2006

Transfer of Training from Flight Training Devices to Flight for Ab-Initio Pilots

Nickolas D. Macchiarella
Embry-Riddle Aeronautical University, macchian@erau.edu

Pamela K. Arban
Embry-Riddle Aeronautical University

Shawn M. Doherty
Embry-Riddle Aeronautical University

International Journal of Applied Aviation Studies, Volume 6, Number 2

Transfer of Training from Flight Training Devices to Flight for Ab-Initio Pilots

Nickolas D. Macchiarella,

Pamela K. Arban

and

Shawn M. Doherty

Embry-Riddle Aeronautical University
600 S. Clyde Morris Blvd.
Daytona Beach, FL 32114-3900

Abstract

The application of flight simulation to meet pilot training needs continues to evolve. Flight simulations built with powerful and inexpensive computers are making high fidelity simulation available as a medium for training ab-initio pilots at Pilot Schools and Training Centers. The researchers conducted an 18-month study that applied an experimental flight-training curriculum comprised of 60% flight training device (FTD) flight and 40% airplane flight to certify Private Pilots under Federal Aviation Regulation (FAR) Part 142. The results from the research provided data to ascertain the effective transfer for each flight-training task. Ab-initio student pilots practiced each task to standard in an FTD prior to training in an actual airplane. The researchers measured a significant degree of effective transfer for the majority of flight tasks examined.

Introduction

As flight simulations increase in fidelity and decrease in relative cost, the possible applications of simulation for training necessitates continued investigation. Flight training devices (FTD) frequently include high levels of fidelity for aerodynamic modeling. The Federal Aviation Administration (FAA) defines an FTD as,

> a full scale replica of an airplane's instruments, equipment, panels, and controls in an open flight deck area or an enclosed airplane cockpit, including the assemblage of equipment and computer software programs necessary to represent the airplane in ground and flight condi-

Requests for reprints should be sent to Kay Chisholm, FAA Academy, AMA-530, P.O. Box 25082, Oklahoma City, OK 73125. E-mail to kay.chisholm@faa.gov.

> tions to the extent of the systems installed in the device; does not require a force (motion) cueing or visual system; is found to meet the criteria outlined in this AC for a specific flight training device level; and in which any flight training event or flight checking event is accomplished (Federal Aviation Administration, 1992, p. 3).

Recently developed FTDs often include visual systems, force cueing, and aerodynamic modeling characteristics that were not readily available when the FAA first defined and then prescribed how these nonmotion-based flight simulators could be used for pilot training. The purpose of this study was to examine the transfer of training (ToT) from specific recently developed FTDs for ab-initio pilots who trained with a hybrid curriculum of simulated and actual flight.

Starting August 2005, Embry-Riddle Aeronautical University (ERAU)'s Daytona Beach campus conducted an 18-month research project as part of its effort to optimize the application of training that heavily integrates simulated flight during the training of ab-initio student pilots. This longitudinal study followed the performance of participant pilots from a novice condition to FAA certification as a Private Pilot. The transition to powerful personal computer (PC) systems used to drive FTDs is enabling higher levels of fidelity at lower costs while accurately modeling specific aspects of flight. The researchers examined the skill transfer from a Frasca 172 FTD to single engine airplanes for ab-initio student pilots. The Frasca 172 FTD is an FAA qualified Level 6 FTD with a 220-degree wraparound visual system and enhanced aerodynamic modeling that includes non-linear dynamic coefficients, accurate p-factor, slow flight, stalls, left turning tendencies, and force cueing (Anderson & Macchiarella, 2004). This study differed from previous skill transfer studies due to its application of a hybrid curriculum based primarily in simulation and the degree of simulation use approved by the FAA to certify pilots under Federal Aviation Regulation (FAR) Part 142. The research used Flight Training Devices for 60% of the hybrid curriculum's training while airplanes were used for the remaining 40%.

Transfer of Training

Evidence exists indicating that flight training in simulators can yield a positive transfer to performance in real flight (Hays, Jacobs, Prince, & Salas, 1992; Rantanen & Talleur, 2005; Stewart, Dohme, & Nullmeyer, 2000; Waag, 1981). For example, Stewart, Dohme, and Nullmeyer (2000) replaced 7.8 hours of training in the aircraft with nine hours of training in a relatively low fidelity simulator for a group of ab-initio pilots. The measures for this experiment included whether students were set back or eliminated from the training program. The simulation-based training resulted in the experimental group students achieving standardized performance without being set back or eliminated. These findings led Stewart et al., (2000) to conclude that simulated flight had utility for ab-initio flight training.

Using a meta-analysis Rantanen and Talleur (2005) found few differences between transfer of training (ToT) studies that used simulation to train instrument tasks and those that trained visual tasks. This suggested that the procedural aspects of visual flight could be effectively trained in simulation. They also found that training in a conventional simulator without a visual system becomes less cost effective as training extends beyond ten hours. However, simulators with some type of visual system offer new cues and may be potentially cost effective beyond ten hours, although the nature of their effectiveness is not well documented.

Additional studies examined the application of simulated flight to train pilots that ranged in skill levels from ab-initio student pilots to experienced airline transport pilots (ATP) (Brown, Cardullo, & Sinacori, 1989; Go, Bürki-Cohen, & Soja, 2000; Jacobs & Roscoe, 1975; Waag, 1981; White & Rodchenko, 1999) . However, these studies did not specifically address the use of modern high fidelity FTDs to meet the training needs of ab-initio student pilots.

Although previous studies demonstrated the effectiveness of simulation for flight training, questions remained regarding how effective simulation is for training initial flight skills in ab-initio pilots as findings in prior work have generated mixed results (Rantanen & Talleur, 2005). The need for further research examining the effect of FTDs on ab-initio pilot training remains open for examination.

Measurement of Transfer

The most common method of measuring the degree of skill transfer between simulation to the aircraft in order to determine simulation effectiveness is ToT (Roscoe & Williges, 1980). The concept of ToT is derived from learning theory. Researchers have shown that learning and skill acquisition can be transferred from one setting to another similar setting (Gerathewohl, Mohler, & Siegel, 1969). Existing skills can either help or hinder the learning and development of new skills. When pre-existing skills have a positive effect on the development of a new skill, the change in skill is referred to as positive transfer. Conversely, hindrance of new skill acquisition by pre-existing skills is called negative transfer (Patrick, 2003; Roscoe & Williges, 1980). The degree of positive or negative transfer can be measured by a transfer effectiveness ratio (TER) (Roscoe & Williges, 1980).

Calculating the TER requires counting the practice iterations for a task until experimental and control group participants achieve prescribed levels of proficiency in their respective training program. A TER is calculated by subtracting the number of iterations of a task in the aircraft performed by the experimental group from the number of iterations for that task in the aircraft for the control group. This resultant number is subsequently divided by the number of iterations in the simulator (i.e., an FTD) by the experimental group (see Figure 1) (Roscoe & Williges, 1980). Higher TERs indicate greater transfer from simulation to actual airplane flight (e.g., a TER of 1.0 indicates a higher level of transfer than a lower TER like 0.4). A TER of one indicates that for every iteration in the FTD one iteration is saved in the airplane. All positive ratios demonstrate savings in airplane flight for the experimental group.

$$\mathbf{TER} = \frac{\mathbf{C - E}}{\mathbf{E_{(FTD)}}}$$

C is Control Group Task Iterations in an actual airplane
E is Experimental Group Task Iterations an actual airplane
$E_{(FTD)}$ is Experimental Group Task Iterations in an FTD

Figure 1. TER Formula and Definitions of Terms

As an example, Stewart et al. (2000) pre-trained ten pilots in simulated flight for eight flight tasks. They recorded the number of iterations necessary to achieve standard in the aircraft following the pre-training in simulation. A control group of 21 pilots received no simulated flight training. These researchers found that for all eight maneuvers pre-trained, there was a positive ToT from simulated flight to aircraft flight. The overall TER for the eight tasks was 0.55. This number indicated that each iteration practiced in simulated flight saved approximately one-half iteration during aircraft flight training. Similar transfer effectiveness ratios were anticipated for the current study at ERAU using an FTD with greater fidelity and a curriculum that is tailored specifically for the incorporation of simulation. The researchers hypothesize the ab-initio pilots participating in flight training integrating Frasca 172 FTDs and real flight will meet training standards with significant TERs.

Methods

Participants

This study used 38 participants: 18 were in an all-flight control group, and 20 were in an experimental group that used the hybrid FTD and airplane flight curriculum. The number of participants for each group was selected based on a previously conducted power analysis that indicated that 18 participants would be adequate for an in-study power of .80. All participants were ab-initio student pilots with a trivial amount of previous flight training (mean of 0.24 flight hours). The mean age of the all-flight control group was 18.5 and the mean age of the experimental group was 18. The all-flight control group contained 14 males and 4 females and the experimental group contained 15 males and 5 females. The participants were seeking a Bachelor of Science in Aeronautical Science at ERAU. They were regularly enrolled students seeking credits. Flight cost for study participants were normalized to the university's regular flight costs. Each participant possessed, as a minimum, a current Class III Medical Certificate.

Apparatus

This research used aircraft and FTDs obtained from the university's regular training fleet. Flight instructors used the Cessna C-172S "Skyhawk" for 100% of the control group's flight training and 40% of the experimental group's flight training. The C-172S was equipped with NAV II Avionics that includes traditional round dial instrumentation, Garmin 430, global positioning system (GPS), VOR, and DME. Additionally, the Frasca 172 FTD was used for the bulk (i.e., 60%) of the experimental group's curriculum. A Level 6 FTD is defined as a non-motion training aid that is aircraft specific (Federal Aviation Administration, 1992). The device used at ERAU was qualified as a Level 6 Flight Training Device. This device was further enhanced to handle the high angle of attack envelope necessary to train ab-initio pilots. The new aerodynamic models necessary to achieve the desired fidelity were longitudinal and lateral-directional propeller destabilizing effects, longitudinal and lateral-directional gyroscopic effects, p-factor, stall model, and an asymmetric wing lift (spin) model. The researchers at ERAU referred to these FTD as being Level 6 Plus to reflect these enhancements. These FTDs are embedded within an actual Cessna C-172S cockpit from the front of the airplane to just behind the pilot seats. From the firewall forward, the FTDs house the flight control loading equipment. Behind the pilot seats is an instructor's station with a computer workstation to monitor and control the simulation. The visual system provides a 220-degree out-of-the-cockpit view of the flight environment. Air vents in the cockpit blow air on the pilot to replicate the cabin airflow levels experienced in flight. Aural cues change dependent on RPM settings, flap movements, stall warning, airspeed, and engine power. The radio and intercom systems functionality match actual radio and intercom systems in a C-172S and have the capability of being networked with other FTDs for a fleet-wide simulation. All of the Frasca 172 FTDs are equipped with Global Positioning System (GPS) and Instrument Landing System (ILS) navigation capabilities. The aerodynamic modeling is based upon comprehensive flight test data collected at ERAU of a full flight regime to include all aspects of slow flight and stall performance (Anderson & Macchiarella, 2004). This configuration is currently commercially available from Frasca International, Inc.

Flight Training Curricula

Two separate curricula were approved by the FAA to conduct this study. The curricula were structured to sequence tasks in the same manner for both groups. Variations in the curricula between the control and experimental group were minimized. Very little research has been done concerning when and how simulation should be integrated into a flight-training curriculum (Champney, Milham, Carroll, Stanney, & Cohn, 2006). The curriculum selected for training the experimental group (Embry-Riddle Aeronautical University, 2005a) was designed to sequence flight tasks first in the FTD with the goal of obtaining FAA prescribed criterion prior to aircraft flight. In cases where the Practical Test Standard (PTS) was ambiguous with regard to measurable task completion, researchers applied a criteria derived from the ERAU Standard Operating Procedures (SOP) (Embry-Riddle Aeronautical University, 2003) (e.g., Preflight Inspection and Cockpit Management). The experimental curriculum contained 60% simulated flight and 40% airplane flight for a total of 69.7 hours of flight training. Students successfully training with this curriculum had approximately 28 hours of flight in the real aircraft. The control group's curriculum was comprised of 100% aircraft flight.

Data Collection

The FAA Private Pilot Practical Test Standards for Airplane (SEL, MEL, SES, MES) (Federal Aviation Administration, 2002) served as the source for task criteria. Instructor pilots collected data by recording task iterations on paper forms for each participant during training flights. Iterations included any attempt by the student to perform a PTS task including successful completion of the task to standard. Data were collected in the same manner during training with the airplane and FTD. Researchers chose to utilize the tasks from the PTS as the measurement of pilot performance due to the PTS's regulatory authority in the certification of pilots. All FAA certified flight instructors and pilot examiners must comply with these standards when conducting practical tests that come at the end of the Private Pilot certification course. The PTS standards specify the Areas of Operation for which students must show competency before receiving a Private Pilot certificate (Federal Aviation Administration, 2002). Researchers listed each task from these respective Areas of Operation on a paper data collection form referred to as an iteration slip. On the iteration slip, instructor pilots recorded each iteration of PTS tasks attempted and whether the iteration was successfully completed. Iteration slips were bound and placed on kneeboards to accommodate the less-than-optimal data collection conditions that instructor pilots experience during flight training. The data collection device listed all tasks on the front side of the iteration slip in large print (Beaubien, 2004).

As part of the effort to enhance reliability, the instructor pilots received data collection training to standardize the collection procedures. The standardization occurred through an initial 3-hour training period and subsequently reinforced with a monthly review of procedures. The instructor pilot training addressed the PTS standards and necessity of adherence to the curricula approved by the Orlando Flight Safety District Office (FSDO)-15 (Embry-Riddle Aeronautical University, 2005a, Embry-Riddle Aeronautical University, 2005b).

Design

This experiment was a two group between subjects design. The independent variable was the training platform. The control group's condition included full flight in the C-172S with no FTD exposure. The experimental group's condition contained C-172S flight and FTD flight. There were 34 dependent variables. These 34 dependent variables were represented by the number of iterations necessary to achieve the PTS standards for 34 tasks associated with Private Pilot certification.

Procedure

The university institutional review board examined all procedures and approved the study. Researchers carefully followed the approved procedures. Participants were pre-briefed and randomly assigned to a group before signing an informed consent form. As students registered to participate in the study the university registrar randomly divided the students into groups and, when all participants were assigned, sent a list of participants for each group to the researchers. Each group had a slightly different informed consent form to account for the different benefits available to each group for participation in the study. Researchers briefed members of both groups on their respective curriculum. Each participant filled out biographical data including contact information and number of flight hours. All participants were screened to ensure they had no more than a trivial amount of prior flight experience (i.e., < 1 hour).

Participants received the same academic ground training as the general population of Aeronautical Science students. However, researchers assigned participants to flight training sections (i.e., flight blocks) that delivered only the prescribed curriculum to their respective group. ERAU's flight training focus is to produce pilots well prepared for employment as professional pilots. Consequently, specific skills (e.g., cockpit flows and call outs) are standardized and embedded into all fight-training curricula.

The experimental and control curricula were subdivided into units. The participants completed a unit of their group's curriculum during an assigned flight block. Each task had a prescribed training standard graduated in nature to progress from a lower initial level of ability to a higher-level ability as prescribed by PTS. For example, a participant in an early unit would not be expected to land within PTS standards in order to receive a passing grade for the unit. In all cases, participants in the experimental group must perform to PTS standards for a task before attempting that task in an airplane. Units were arranged is such a way that participants were sequenced from FTD-based training to airplane-based training in order to ensure achievement of PTS standards in simulation prior to airplane flight. The sequencing of the curriculum allowed pilots to proceed to subsequent units, but they were not allowed to attempt tasks that had not yet been performed to PTS standards in the FTD. Each unit was graded and iterations were recorded by the participant's assigned instructor pilot. After the unit was complete, the instructor pilot deposited the iteration slip in a designated location for processing by the researchers.

Results

Researchers calculated mean group iterations required to perform to PTS standards for each task (see Table 1). The data were corrected through a logarithmic transformation (see Table 2) to address the restriction of range issue in the data in which there cannot be fewer than one trial to task completion in actual flight. Skew and kurtosis (kurt) are indices of normality in the data. Skew and kurtosis values higher than two for either indicate non-normal data (Aron & Aron, 1999). For a number of the variables under investigation in this study values for skew and kurtosis indicated non-normality. Logarithmic transformations are a typical method used to correct the data toward a normalized data distribution that is an assumption necessary for MANOVA analyses. The skew and kurtosis values reduced from an average of 1.16 and 1.54 respectively for the untransformed data to 0.22 and -0.23 for the transformed data (see Tables 1 and 2). MANOVA analyses were performed on the transformed data. Researchers calculated TER values with these mean scores. The researchers accounted for any voids in task iteration data. Missing data in the study were replaced by the respective group mean of iterations for that specific flight task. Approximately 9.75% of the data points were filled in this manner. The normalized data occurred primarily in four tasks: Lost Procedures, Diversion, Rectangular Course, and Soft-field Approach and Landing.

Table 1
Iterations to PTS in the Airplane for the Control and Experimental Groups by Task

	Control				Experimental				Total			
	M	SD	Skew	Kurt	M	SD	Skew	Kurt	M	SD	Skew	Kurt
Preflight Inspection	3.6	1.0	-0.3	-0.7	1.4	0.6	1.2	0.8	2.4	1.4	0.4	0.1
Cockpit Management	3.6	1.3	-0.7	-0.5	1.4	0.8	2.3	4.9	2.4	1.5	0.8	2.2
Engine Starting	4.8	2.3	1.0	0.7	1.5	0.8	2.0	4.1	3.1	2.4	1.5	2.4
Taxiing	6.5	4.9	1.8	4.2	2.1	1.3	1.9	3.6	4.2	4.1	1.8	3.9
Before Takeoff Check	5.9	2.9	0.9	0.7	1.6	0.9	1.4	1.5	3.6	3.0	1.2	1.1
Traffic Patterns	11.7	7.9	0.8	-0.7	4.0	3.2	0.8	-0.3	7.6	7.0	0.8	-0.5

table continued on next page

Normal and Crosswind Take-off and Climb	6.4	3.7	0.5	-0.2	2.5	2.1	1.6	1.7	4.4	3.5	1.1	0.8
Normal and Crosswind Approach and Landing	20.8	15.4	0.7	-0.4	5.1	3.6	0.5	-0.8	12.5	13.4	0.6	-0.6
Soft-field Takeoff and Climb	2.5	1.4	1.0	0.7	2.3	1.1	0.9	0.9	2.4	1.3	1.0	0.8
Soft-field Ap-proach and Landing	3.7	2.0	0.4	-0.9	2.8	1.2	0.0	-0.4	3.2	1.7	0.2	-0.6
Short-field Takeoff and Max Performance Climb	2.4	1.4	0.8	0.8	1.9	0.8	1.2	2.9	2.1	1.1	1.0	1.9
Short-field Approach and Landing	4.0	2.8	1.6	1.7	2.8	0.9	-0.7	-0.5	3.4	2.1	0.4	0.6
Forward Slip to a Landing	2.9	2.1	0.7	-0.7	1.6	0.7	0.9	-0.2	2.2	1.6	0.8	-0.5
Go-Around/Re-jected Landing	3.2	2.9	1.7	2.6	1.6	1.0	2.4	6.7	2.4	2.2	2.0	4.7
Steep Turns	4.4	3.4	0.7	-0.1	2.6	1.4	0.9	0.3	3.4	2.7	0.8	0.1
Rectangular Course	2.6	1.3	1.1	1.6	2.0	0.7	-0.3	-1.0	2.3	1.1	0.4	0.3
S-Turns	4.1	2.8	0.6	-1.0	2.5	1.0	-0.3	-1.3	3.3	2.2	0.2	-1.2
Turns Around a Point	3.3	2.3	0.5	-0.4	2.7	1.5	2.5	9.7	3.0	1.9	1.5	4.6
Pilotage and Dead Reckoning	1.5	0.8	2.7	8.2	1.4	0.5	1.9	4.2	1.5	0.7	2.3	6.2
Diversion	1.5	0.5	1.9	3.8	1.5	0.9	1.6	2.5	1.5	0.7	1.7	3.1
Lost Procedures	1.4	0.4	0.7	-1.2	1.2	0.3	1.7	2.8	1.3	0.4	1.2	0.8
Navigation Sys-tems and Radar Services	1.9	1.7	1.3	1.0	1.7	0.7	0.9	-0.1	1.8	1.2	1.1	0.4
Emergency Approach and Landing	4.1	3.6	1.4	2.6	2.2	1.3	1.1	0.9	3.1	2.8	1.3	1.7
Systems and Equipment Malfunctions	2.9	2.3	2.1	5.4	1.8	0.8	0.5	-1.0	2.3	1.8	1.3	2.2
Straight-and-Level Flight (IFR)	2.4	2.0	1.7	2.3	2.1	1.7	0.8	-0.4	2.2	1.8	1.2	1.0
Constant Airspeed Climbs (IFR)	2.4	2.1	2.2	5.7	2.1	1.5	1.8	2.9	2.2	1.8	2.0	4.3

table continued on next page

Constant Airspeed Descents (IFR)	2.5	1.9	1.8	3.2	2.4	2.0	1.8	2.6	2.4	1.9	1.8	2.9
Turns to Headings (IFR)	2.7	1.9	1.3	1.9	2.0	1.8	1.9	3.4	2.3	1.9	1.6	2.6
Recovery from Unusual Attitudes (IFR)	2.0	1.1	0.9	-0.7	1.7	1.2	1.7	2.4	1.8	1.1	1.3	0.9
Radio Communication Navigation Systems/Facilities & Radar Services	5.7	4.6	1.0	0.2	2.8	2.4	1.9	3.8	4.1	3.9	1.5	2.0
Maneuvering During Slow Flight	5.7	4.0	0.8	0.0	2.6	2.0	1.0	-0.2	4.1	3.4	0.9	-0.1
Power-Off Stall	5.4	4.0	0.6	-0.8	2.8	2.9	2.2	4.7	4.0	3.7	1.4	2.0
Power-On Stall	6.4	4.5	0.5	-0.9	3.1	3.2	1.6	1.8	4.7	4.2	1.0	0.4
After Landing, Parking and Securing	3.8	2.1	0.4	-0.7	1.4	0.8	2.3	4.9	2.6	2.0	1.4	2.1

n=18 for control group and 20 for experimental group. N=38 total.

Table 2

Transformed Mean Iterations to PTS in the Airplane for the Control and Experimental Group by Task

	In Control				In Experimental				In Total			
	M	SD	Skew	Kurt	M	SD	Skew	Kurt	M	SD	Skew	Kurt
Preflight Inspection	1.2	0.3	-0.8	-0.3	0.3	0.4	0.9	-0.9	0.7	0.6	0.0	-0.6
Cockpit Management	1.2	0.5	-1.4	1.3	0.2	0.4	1.7	1.8	0.7	0.7	0.1	1.6
Engine Starting	1.5	0.5	-0.2	-0.2	0.3	0.4	1.4	0.9	0.8	0.8	0.6	0.4
Taxiing	1.5	0.7	-0.6	0.8	0.6	0.5	0.6	0.0	1.0	0.8	0.0	0.4
Before Takeoff Check	1.6	0.4	-0.2	0.0	0.4	0.5	0.9	-0.6	0.9	0.8	0.4	-0.3
Traffic Patterns	2.1	0.6	-0.2	-0.2	1.0	0.9	0.1	-1.7	1.5	0.9	-0.1	-0.9
Normal and Crosswind Takeoff and Climb	1.7	0.7	-1.1	1.0	0.6	0.7	0.7	-0.7	1.1	0.9	-0.2	0.2
Normal and Crosswind Approach and Landing	2.7	0.7	-0.4	-0.6	1.3	0.8	-0.4	-1.2	2.0	1.0	-0.4	-0.9
Soft-field Takeoff and Climb	0.8	0.6	-0.1	-0.9	0.7	0.5	-0.2	-0.6	0.7	0.5	-0.1	-0.7
Soft-field Approach and Landing	1.1	0.6	-0.6	-0.4	0.9	0.5	-0.9	-0.4	1.0	0.6	-0.7	-0.4
Short-field Takeoff and Max Performance Climb	0.6	0.4	-0.3	-0.3	0.5	0.4	0.0	-0.3	0.6	0.4	-0.1	-0.3

table continued on next page

Short-field Approach and Landing	1.2	0.7	0.2	0.1	1.0	0.4	-1.3	1.2	1.1	0.5	-0.6	0.6
Forward Slip to a Landing	0.7	0.6	0.1	-1.2	0.4	0.4	0.5	-1.4	0.5	0.5	0.3	-1.3
Go-Around/Rejected Landing	0.8	0.7	0.5	-0.7	0.3	0.5	1.2	0.9	0.5	0.6	0.9	0.1
Steep Turns	1.2	0.5	-0.7	0.9	0.8	0.6	0.0	-1.0	1.0	0.6	-0.4	-0.1
Rectangular Course	0.8	0.5	-0.2	-0.1	0.6	0.4	-0.6	-1.2	0.7	0.5	-0.4	-0.7
S-Turns	1.2	0.8	-0.2	-1.1	0.8	0.5	-0.7	-1.1	1.0	0.7	-0.5	-1.1
Turns Around a Point	0.9	0.5	-0.5	-0.3	0.8	0.5	-0.1	1.1	0.9	0.5	-0.3	0.4
Pilotage and Dead Reckoning	0.2	0.3	1.8	3.9	0.3	0.3	1.2	1.1	0.2	0.3	1.5	2.5
Diversion	0.3	0.3	1.2	1.0	0.2	0.2	1.1	0.9	0.2	0.3	1.1	1.0
Lost Procedures	0.3	0.3	0.5	-1.3	0.2	0.2	1.2	1.2	0.2	0.3	0.9	-0.1
Navigation Systems and Radar Services	0.3	0.4	0.9	-0.6	0.4	0.4	0.4	-1.0	0.4	0.4	0.6	-0.8
Emergency Approach and Landing	1.0	0.6	-0.2	0.0	0.6	0.6	0.2	-1.2	0.8	0.6	0.0	-0.6
Systems and Equipment Malfunctions	0.7	0.6	0.5	0.2	0.5	0.4	0.1	-1.7	0.6	0.5	0.3	-0.8
Straight-and-Level Flight (IFR)	0.6	0.7	0.8	-0.7	0.5	0.5	0.4	-1.5	0.5	0.6	0.6	-1.1
Constant Airspeed Climbs (IFR)	0.6	0.7	0.8	-0.1	0.6	0.6	0.7	-0.4	0.6	0.6	0.8	-0.3
Constant Airspeed Descents (IFR)	0.7	0.7	0.5	-0.6	0.6	0.7	0.9	-0.3	0.6	0.7	0.7	-0.5
Turns to Headings (IFR)	0.7	0.7	0.3	-1.3	0.3	0.5	1.3	0.4	0.5	0.6	0.8	-0.4
Recovery from Unusual Attitudes (IFR)	0.5	0.6	0.4	-1.4	0.4	0.5	1.1	-0.1	0.5	0.5	0.7	-0.8
Radio Communication Navigation Systems/Facilities & Radar Services	1.4	0.9	-0.3	-1.0	0.7	0.7	0.6	-0.7	1.0	0.9	0.2	-0.9
Maneuvering During Slow Flight	1.4	0.7	-0.4	-0.5	0.7	0.7	0.4	-1.6	1.0	0.8	0.0	-1.0
Power-Off Stall	1.3	0.8	-0.5	-0.6	0.6	0.8	1.0	-0.3	1.0	0.9	0.2	-0.4
Power-On Stall	1.5	0.7	-0.5	-0.2	0.7	0.9	0.8	-1.0	1.1	0.9	0.1	-0.6
After Landing, Parking and Securing	1.2	0.7	-0.6	-0.5	0.2	0.4	1.7	1.8	0.7	0.7	0.5	0.7

n=18 for control group and 20 for experimental group. N=38 total.

MANOVA

Researchers calculated a MANOVA to determine if the number of flight iterations performed in airplane flight to achieve PTS was significantly lower for the experimental group. Tasks with significantly lower mean iterations for the experimental group are noted with an asterisk in Table 3. There were no tasks with significantly higher mean iterations for the experimental group in the airplane. For all dependant variables p=0.05 with 1, 36 degrees of freedom. A MANOVA analysis was selected for these data to reduce the possibility of a Type I error given the large number of dependant variables.

Table 3
Transfer Effectiveness Ratio (TER) from FTD Flight to Airplane Flight and MANOVA results by PTS Task

	TER	F	p
Preflight Inspection*	0.64	76.98	0.00
Cockpit Management*	0.72	37.84	0.00
Engine Starting*	0.59	67.16	0.00
Taxiing*	0.77	19.58	0.00
Before Takeoff Check*	0.82	71.75	0.00
Traffic Patterns*	2.19	17.58	0.00
Normal and Crosswind Takeoff and Climb*	0.57	18.40	0.00
Normal and Crosswind Approach and Landing*	2.1	31.76	0.00
Soft-field Takeoff and Climb	0.06	0.10	0.76
Soft-field Approach and Landing	0.32	1.45	0.24
Short-field Takeoff and Max Performance Climb	0.13	0.63	0.43
Short-field Approach and Landing	0.27	1.17	0.29
Forward Slip to a Landing*	0.48	5.67	0.02
Go-Around/Rejected Landing*	0.51	4.23	0.05
Steep Turns*	0.32	4.22	0.05
Rectangular Course	0.32	2.77	0.10
S-Turns	0.53	3.30	0.08
Turns around a Point	0.2	0.20	0.66
Pilotage and Dead Reckoning	0.09	0.10	0.75
Diversion	-0.02	1.06	0.31
Lost Procedures	0.18	1.27	0.27
Navigation Systems and Radar Services	0.1	0.63	0.43
Emergency Approach and Landing*	0.69	4.97	0.03
Systems and Equipment Malfunctions	0.41	2.57	0.12
Straight-and-Level Flight (IFR)	0.09	0.45	0.51
Constant Airspeed Climbs (IFR)	0.1	0.09	0.77
Constant Airspeed Descents (IFR)	0.05	0.13	0.72

table continued on next page

Turns to Headings (IFR)*	0.3	3.99	0.05
Recovery from Unusual Attitudes (IFR)	0.09	0.72	0.40
Radio Communication Navigation Systems/Facilities & Radar Services*	0.82	5.50	0.02
Maneuvering During Slow Flight*	0.38	10.75	0.00
Power-Off Stall*	0.27	6.82	0.01
Power-On Stall*	0.34	9.79	0.00
After Landing, Parking and Securing*	0.74	26.92	0.00

* indicates significant F value.

Discussion

The transfer effective ratios (TERs) (see Table 3) indicated that 33 out of 34 tasks had positive transfer from FTD flight to aircraft flight. For 18 of these 34 tasks, the experimental group required significantly fewer iterations to achieve PTS standards in the airplane after they trained to standard in the FTD. The positive direction of the TERs, coupled with significantly lower number of iterations to achieve PTS in the airplane by the experimental group, strongly suggests that these FTDs are an effective means for training ab-initio student pilots. Some tasks were more effectively trained than others were. Flight training developers need to weigh the issue of effective transfer when determining the curricula selected to meet training needs. At times, tasks with apparently low levels of transfer effectiveness are most effectively trained in simulation when safety and/or monetary savings are considered. There are several possible explanations addressing whether a task can be effectively trained in a simulation device with the functionality of these FTDs for ab-initio flight students. Based on direct observations and instructor pilot interviews, the researchers categorized factors that indicate potential explanations for the degree of transfer in multiple tasks.

Visual Fidelity

The FTDs served primarily for training visual flight rule (VFR) tasks. Pilot perceptions of vection (i.e., a visually induced false sensation of self-movement) occur primarily by sensing movement of objects in the peripheral vision. The motion parallax effect afforded by the enhanced visual scene in the simulation enhances perceptions of vection. Tasks performed in close proximity to detailed and well-developed 3-dimensional (3-D) graphic artwork in the virtual world typically indicated higher levels of transfer when compared to those practiced in less developed areas of the virtual world. These tasks included Taxing, Traffic Patterns, Normal and Crosswind Take-Off and Climb, Normal and Crosswind Approach and Landing, Forward Slip to Landing, Go Around/Rejected Landing, Emergency Approach and Landing, and After Landing Parking and Securing. Students performed these tasks in the highly developed virtual flight environment immediately surrounding Daytona Beach International Airport (KDAB). The significance of these tasks suggests that the high fidelity visual display, in conjunction with the well-developed 3-D graphic artwork, had a positive effect on transfer from FTD-based flight to airplane-based flight. Researchers found ToT was not significant in the well-developed 3-D graphic virtual environment for four tasks.

These tasks were Soft-field Take Off and Climb, Soft-field Approach and Landing, Short-field Off Take Off and Max Performance Climb, and Short-field Approach and Landing. Researchers hypothesize these four task's inherent degree of difficulty (i.e., the tasks are difficult to master regardless of application of a real or virtual training environment) affected performance and further research is necessary to isolate the causes.

While fidelity of the visual scene improved ToT for multiple tasks, the impact of a high level of visual fidelity appeared to have minimal positive transfer in other tasks. Rectangular Course, S-Turns, and Turns Around a Point are ground reference maneuvers performed in the practice areas to the northwest and southeast of KDAB between 600 and 1,000 feet above ground level (AGL). Developers optimized the FTD visual system for flight at 3,000 feet AGL and above. This is due to the nature of the satellite imagery underlying the virtual world. As pilots descend to lower altitudes, and in the absence of 3-D graphics, visual fidelity is compromised. This impairment to visual fidelity can account for the minimal positive transfer for these tasks.

Pilotage and Dead Reckoning, Diversion, and Lost Procedures were not significantly different between the two groups for transferring skills to airplane flight. The researchers hypothesize the optimization of the visual system at 3000 feet AGL in conjunction with a lack of detailed 3-D graphical art work across a relatively long (i.e., 150 nautical mile) flight route may have failed to deliver the cues necessary to effectively train these tasks that are heavily reliant on external visual cues. Diversion was the only task indicating negative transfer. This negative transfer was not significant for this task, but warrants further investigation. Diversion might be a difficult task in the virtual environment due to its inherent lack of well-developed visual virtual landmarks. Being diverted in the real world environment (i.e., flying into new airspace) is greatly aided by a surplus of visual landmarks that might be useful during navigation.

Procedural Similarity

The theory of Identical Elements as initially stated by Thorndike (1906) suggested that transfer only occurs in the presence of specific common elements. High fidelity in the forms of physical fidelity (e.g., the FTD's real Cessna C-172S cockpit), cognitive fidelity (e.g., instructor pilots role playing air traffic/air traffic control and ab-initio pilot realistically experiencing cognitive work loading during training), control loading fidelity, (e.g., realistic force feed back on flight controls), and aerodynamic fidelity enables the FTD to properly mimic airplane flight. The researchers deem certain PTS tasks are highly procedural in nature and are readily replicated in the simulated flight training environment used at ERAU for research. These tasks include: Preflight Inspection, interior cockpit only; Cockpit Management; Engine Starting; Before Take-Off Check; Radio Communication Navigational Systems/Facilities and Radar Services; Traffic Patterns; Steep Turns; and After Landing Parking and Securing.

Difficulty of Tasks

Several flight tasks necessitate higher levels of skill than others (e.g., it is inherently more difficult to perform a Short-Field Approach and Landing than a Normal and Crosswind Approach and Landing, the PTS standard for a Short-

Field Approach and Landing is 200 feet while the PTS standard allows 400 feet for a Normal and Crosswind Approach and Landing). Typically, ab-initio pilots master these tasks during the later stages of their training. Soft-Field Takeoff and Climb, Soft-Field Approach and Landing, Short-Field Takeoff and Climb, Short-Field Approach and Landing are taught late in the curricula. These tasks proved more difficult to master for participants in both the experimental and control groups. Positive transfer occurred for each task but the difference between the simulation group and the control group was not significant. The data suggested that these tasks are difficult to achieve no matter where they were first learned. Training to standard in the FTD did not seem to mitigate the difficulty of mastering these tasks. The sequencing of training tasks in the curricula had the goal of adhering to the building block principle of learning (i.e., a concept where knowledge and skills are best learned based on previous associated learning experiences) (Federal Aviation Administration, 1999).

Visual Scanning and Response

The tasks of Slow Flight, Power-Off Stalls, and Power-On Stalls also showed a significantly lower number of iterations necessary for the experimental group to achieve PTS standards in the airplane when compared to the control group. While in actual flight performance of these tasks rely heavily upon the students' ability to perceive and respond to proprioceptive stimulation for pitch attitude and the sensation of falling. Participants learning these tasks in the FTD perform in the absence of proprioceptive stimulation. They were forced to rely exclusively upon their visual sense to determine the aircraft state as it approaches the indicated airspeeds (IAS) that result in a stalled condition. The students' ability to maneuver during slow flight and properly recovering from a stalled flight condition was positively affected by their training in the FTD. Enhanced attention to the flight instruments may allow the participants to perform these tasks in flight after training in the FTD. Ab-initio students may learn to scan more efficiently between instruments and the out-of-the-cockpit visual scene while mastering these tasks in the FTD.

Dynamic Flight Environment

The FTDs incorporate a degree of unstable air mass modeling. The weather modeling is optimized to replicate flight conditions experienced during relatively stable departure, enroute, and approach stages of flight. Complex and changing combinations of updrafts, downdrafts, crosswinds, and headwinds tremendously affect control inputs necessary to perform flight tasks and remain within PTS prescriptions. Previous research examining the transfer of skills from simulated flight to real flight under simulated instrument meteorological conditions (IMC) has not addressed performance by ab-initio pilots. This previous research typically addressed performance by pilots with at least Private Pilot certification. More experienced pilots are already familiar with the feel of the aircraft and how it will react during each maneuver. Straight-and-Level Flight, Constant Airspeed Climbs, Constant Airspeed Descents, Turns to Headings, and Recovery from Unusual Attitudes are tasks taught to ab-initio pilots under instrument flight rules (IFR) in simulated IMC. None of the basic instrument tasks showed a significant difference in airplane iterations between the two groups, with the exception of Turns to Headings in the transformed data. The researchers hypothesize that the FTD does not mimic all of the complexities of air currents experienced in actual flight.

Conclusion

The researchers' purpose for this study was to quantify the transfer effectiveness of training in FTDs to performance in an actual airplane. This study used simulated flight as the primary means of training ab-initio pilots as they earned a Private Pilot's certificate. The study was longitudinal in nature. It followed the performance of participant pilots from a novice condition to certification by the FAA as a Private Pilot. This study included elements that differentiate it from other studies in that it included ab-initio pilots culminating in FAA certification as a Private Pilot under a Part 142 approved curriculum. The curriculum was primarily comprised of flight training with simulated flight.

The analysis of the data and direct observations of performance lead the researchers to believe training ab-initio pilots with an FTD that has the functionality and fidelity of the devices in use at ERAU can be effective. Transfer of training was positive in 33 out of 34 tasks and significantly different from the control group in 18 out of 34 tasks. Optimizing flight curricula to capitalize on the strengths and weaknesses of the device is critical to flight training. Embry-Riddle Aeronautical University is in the process of applying the results of this research to its flight curricula developmental process. Now and in the future, ERAU ab-initio pilots will train with a flight curriculum that relies heavily upon FTD flight.

References

Anderson, R. P., & Macchiarella, N. D. (2004). Nonmotion flight simulation development of slow flight and stall tasks for use in ab-initio flight training. *Proceedings of the Human Performance, Situation Awareness and Automation Technology II* (HPSAA II) Conference. Daytona Beach, FL, II, 180-184.

Aron, A., & Aron, E.N. (1999). Strategies when population distributions are not normal: Data transformations, rank-order tests, and computer-intensive methods. In *Statistics for psychology* (2nd ed., pp. 458-487). Upper Saddle River, NJ: Prentice Hall.

Beaubien, M. J., Baker, D. P., & Salvaggio, A. N. (2004). Improving the construct validity of line operational simulation ratings: Lessons learned from the assessment center. *International Journal of Aviation Psychology, 14*(1), 1-17.

Brown, Y. J., Cardullo, F. M., & Sinacori, J. M. (1989). *Need-based evaluation of simulator force and motion cuing device* (No. 89-3272-CP). Reston, VA: American Institute of Aeronautics and Astronautics.

Champney, R., Milham, L., Carroll, M. B., Stanney, K. M., Cohn, J. (2006). A method to determine optimal simulator training time: Examining performance improvement across the learning curve. *Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting*. San Francisco, CA, 2654-2658

Embry-Riddle Aeronautical University. (2003). *Cessna 172S standard operating procedures*. Daytona Beach: Embry-Riddle Aeronautical University.

Embry-Riddle Aeronautical University. (2005a). *Private pilot SEL training manual.* Unpublished Curriculum, Approved by FSDO-15. Embry-Riddle Aeronautical University, Daytona Beach, FL.

Embry-Riddle Aeronautical University. (2005b). *Private pilot TCO.* Unpublished Curriculum, Approved by FSDO-15. Embry-Riddle Aeronautical University, Daytona Beach, FL.

Federal Aviation Administration. (1992). *Airplane flight training device qualification*. Advisory Circular (AC) 120-45A, Author.
Federal Aviation Administration. (1999). *Aviation instructor's handbook.* (FAA-H-8083-9). Author.
Federal Aviation Administration. (2002). *Private pilot practical test standards for airplane* (FAA-S-8081-14AS). Author.
Gerathewohl, S. J., Mohler, S. R., & Siegel, P. V. (1969). *Fidelity of simulation and transfer of training: A review of the problem* (No. AM 69-24): Federal Aviation Administration, Office of Aviation Medicine.
Go, T. H., Bürki-Cohen, J., & Soja, N. N. (2000). *The effect of simulator motion on pilot training and evaluation* (No. AIAA 2000-4296). Denver, CO: AIAA Modeling and Simulations Technologies Conference.
Hays, R. T., Jacobs, J. W., Prince, C., & Salas, E. (1992). Flight simulator training effectiveness: A meta-analysis. *Military Psychology, 4*(2), 63-74.
Jacobs, R. S., & Roscoe, S. N. (1975). Simulator cockpit motion and the transfer of initial flight training. *Proceedings of the 19th Meeting of the Human Factors Society,* Santa Monica, CA.
Patrick, J. (2003). Training. In P. S. Tsang & M. A. Vidulich (Eds.), *Principles and practice of aviation psychology.* NJ:Mahwah: Lawrence Erlbaum Associates, Publishers.
Rantanen, E., & Talleur, D. A. (2005). Incremental transfer and cost effectiveness or ground-based trainers in university aviation programs. *Proceedings of the Human Factors and Ergonomics Society, 49th Annual Meeting*, Orlando, FL, 764-768.
Roscoe, S. N., & Williges, B. H. (1980). Measurement of transfer of training. In S. N. Roscoe (Ed.), *Aviation psychology* (pp. 182-193). Ames: Iowa State University Press.
Stewart, J. E., Dohme, J. A., & Nullmeyer, R. T. (2000). U.S. Army initial entry rotary-wing transfer of training research. The *International Journal of Aviation Psychology, 12*(4), 359-375.
Thorndike, E. L. (1906). *The principles of teaching based on psychology.* New York: A.G. Seiler.
Waag, W. L. (1981). *Training effectiveness of visual and motion simulation* (No. AFHRL-TR-79-72). Brooks Air Force Base, TX: Air Force Human Resources Laboratory.
White, A., & Rodchenko, V. (1999). *Motion fidelity criteria based on human perception and performance* (No. AIAA-99-4330). Vienna, VA: American Association of Aeronautics & Astronautics.