The SWM factor was chosen as a matching variable because Taylor, et al. (2000) found that it had the highest correlation with participant performance summary scores on a jet simulator task (Spearman  $r = 0.57$ ). In addition to pairing students on the basis of CSAE scores, reported previous flight and PC experience was taken into consideration when average CSAE ranks were similar.

To control for differential teaching effectiveness, as many students as possible were assigned to instructors as intact pairs, with individual instructors being assigned a maximum of two research pairs (four participating students). After scheduling challenges were addressed, 10 of the 14 total pairs shared the same instructor. One member of each pair was then randomly assigned to the treatment condition, and participants were contacted by e-mail and/or telephone by the first author and informed of their group assignment and responsibilities. When participants were informed of their group assignment, they were also asked not to divulge their group membership to instructors. Flight instructors at the PO were encouraged by memo not to inquire about whether or not their students were participating in the study.

### *Experimental Laboratory and Equipment*

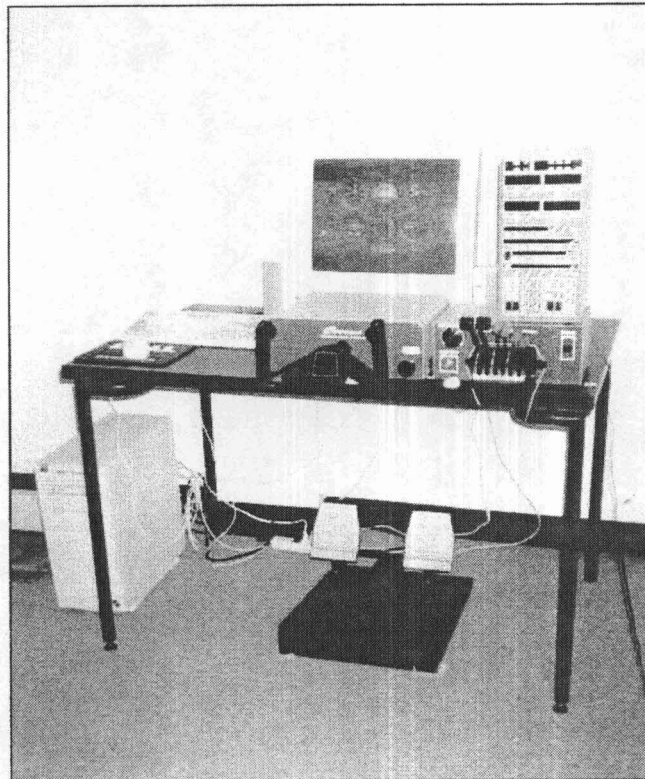
The experimental training was conducted in a laboratory room 2.60m high, 2.44m wide, and 3.51m long, equipped with a remote controlled camera mounted in an upper corner of the room. The PC used as the base

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configuration for the PCATD was equipped with a Pentium II® 300 megahertz processor, 4 megabytes of SGRAM video memory, and 64 megabytes of SDRAM memory. Other PC related hardware included a Dell QuietKey® keyboard, a traditional style roller-ball mouse, a monitor (actual screen size 27.61cm high X 36.20cm wide), and two JUSTer® SP-660 3D speakers. Relevant software included Windows 95® and OnTop® IFR Proficiency Simulator version 6.0. All other equipment used to configure the PC as an FAA approved PCATD was manufactured by Precision Flight Controls® and included a Cirrus yoke, a throttle quadrant, an avionics panel, and rudder pedals.

The keyboard, mouse, monitor, speakers, yoke, throttle quadrant, and avionics panel were assembled on a

table 76.20cm high, 76.20cm deep, and 121.92cm wide. The yoke was secured in place using plastic brackets mounted to the table to prevent drift or sliding during manipulation. The monitor was placed directly behind the yoke. The throttle quadrant was placed to the right of the yoke with the avionics panel resting on top of it. The rudder pedals were attached to the carpeted floor with Velcro™ directly below the yoke, with the pedals positioned 33.00cm deep from the front of the table. Two cushioned office-style chairs were used for the set up with adjustable seat height, backrest position, seat pitch, and armrest height. See Figure 1 to view a photograph of the training set up.



*Figure 1. PCATD Station*

### **Independent Variable**

The PCATD training was administered by a certified flight instructor (CFI) at the PO, hereafter referred to as the treatment instructor (TI), who was not the primary instructor for any beginning flight students during the semester of the study (Female; age 29). The training took place during the first two months of a winter semester between each student's first and ninth flight hours at the PO. The TI was paid with funds obtained through small research grants according to her current PO pay rate (\$14.00 per hour). Treatment participants were not paid. The PCATD training was administered across two sessions of approximately 1.5 hours each. Exceptions to this rule included one participant who completed the training across three sessions, and two participants who were both permitted to complete all six trials in one session due to extreme scheduling challenges.

The training resembled the skill-pattern practice condition described by Lintern, Taylor, Koonce, Kaiser, and Morrison (1997) as closely as possible. Lintern, et al. (1997) wrote that a skill-pattern practice trial required students to perform "...a takeoff and then engage in a series of precision constant-altitude turns, descending and climbing turns, and speed changes. The task then ended with VOR (very high frequency omni range) tracking for 3 minutes" (p. 154). Lintern, et al. (1997) reported that one trial of the skill pattern required approximately 25 minutes to complete. Don Talluer, a faculty member at the University of Illinois at Urbana-Champaign who assisted in the Lintern, et al. (1997) study, provided additional information on this skill pattern condition (D. Talluer, personal communication, November 11, 2001). He wrote that the pattern closely resembled a standard type A pattern from lesson 15 of the *Instrument Flying Handbook* (U.S.

Department of Transportation & Federal Aviation Administration, 1980). Differences between the skill pattern used in Lintern et al. (1997) and the *Instrument Flying Handbook* (U.S. Department of Transportation & Federal Aviation Administration, 1980) included replacing some of the straight and level turns with climbing and descending turns. Talluer also reported that full flight instruction was provided for participants during the skill pattern training sessions.

Based on the information gathered from Lintern et al. (1997) and from Talluer (2001), a protocol for the treatment condition in the current study was developed by the first author and the TI. The skill pattern was based directly on pattern A from the previous version of the *Instrument Flying Handbook* (1980) and included 16 phases or legs. The second turn of pattern A was replaced with a climbing turn at 500 feet per minute and the sixth turn was replaced with a descending turn at 500 feet per minute. No changes were made to the timing of skill pattern legs. In accordance with the skill pattern activity reported by Lintern, et al. (1997), each trial began with the student performing a take off and ended with three minutes of VOR tracking. A complete trial required 21 minutes and 45 seconds to complete. For the simulated take off, a runway at the host airport was programmed, and participants were allowed four minutes to climb to 3000 feet above sea level and establish normal cruise speed. The VOR for a nearby airport was used for VOR tracking and began 30 seconds after the last timed turn had been completed. Visually referenced flying was prevented by programming OnTop® to generate clouds with bases of 2000 feet and ceilings of 5000 feet. Winds were programmed at zero. See Figure 2 to view a diagram of the experimental version of pattern A.



A timer on the OnTop® instrument panel was started at the beginning of each skill pattern trial by the TI and was used by both the TI and participants to track leg changes. The TI announced the type and duration of the upcoming skill pattern leg to participants several seconds in advance. At the conclusion of each leg, participants were generally prompted by the TI to correct any deviations from performance targets and/or praised for meeting or maintaining performance targets.

*Performance targets during the skill pattern condition.* Based on the initial heading of 230 degrees of the runway used for the simulated takeoff, the author and the TI established target headings for each leg of the pattern. Target altitudes were established by requiring participants to begin the pattern at 3000 feet above sea level. With climbing and descending rates established at 500 feet per minute, altitude targets alternated between 3000 and 3500 feet, depending upon the leg of the pattern. Normal and low cruise rates were established as 2200 engine revolutions per minute (rpms) and 1900 rpms respectively. These rpms were derived from PO standards for operating a Cessna 172R single engine aircraft.

*Measures of performance during PCATD training sessions.* Deviations from performance targets during each participant's six skill pattern trials were measured by the TI using a paper data sheet due to the data collection limitations of OnTop® 6.0 (e.g., the instrument panel is not visible when saved OnTop® flights are replayed and the graphic display of performance parameters does not include time hatch marks on the abscissa). During the first several seconds of a new leg, the TI recorded altitude, heading, and engine rpm for each participant from the instruments displayed on the monitor. The video camera in the laboratory was focused on the PCATD monitor, and the first author or a research assistant simultaneously recorded the same measures for 30% of the skill pattern trials from a remote observation room to assess reliability.

*PCATD participant survey.* A survey was administered to the 14 treatment participants by e-mail after the PCATD training was completed. All 14 participants responded to the survey, which included Likert-type and open-ended questions about their experience in the training condition and their opinions about its effects.

#### ***Dependent Measures in the Field***

Existing records and databases at the PO were used to collect performance measures. The first category of performance measures were estimates of the efficiency of student progress through the flight lessons and were calculated for each student by computing ratios of the absolute number of lessons completed versus the total number of training flights completed at different points in time during the semester. Ratios were computed at the following four points in time: (1) the first successful progress check (progress ratios), (2) the first solo flight (solo

ratios), (3) week eight of the semester (week eight ratios), and (4) at the end of the semester (end ratios). In addition to these measures, both the number of flight hours logged and the number of landings practiced by students prior to accomplishing progress checks and solo flights were counted, resulting in the following four additional measures: (5) pre-progress check hours, (6) pre-progress check landings, (7) pre-solo hours, and (8) pre-solo landings. Pre-progress check and pre-solo measures were redundant to some extent because a successful progress check was required before a student could be cleared for a first solo flight. However, all measures will be reported and analyzed here due to the exploratory nature of the study.

*Additional landing measures.* At the time the project was taking place, all beginning flight students (including both treatment and control group participants from the current study) and their instructors were simultaneously participating in a data collection procedure regarding student landing performance as part of a more comprehensive risk management initiative at the PO. The primary aspect of this measurement system required both instructors and students to rate the last student landing of each training flight across twelve dimensions of performance. In general, each performance dimension was rated as meeting performance standards or deviating from them in a specific fashion (i.e., errors). This system is mentioned briefly here because it allowed us to compare general patterns in landing errors across groups in the current study.

## **RESULTS**

### *Performance During PCATD Training*

As described in the Method section, altitude, heading, and engine rpm were collected in vivo by the IT during PCATD training sessions. Engine rpms did not vary enough to warrant analysis. Patterns in altitude and heading deviations are discussed below.

*Group absolute deviations from heading and altitude targets by trials.* For the treatment group ( $n = 14$ ), mean absolute deviations from altitude targets in feet and variability in altitude performance generally decreased across trials. Variability in the data also generally decreased across trials. An ANOVA of altitude deviations was statistically significant,  $F(5, 1241) = 4.945$ ,  $p = .000$ , with Tukey multiple comparison tests finding significant differences between trials 1 and 5 ( $p = .026$ ), 1 and 6 ( $p = .000$ ), and 2 and 6 ( $p = .003$ ). Regression analyses were not conducted due to the heterogeneous variance across trials.

Mean absolute deviations from heading targets in degrees and variability in heading performance generally decreased across trials. An ANOVA computed for heading deviations was statistically significant,  $F(5, 665) = 12.824$ ,  $p = .000$ , with Tukey multiple comparison tests finding significant differences between trials 1 and 2 ( $p = .000$ ), 1 and 3 ( $p = .001$ ), 1 and 4 ( $p = .000$ ), 1 and 5 ( $p = .000$ ), 1 and 6 ( $p = .000$ ), and 3 and 6 ( $p = .048$ ). As with altitude



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deviations, Regression analyses were not conducted due to heterogeneous variance across trials.

Table 1

*Group Performance Across Skill Pattern Trials*

Trial	Heading Deviations in Degrees		Altitude Deviations in Feet	
	<i>MAD</i>	<i>SD</i>	<i>MAD</i>	<i>SD</i>
1	29.46	32.14	138.90	149.62
2	16.29	15.79	131.93	161.62
3	19.32	18.82	120.10	117.85
4	12.90	14.59	116.17	122.62
5	14.38	14.78	99.04	118.39
6	11.70	12.53	84.25	16.82

$n = 14$  for all trials; *MAD* = mean absolute deviations

**Reliability of heading and altitude measures.** Inter-observer agreement (IOA) percentages for heading and altitude measures were calculated by dividing the number of agreements by the number of agreements plus disagreements, and then multiplying the result by 100. For measures of altitude collected during PCATD trials, an observation was counted as an agreement if the secondary data collector's record was plus or minus 40 feet from the IT's record (the altimeter had minor and major tick marks, where the difference between minor tick marks was 20 feet). At this level of sensitivity, overall average IOA for altitude measures was 82.04% (range for separate legs of the skill pattern: 67.9% - 96.7%). For measures of heading, an observation was counted as an agreement if the secondary data collector's record was plus or minus 10 degrees from the IT's record (the heading indicator had major and minor tick marks, where the difference between major tick marks was 10 degrees). At this level of sensitivity, overall average IOA for heading measures was 93.34% (range for separate legs of the skill pattern: 83.3% - 96.7%).

**Survey Results**

All Likert-style questions were five point scales with five being the most favorable response. The results of the Likert-style survey questions indicated that students generally believed that their performance improved across

skill pattern trials ( $M = 4.4$ ). Participants also recommended PC-based training for other beginning students in the future ( $M = 4.0$ ). However, students generally felt that it was too early to judge whether the training positively impacted their performance in the field ( $M = 3.6$ ). In open ended questions, two students expressed feelings that the PCATD training created some negative transfer to their learning in the field, causing them to pay too much attention to their instrument panel during flight lessons. Many students reported that the most useful aspect of the instruction was learning how instruments worked together and/or practicing instrument related maneuvers, and that the least useful aspect of the training was the over-sensitivity or inaccurate feeling of the controls. Also, a female student who was considering quitting the flight program reported that the PCATD training had boosted her confidence and caused her to decide to continue with flight training.

**Between Groups Comparisons**

One participant dropped out of the flight program eight weeks into the semester, and at the conclusion of the semester, eight students had still not flown solo. After tracking participants for an additional month, five had still not flown solo. At that point in time, the window for analysis was closed due to inconsistent student flying during the summer and the growing temporal distance of the

performance from the experimental training condition.

The treatment group performed better on average on all dependent measures collected. However, none of the independent samples *t* tests on mean differences were statistically significant (*p* value range = .28 to .99). Given that the relatively small sample may have affected the statistical power of the study, it is useful to examine effect sizes, which transform mean differences into pooled

standard deviation units. Effect sizes ranged from .00 to .49 ( $M = .35$ ). According to Cohen's (1988, 1992) effect size conventions, .20, .50, and .80 effect sizes are considered small, medium, and large respectively. Table 2 summarizes treatment and control group means, standard deviations, *t* values, *p* values, and effect sizes for each of the dependent measures.

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Table 2

*Summary of Dependent Measures and Statistics for Treatment and Control Groups*

Measure and Group	<i>n</i>	<i>M</i>	<i>SD</i>	Min	Max	<i>t</i>	<i>p</i>	<i>d</i>
Pre-Progress Hours						1.07	.30	.46
Control	11	23.26	5.49	13.70	33.50			
Treatment	11	20.32	7.29	10.60	32.40			
						.99	.33	.42
Control	11	53.00	15.14	26.00	81.00			
Treatment	11	47.27	11.67	28.00	62.00			
						-1.10	.28	.49
Control	11	.37	.11	.26	.56			
Treatment	11	.43	.14	.27	.69			
						.79	.30	.33
Control	11	27.62	7.16	17.80	43.60			
Treatment	11	25.23	7.07	15.30	37.90			
						.63	.33	.26
Control	11	64.91	19.55	38.00	104.00			
Treatment	11	60.73	10.54	42.00	77.00			
						-1.04	.28	.48
Control	11	0.39	0.12	0.24	0.61			
Treatment	11	0.45	0.13	0.30	0.65			
						-0.12	.99	.00
Control	14	0.38	0.14	0.21	0.63			
Treatment	14	0.39	0.17	0.17	0.68			
						-0.85	.93	.36
End Ratios								
Control	13	.42	.12	.24	.59			
Treatment	14	.46	.10	.32	.60			

**Landing errors.** The control group averaged 4.18 ( $SD = 2.93$ ) errors per landing and the treatment group averaged 3.94 ( $SD = 2.97$ ) errors per landing. However, there was a negative linear relationship between number of errors per landing and measures of experience (e.g., flight lessons completed). Therefore, errors per landing were regressed on lesson numbers for each group instead of comparing means. For the control group  $F(1,236) = 26.77, p = .000$ , and the standardized slope of the regression line was  $-.33$ . For the treatment group  $F(1,240) = 33.03, p = .000$ , and the standardized slope of the regression line was  $-.35$ . These analyses indicated, once again, slight differences between groups in favor of the treatment condition (i.e., slightly steeper decline in error rate).

## DISCUSSION

### *Potential Practical Significance*

No meaningful negative transfer of training was observed, and the treatment group showed better average performance on all dependent measures. Although the results were not statistically significant, they may be practically significant if the favorable small to medium effect sizes are replicable across semesters. For example, the treatment group averaged approximately four fewer pre-solo landings and approximately two fewer pre-solo hours than the control group. The average number of landings practiced per training flight during the course of the study was 3.5, and the average length of a training flight was 1.5 hours. So, from a practical standpoint, a reduction in four landings practiced could translate into a savings of 1.5 hours of flight time for each student. Instruction and aircraft rental costs for a 1.5-hour instructional flight at the PO were approximately \$174.00 at the time of the study. Multiply this figure by a group of 40 beginning students, and the potential savings would be \$6,960.00 for the group minus the costs of PCATD training. Hypothetically, the savings for the PO would be in reduced time demands on the fleet (i.e., approximately 60 fewer hours per semester), and in reduced aggregate student error. There could be additional gains in efficiency and profitability if flight schools could utilize the added fleet time by training more students. If PCATD training was intentionally designed for greater impact, learning and safety benefits could be even greater than those observed in the current study.

### *Comparisons to Previous Relevant Research*

Actual mean differences in pre-solo landings between our groups were smaller in magnitude than those reported by Lintern and colleagues in previous relevant studies. Lintern, Roscoe, Koonce, and Segal (1990) reported a mean difference of nine pre-solo landings in favor of the

treatment group in an experiment evaluating simulated landing practice in FTDs, and Lintern, Taylor, Koonce, Kaiser, and Morrison in (1997) speculated about a mean difference of approximately 21 pre-solo landings between their skill pattern practice group and the control group from the earlier 1990 study. As discussed previously, we observed a mean difference of approximately four pre-solo landings. On the measure of pre-solo hours, however, the treatment group in the current study averaged approximately two fewer hours than the control group, which is more than twice as large as the difference observed by Lintern, Roscoe, Koonce, and Segal in 1990, who found a difference of only one hour between treatment and control groups on that measure.

### *Hypotheses and Future Directions*

In the Method section we proposed hypotheses about the effects of the skill pattern condition on the performance of beginning flight students, and as discussion points, it is worthwhile to consider to what extent each was supported by the data. As previously discussed, our null hypothesis was that the skill pattern practice condition would have no effect on performance in the field ( $H_0: \mu_1 = \mu_2$ ). Our alternative hypothesis was that the treatment condition would either cause worse performance in the field than the control condition (i.e., negative transfer of training) or better performance in the field than the control condition ( $H_1: \mu_1 \neq \mu_2$ ). We favored the "better performance" prediction.

Although we were not able to reject the null hypothesis based on the traditional cut off values for statistical significance, the small sample size may have resulted in lower than desired experimental power, which would have inflated the probability of making type II errors (i.e., incorrect retention of null hypotheses). An inflated type II error rate does not exclude the possibility that the favorable results we observed were simply due to random sampling variation, but it does invite a cautious attitude about statistical conclusions. In this light, we believe that the mean differences in performance in favor of the treatment group suggest that the alternative hypothesis should not be discarded.

With regard to the alternative hypothesis, we believe that the data do not support the notion that the skill pattern condition causes improvements in performance as large as those observed by Lintern, et al. (1997; e.g., 21 fewer pre-solo landings on average). It is possible that the potency of the skill pattern is greater when FTDs are used, or that we failed in some way to replicate some meaningful aspect of the training condition used by Lintern et al. (1997),

## *PCATDs and Beginning Students*

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but we think it is most probable that the PCATD skill pattern activity causes small-to-moderate improvements in beginning flight student performance. In fact, it would be surprising if beginning students did not benefit from an extra three hours of training with a CFI. Not only were mean differences in favor of the treatment group, but a visual inspection of variability in performance reveals generally better minimum and maximum scores in favor of the treatment group (see Table 2 to review performance data). These patterns could be due to random sampling variation, but the matched pairs research design should have minimized this concern. Given, the extent of our experimental control and the strong patterns in favor of the treatment group, we believe the best working hypothesis for future research is that the skill pattern causes some small but potentially practically significant improvements in performance. In this light, our results should be interpreted as promising but inconclusive pending replications of our obtained effect sizes.

### ***Designing PCATD Training for Higher Impact***

If the skill pattern activity is potent, the mechanisms by which it improves student performance in the field are unknown. The task overtly teaches skills related to instrument flying, but so far its potential benefits have been assessed using metrics more closely related to student landing skills. The main question is "how might the skill pattern task benefit beginning flight students?" In our view, the task could have taught (1) technical skills directly related to landing (e.g., directional control skills), (2) technical skills that were supportive or indirectly related to landing (e.g., instrument skills helping with base leg and final approach), or (3) cognitive skills or knowledge that indirectly supported performances we measured in the field (e.g., thinking or problem solving skills learned with the CFI). In addition, one or more of these types of knowledge and skill sets could have reduced cognitive workload in the air as new pilots attempted to manage the complexities of the flight environment.

In the absence of evidence suggesting large

performance improvement effects with the skill pattern activity, it may be wise to move toward designing PC-based training that intentionally targets repertoires relevant to the challenges faced by beginning students. In our opinion, several potential performance targets for PC-based training with beginning students are (1) teaching procedures relevant for beginning students, including those that are unique to the training airport and other frequently utilized facilities, (2) teaching knowledge of the local training area, including practice areas and major landmarks, (3) teaching basic directional control skills and familiarizing beginning students with the basic feel of and coordination among airplane control interfaces, and (4) teaching a select sample of instrument skills. Identifying possible target repertoires is, of course, only the first step toward designing PC-based training with high impact on beginning flight student performance. Success will also require effective instructional design and valid performance measures in the field.

### **CONCLUSION**

PC-based training for beginning flight students is an important potential tool for improving learning and safety in flight school environments. While some scientists and practitioners may be concerned about negative transfer while expanding PC-based training applications, we found no meaningful evidence for this concern in relation to our independent variable. To the contrary, we observed effects in favor of the treatment group that would be practically significant if replicable. In general, we hope this exploratory study functions as a stimulus for the development of PC-based training that is designed for high impact on beginning student performance in the field. Benefits of this type of instruction may be achieved directly through teaching technical skills or indirectly through teaching verbal and procedural repertoires that free cognitive resources during flight. What can and cannot be taught effectively using PC-based systems is ultimately an empirical question, and, in our view, scientists and practitioners who invest in this area are likely to discover applications of great practical value. →

**Ryan Olson** is currently an Assistant Professor of Psychology at Santa Clara University located in the heart of the Silicon Valley in Northern California. He received his BS degree from Utah State University and MA and PhD degrees from Western Michigan University. He is affiliated with the Center for Science, Technology, and Society at Santa Clara University as a member of the Research Group for Innovation and Organizational Change. He has published research and scholarly papers on the topics of performance improvement, occupational health and safety, work motivation, and aviation psychology, and has served as a guest editor for the *Journal of Organizational Behavior Management* and the *Journal of Applied Behavior Analysis*. He has consulted with bus transit, aviation, auto parts and paper products manufacturing, higher education, and pharmaceutical organizations on training, safety, psychological assessment, and performance improvement issues.

**John Austin** is currently Associate Professor in Psychology in the Industrial-Organizational Psychology and Applied Behavior Analysis programs at Western Michigan University. Dr. Austin received his BA from the University of Notre Dame, and his MS and PhD from Florida State University with a strong record in organizational consultation, teaching, and research before joining the faculty in the Department of Psychology at Western Michigan University in 1996. He is currently co-editor of the *Journal of Organizational Behavior Management*, and on the board of editors for three other comparable journals, including the *Journal of Applied Behavior Analysis*. In the area of improving human performance he has published more than 60 articles and chapters, delivered more than 120 presentations at regional, national, and international conferences, and has published two books, *Organizational Change*, and *Handbook of Applied Behavior Analysis* (available through Context Press). He has consulted with organizations to improve safety and productivity in the public and private sectors including government, construction, glass and plastics manufacturing, chemical, utilities, retail, food service, higher education, and other industries. He currently teaches organizational and behavioral psychology, performance management, behavioral safety, consultation at the graduate and undergraduate level, and trains graduate students in organizational consultation.

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**END NOTES**

1. Data collected from these participants were also used to conduct empirical analyses of the relationship between the CogScreen™ Aeromedical Edition Test and performance in the field.



