Distance Learning for Instrument Flight: Evaluating the Effectiveness of a Virtual Mentor

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DISTANCE LEARNING FOR INSTRUMENT FLIGHT: EVALUATING THE
EFFECTIVENESS OF A VIRTUAL MENTOR

by

ANDREW S. MENDOLIA
B.S., Longwood University, 2007

A Thesis Submitted to the
Department of Human Factors & Systems
in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Human Factors and Systems
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DISTANCE LEARNING FOR INSTRUMENT FLIGHT: EVALUATING THE
EFFECTIVENESS OF A VIRTUAL MENTOR

By: Andrew S. Mendolia

This thesis was prepared under the direction of the candidate's thesis committee chair, Dr. Elizabeth Blickensderfer, Ph.D., Department of Human Factors & Systems, and has been approved by members of the thesis committee. It was submitted to the Department of Human Factors & Systems and has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Human Factors & Systems.

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Abstract

PC-based flight simulators are sometimes used as an alternative to traditional forms of instrument training. This type of training typically requires an instructor to be present with the student in order to facilitate training. Flight instructors play many important roles in aviation training, one of which is the role of a mentor. The premise of this study was to examine the use of synchronous web-based instruction for instrument flight via Microsoft Flight Simulator’s (10.0) “shared-cockpit” feature, where the instructor serves as a mentor from a distance. The results indicate that web-based instruction is no more effective than practice without instruction. Although additional research is needed, the results are encouraging for students looking to practice a specific instrument task that may not require instruction.
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Introduction

There is great potential for using personal-computer based flight simulation (PC-based flight simulation) for research and training purposes. Over the past decade, enhancements in personal computers with increased processor speed, powerful video cards, and increased memory capability have improved the quality of PC-based flight simulation. There are various levels of flight simulation. These levels range from low-fidelity, low cost simulators such as PC-based flight simulation to high fidelity, and high cost motion simulators with six degrees of motion. The levels of complexity vary tremendously between these two levels of simulation, however both provide adequate levels of training that can be transferred to actual aircraft (Beringer, 1996).

In conjunction with personal computer enhancements, the accessibility of the internet adds a new facet to human communication. The internet eliminates many of the constraints on information sharing and communicating with people from various geographical locations. Consequently, this also makes training and education more accessible. In the past 10 years, web-based training has become prevalent for the use of post-secondary education and job-training. Some web-based training platforms provide live instruction, where the student can receive instruction from home while the mentor or teacher is lecturing from a distant location. In other situations, the mentor records a lecture and allows his or her students to access the lecture anytime. The lecture can be in an audio format, video format, or both.

Some forms of web-based learning are centered on coaching (mentoring), particularly one-on-one relationships where a coach or mentor interacts with the student (Noe, 1999). The responsibilities of a coach are to provide a student instruction as needed, reinforcement and feedback, and resources necessary to accomplish a particular task. Mentoring of this nature over
the internet leaves several questions unanswered. Do students acquire more information if they are face-to-face with their instructor as opposed to web-based learning, or are there no differences between the two? What skills are acquired from utilizing face-to-face learning and web-based learning? In addition, can certain aspects of flight training be delivered via the internet and the use of flight simulation software?

Currently, no research studies have tested web-based training as an effective alternative for flight instruction. The purpose of this research study was to investigate the effectiveness of web-based learning via a PC-based flight simulator. Specifically, this study focused on introductory instrument training for pilots with little or no experience in a conventional (six-pack) display cockpit. The learners were students with training up to his or her first solo cross-country flight. This study will provide insight into the effectiveness of distance learning and flight training. The following literature review will discuss cognitive skill acquisition followed by an overview of PC-based flight simulation research. Finally current web-based mentoring literature will be discussed.

Learning and Cognitive Skill Acquisition

In order to understand the effectiveness of a particular training paradigm, a brief overview of learning and cognitive skill acquisition needs to be addressed. Considerable research exists on skill acquisition. It involves an area of cognitive psychology dominated by topics such as memory, problem solving, decision making, and attention. It also concerns differentiating between novice and expert performance. However, the fundamentals of adequate training start with learning and memory. More importantly, the foundation of good training begins with the instructor highlighting the appropriate stimuli within the training environment and priming the student to attend to those stimuli.
Learning and Attention.

Learning is defined as finding out about the environment and then behaving in accord with it (Leahey, 1997). There are three primary stages of learning and memory: attending to a particular stimulus in a “noisy environment” (many stimuli), attending to a specific stimulus or series of stimuli, and storing the information learned from the environment to use at a later time. These three stages of attending, learning, and storing are associated to the three stages of memory: sensory register, working memory, and long-term memory (Tefler & Biggs, 1988).

When learning a new concept, the learner must develop a method to focus (attend) on the most important information while ignoring some of the noise in the environment. Filtering noise and attending to specific stimuli contains three primary mechanisms. First, one can develop a mental set or establish a plan in anticipation of an event. For example, if a pilot is aware he or she is approaching a controlled airspace, the pilot will already have planned an approximate location to contact the appropriate approach frequency. The second means of attending to a specific stimulus involves the actual physical properties of the stimulus. This pertains to the saliency of the stimulus. For instance, if the stall warning horn device in an aircraft is barely audible to the pilot, the saliency of the stall warning horn is insufficient to attract the pilot’s attention. This could result in an unexpected stall, putting the pilot in grave danger. The physical properties of this device should be designed to immediately capture the pilot’s attention in order to mitigate a dangerous situation. Lastly, the psychological or physiological state can affect the learner’s attentional capability. If the learner is depressed or recovering from the flu, these states may inhibit the learner’s ability to attend to a specific stimulus. Proper attention to pertinent stimuli is an important component to learning.
The way individuals attend to a stimulus is also affected by the individual's background, personal needs, and priorities (Tefler & Biggs, 1988). In an aviation training setting, the instructor's priorities may be completely different from the student's priorities. This differentiation can lead to communication gaps. For example, if a student pilot working on his or her private pilot's certificate may only be concerned with the end result: obtaining the certificate. This priority may conflict with the instructor's goal of teaching the student how to perform a specific task. The student may become frustrated due to the level of responsibility involved in learning a new task and the instructor may become frustrated due the student's inability to focus on one task. Since the two mental sets are incompatible, the objective in many aviation instructional settings is to motivate the student to adopt the same priorities as the instructor. In other words, they need to share the same mental set.

Strategies to direct the student's attention include a “pretest” (an objective evaluation of the task(s) that are to be performed later on in training), behavioral objectives (detailing the type of behavior that is expected), or sample items (providing students with example(s) of a situation(s) he or she may experience later in training). All are pertinent to this study. In terms of the sample items, there are a variety of ways to convey sample items. One approach is to give a written description of a scenario and have the student answer questions about it. Another way of facilitating a sample item is through a simulated environment which is the main focus of this study. A simulated environment is particularly appropriate for aviation training as it provides the student practice with manipulating the dynamic components of the aircraft. It is practice with the aircraft that allows the learner to attend to stimuli during specific portions of flight and to commit this experience into long-term memory in the form of procedural knowledge. Furthermore, simulation based training allows the student to practice in a safe environment
without the burden of high operational costs. Numerous practice scenarios enable the learner to focus on specific tasks and adopt a similar mental set with the instructor while acquiring the desired skills and knowledge. To ensure the student attends to necessary information and stores this information in long-term memory, the learner must effectively accomplish all phases of learning. The next section will illustrate how each phase contributes to learning and what is achieved through each phase.

**Phases of Skill Acquisition.**

At the basic level of training, one is typically exposed to verbal or declarative knowledge, which must precede higher-order development. Declarative knowledge is factual knowledge that people can either report or describe (Anderson, 1993, p. 10). Once declarative knowledge is established, organization of that knowledge comes to fruition. Kraiger, Ford, and Salas (1993) argued that it is not the amount or type of knowledge that is important in training as much as how that knowledge is organized. During training, participants develop a mental model of how a process works utilizing the declarative knowledge to bring together a clearer, overall understanding of that task at hand. Finally, once organization of declarative knowledge is established, the trainee develops cognitive strategies to maintain an “expert-like” level of performance (Anderson, 1993). Kraiger et al. (1993) suggested that at the expert performance level of cognition, the trainee is cognitively aware of a particular task, maintaining a level of self-awareness and self-evaluation while learning. This is referred to metacognition. In essence, metacognition is a means of continual self-evaluation which is an integral component toward the development of expertise. Expert performance therefore can be defined as the ability to plan solutions for a problem using memory or past exposure with the task. Solutions to a problem via memory retrieval can expedite one’s ability to solve a problem and is the cornerstone of expert...
performance. On the other hand, novice performance is defined as the ability to solve a problem using only features of the problem statement itself. Novices lack the past exposure and continual self-evaluation stemming from the past exposure to find the solution to a problem. In order for a novice to make the transition to expert performance, there are three phases of skill acquisition the learner must progress through: early, intermediate, and late (VanLehn, 1996).

As noted earlier, the early phase of skill acquisition concerns learning basic knowledge. Next, in the intermediate phase (applying what has been learned) the individual practices and acquires problem solving techniques. As VanLehn (1996) described, the intermediate phases centers on the learner identifying the flaws in his or her problem solving technique and helps to mature the learner's conceptual understanding of the domain. Solving a problem without conceptual error but only with occasional errors or slips marks the beginning of the late or final phase of acquisition. In the final phase, the learner obtains exposure to different solutions for a particular problem, updates his or her repertoire of solutions in memory, and increases the speed and accuracy of his or her response. This process occurs through repeated practice in an applied setting.

When the learner is learning a single task, the learner's preferences are typically associated with "learning from example" or practice. "Learning from example" can be applied in one of two forms: retrieved deliberately (the learner is given a hint) or spontaneously (the instructor hides the relationship between the training and testing, providing only reminders) (VanLehn, 1996). Spontaneous retrieval occurs generally at a superficial level. That is, the learner considers an example he or she is familiar with from training but not real-world experience to select a response.
In regard to learning from example, students benefit particularly from self-explanation. This is especially the case in situations when the student is introduced to a topic. Self-explanation occurs when the learner makes inferences about a particular problem that goes beyond the information that is given (VanLehn, 1996). A student who can solve a problem and provide a solution independent to previous examples, likely has achieved inherent understanding of the material. As VanLehn (1996) suggested, good learners minimize the number of analogies used in a problem solving situation and only utilize them when there are no other alternatives. Poor learners rely heavily on analogies of problem solving (solving through similar examples), applying techniques that worked in a previous example that may not be appropriate for the current problem. For example, when a student is factoring an algebraic expression such as \( x^2 - 4 \), the student should have inherent knowledge of basic algebra in order to factor this problem. The student should also ask questions such as what combination of numbers will result in \(-4\) and will negate the middle factor (a variable at the first power). In this case, the factored expression is \((x - 2) (x + 2)\). In this situation, the student is applying his or her knowledge of algebra to factor the expression. Using solely superficial examples would not work because the problem is unique. Thus, it is important for the learner to engage in a conceptual understanding of an experience (experiential learning), but not rely on the experience as a means of acquiring the solution to every situation. This example is especially true in aviation where the pilot may not have enough time to use a previous situation to solve a problem. In actuality, the pilot cannot rely on one style but many styles depending on the situation. In some instances, previous experiences may reoccur later in training and the pilot may need to resort to his or her past experience with that situation to resolve the issue (i.e. knowing not to turn off the carburetor
heat). In other instances, the instructor may not be able to simulate or practice a particular situation and will have to adopt another instructional strategy in order to achieve the experience.

It was previously mentioned that the basic foundation of learning is through the introduction of declarative or factual knowledge. The next section discusses the two primary levels of knowledge: declarative and procedural in more detail and will illustrate how these forms of knowledge are not always dependent on each other.

_Proceduralization._

The distinction between declarative and procedural knowledge is centered on cognitive architectures. Cognitive architectures are essentially complete proposals of the structure of human cognition and how knowledge is categorized (Anderson, 1993, p. 4). They provide a complete specification of cognitive systems, but are centered on a level of abstraction as they are not concerned with details down to the single neuron level in cognitive architectures. As mentioned previously, there appears to be two primary levels of knowledge: declarative and procedural.

Declarative knowledge is based on factual information. Procedural knowledge is information people can only manifest through performance. It is common for declarative knowledge to transform into perceptual knowledge, decreasing the likelihood that the declarative information can be recalled. Procedural knowledge has a tendency to be automatic, displaying very little reliance on declarative knowledge in order to be able to complete a task. For example, typing is a task that heavily demands procedural knowledge but requires little if any declarative knowledge. In many instances, individuals can type proficiently while not being able to locate the position of a specific letter on the keyboard through memory alone. The inability to locate a letter on a keyboard by memory is a lapse in declarative knowledge. This may stem from very
little need or opportunity to have to memorize the position of a specific letter. This illustrates that in many instances, declarative knowledge is not needed to sustain a procedural task. In aviation training, there are no tasks that can be executed through procedural knowledge that is not contingent on declarative knowledge. This is primarily because if an emergency were to occur the pilot would have to use his or her knowledge of the components of the procedure to resolve the problem. For example, if a pilot were to experience carburetor ice during flight, the standard procedure is to turn on the carburetor heat to burn off the ice. Immediately after the carburetor heat is applied, the engine roughness will appear to have worsened as applying carburetor heat reduces engine performance slightly. In this situation the pilot is familiar with the procedure, but declarative knowledge is needed to proceed properly. For instance, in this situation the build-up of carburetor ice may be substantial and the aircraft’s engine may perform poorly for a few minutes as the ice melts. A poorly trained pilot may link the decrease in engine performance to applying carburetor heat and turn off the heat. However, this is a normal consequence and requires a conceptual understanding of the components of the carburetor in order to resolve the problem. In essence, procedural knowledge alone cannot mitigate the situation. Thus, appropriate balance of declarative and procedural knowledge is needed in aviation training. Any aviation training program should allow the student to practice a specific procedure while being provided feedback to address the appropriate declarative knowledge associated with the procedure. However, in order to facilitate practice with procedures, the student needs exposure to the actual systems of the aircraft. Training a specific aviation task requires declarative and procedural knowledge trained through rigorous practice and feedback. However, determining the appropriate levels of practice and feedback for a specific task maybe contingent on the student’s learning preference.
Cognitive learning styles.

Some researchers argue that in order for training to be successful, the instructor must determine the student's learning (Sternberg & Zhang, 2001). According to Sternberg and Zhang (2001), some learners prefer concrete knowledge, or knowledge that is obtained through physical experience. Others prefer abstract conceptualization, or knowledge obtained through symbolic representation. In addition, some learners prefer reflective observation, watching others perform a task and reflecting on his or her results. Other learners transform information by actively participating in an event (Sternberg & Zhang, 2001, p. 228; Kolb, 1984). Regardless, the important component concerning experiential learning is that the learner has a choice as to which approach suits his or her learning capabilities and more importantly the learner adapts to the task at hand. This is referred to as learning styles and is composed of the four modes of transforming knowledge: concrete knowledge, abstract conceptualization, reflective observation, and active participation.

Sternberg and Zhang (2001) argued that the type of learning style used is primarily influenced by the type of information being acquired. In most cases, a particular domain is not exclusively dependent on one learning style but falls within a continuum or combination of at least two learning styles. For example, if the domain is mostly dependent on routine and mechanical activities, the learning style will be predominantly composed of concrete experience and active experimentation. On the other hand, if the task is more passive and abstract, relying more on problem solving skills, the learning style for this group of learners will be more reflective, engaging in abstract conceptualization. In many instances, a particular domain may demand concrete experience and abstract conceptualization as well as active experimentation and reflective observation. In this instance, the training paradigm would follow a cycle, starting with
concrete experience, reflective observation, abstract conceptualization, and active experimentation. Once the cycle is complete, the learner applies what is learned into a new concept, restarting the cycle. This process seems ideal for aviation training which relies on practice and feedback. For a training cycle to successfully continue, the instructor must be able to provide the student with performance feedback and practice as a means of improving performance.

Practice and feedback.

Effective training systems allow participants to develop and maintain appropriate competencies needed to perform a task (Oser, Cannon-Bowers, Salas, & Dwyer, 1999). Any training must incorporate three important components: (a) include all phases of training development, (b) provide performance measurement criterion, and (c) display feedback to the user. The last two components are especially important because the learner needs his or her performance periodically evaluated throughout training. Furthermore, the trainee must be provided effective feedback as a means of determining whether a learned behavior needs to be modified. This can be accomplished by using effective performance measures.

As described by Oser et al. (1999), performance measurements and standards provide the trainer with a comparison of acceptable and unacceptable levels of performance. Using performance measures, the trainer can interpret or diagnose the learner's performance and provide accurate feedback. While quality feedback (appropriate detail and timing) is preferable, even low quality feedback is better than not employing any feedback. Without feedback, students are unable to address and correct the flaws in his or her conceptual understanding. The timing of feedback is less important than no feedback so long the student has access to fixing incorrect or missing knowledge (Oser et al., 1999). Lewis and Anderson (1985) argued that in situations
where feedback is essential (i.e. landing an aircraft), immediate feedback is less useful in
detecting errors. This is because immediate feedback leaves little time for the learner to
acknowledge the error. If immediate-feedback is the only means of training, than it is imperative
for the student to have an opportunity to understand his or her mistakes. A particular skill such as
flight training requires an opportunity for someone to alert the learner of the mistake, explain the
significance of the mistake, and most importantly provide the learner with an opportunity to fix
the mistake.

Feedback and debrief are critical components of training as it ensures internal consistency
throughout a scenario (Oser et al., 1999). It is important the learner understands his or her
strengths and weakness and what performance goals were expected. This can help the learner
understand which areas were underperformed and this require more of his or her attention and
practice. Accordingly measures can provide the trainer a comparison of trainee performance with
“normal” performance parameters for an individual at that stage of skill development. The
challenge in aviation training is that collecting performance parameters during flight can be
difficult and costly, and this is one important reason for using simulation-based training. Even
flight simulators can be expensive. Fortunately, however, over the past decade dramatic
improvements in flight simulation technology have provided reasonable and affordable means of
acquiring aviation training. In fact, this technology can be accessed through one’s own personal
computer providing the user with a variety of ways to train and monitor task performance.

*Flight Simulation and Research*

Several researchers have investigated the use of simulation in flight training (Ortiz, 1994;
Talleur et al. 2003). In most studies, there were significant differences between the groups that
did not receive simulation-based training and those that have received simulation-based training
(Hays, Jacobs, Prince, & Salas, 1992). Those who received the simulation-based training performed better than those who did not. In addition, there has been extensive research in the area of PC-based flight simulation and transfer-of-learning; the majority of the former took place in the mid-to-late 1990s. Most of the research concerning these two components has provided favorable results: those who had used PC-based flight simulation performed better than those who did not (Ortiz, 1994). For example, Ortiz (1994) conducted a study which investigated the feasibility of using a PC-based flight simulation on ab initio candidates. Sixty participants were randomly assigned into one of two conditions: the computer-based flight simulation trained experimental group and a control group which received no computer-based flight simulation training. All participants performed a square flight task and practiced this maneuver until they reached a particular minimum. Participants in the experimental group experienced all computer-based flight simulation training until they reached a performance minimum which they were then asked to test their abilities in an actual aircraft. Participants in the control group devoted all of their time in an actual aircraft. Using the transfer-of-effectiveness ratio, participants in the experimental group spent significantly less time in the aircraft than the control group (they measured the amount of time it took to pass the minimum flight performance requirements). Although this may seem obvious since the participants in the experimental condition devoted most of their training in a simulator, the important thing to note is that the skills transferred effectively to an actual aircraft and participants in this condition were able to complete a square task efficiently while saving a considerable amount of money. Koonce and Bramble (1998) reported that for every two hours of simulator training results in a savings of 1.5 hours of actual flying time when learning how to land. With today’s high fuel costs, these savings are very important.
Taylor, Lintern, and Hulin (1999) insisted that PC-based flight simulation is a great tool for instrument instruction but may deter instructors from using these programs when conducting visual flight instructions (such as private pilot instruction). This is because the level of visual fidelity is insufficient to properly train a private pilot candidate. Such issues included poor graphical detail and visual restrictions (limited to forward vision with no peripheral cues). Dennis and Harris (1998) suggested that although PC-based flight simulation is an excellent tool for initial flight training, it does not simulate proper psychomotor techniques.

Moroney, Hampton and Biers (1999) provided a general framework for PC-based flight simulation training. The framework includes a separate control panel (which includes the conventional six pack display, engine instruments, and radio stack), a large display screen which incorporates peripheral vision, realistic instrument failures, realistic compass with gravitational lag, and ATC simulation capability. In addition, Moroney et al. (1999) found that only specific demonstrations could be used such as flying basics (how to use a checklist, power settings, and navigation), failures, weather effects, fuel management, navigation, GPS usage, and changes in center of gravity.

In another study conducted by Talleur, Taylor, Emanuel, Rantanen, and Bradshaw (2003), 106 instrument rated (but not current) pilots were evaluated to determine the effectiveness of PC-based flight simulation in maintaining instrument currency. These participants were divided into one of four groups: PC-based flight simulation device training, FAA approved flight training device (FTD), training in an actual aircraft, and a control group which received no recurrent training (just an initial current proficiency test in the beginning of the study and at the end). The PC-based flight simulation and FTD conditions all experienced an integration of simulator training and actual flight training. Talleur et al. (2003) found that
participants in the PC-based flight simulation and FTD conditions performed significantly better than participants trained solely in an aircraft or who did not receive any training at all. Talleur et al. suggested that the reason for this is because the users were allowed to stop and review certain components of flight in a simulated environment, focusing on the areas of weakness. Talleur et al. argued that in many cases there is not enough time to focus on small mistakes made during an actual flight and when the flight is over, not all of the mistakes made in a particular flight were remembered during flight debriefing.

One aspect of simulation that is useful for instruction is that simulations (both FAA approved simulations-FTD and PC-based flight simulation) provide the learner with the ability to focus and evaluate a particular component of flight by “pausing” the simulator. This way the instructor can explain to the student alternatives to performing a maneuver, and allow the user to re-practice the maneuver without ever paying for aircraft time. Consequently, pausing provides the student with an opportunity to thoroughly focus on a specific component of flight without the added constraints of time and consequences of error experienced in actual flying conditions.

In review, PC-based flight simulation has several major benefits. Such benefits include a high transfer-of-effectiveness ratio for basic introductory instructions, ability to demonstrate of basic flying skills (navigation, fuel management, checklist procedures, power management, and GPS usage), as well as more advanced instrument skills, a pausing function which allows the instructor to explain a particular component of flight and feedback, and reduced costs of training. Unfortunately, a good portion of PC-based flight simulation research took place 10 years ago, and more current research using the latest high fidelity, PC-based flight simulation platforms is needed. Although simulation fidelity is not a major component of this research study, it poses a
substantial contribution to the effectiveness of training, particularly in regard to realism; hence, the topic of simulation fidelity is described next.

**Fidelity and its effects on reality and realism.**

Alexander, Brunye, Sidman, and Weil (2005) define fidelity as the extent to which the virtual environment emulates the real world. There are three primary forms of fidelity: (a) physical fidelity, (b) functional fidelity, and (c) psychological fidelity. Physical fidelity concerns the degree to which the simulation looks, sounds, and feels like the actual environment. These characteristics are in terms of visual displays, control devices, and auditory sensations. Functional fidelity is the degree to which the simulation responds like the actual environment. Psychological fidelity is the degree to which the simulation replicates the psychological factors associated with the actual task (e.g. stress and fear). If appropriately simulated, the psychological fidelity should provoke the same responses in the simulation as would be expected with the actual equipment in the real-world environment. This is sometimes referred to as cognitive fidelity. Cognitive fidelity is the degree to which the environment requires a user to exercise the same cognitive and processing (e.g. attention and workload) as to what is experienced in the actual setting (Lee, 2005, p. 65). In addition, even if a simulator does not have exact physical fidelity as actual flight, the level of physical fidelity can be irrelevant for certain tasks and skill levels. In other words, the level of fidelity necessary is contingent on the task being trained and the skill level of the learner. For example, if the training task is to teach the learner about making decisions, the level of physical fidelity needed to promote adequate training may not be as high as a task which requires landing a plane (precision). In reality, physical fidelity only contributes to a small portion on evaluating the usefulness of PC-based simulations.
Some researchers argued that "immersion" is useful in evaluating the effectiveness of PC-based simulations (Perez, Gray, & Reynolds, 2006). Immersion is defined as the degree to which the individual feels absorbed by the experience (Perez, Gray, & Reynolds, 2006). There are two primary forms of immersion: diegetic and presence (situated). Diegetic is defined as the user simply being affected by the game or simulation. Presence on the other hand is the illusion of existing within the game space. Presence is the sensation of actually being there (i.e., in the game). Factors that contribute to the sense of presence include control (anticipation of events and being able to control the events), sensory (incorporation of all sensory modalities contributing to the task), distraction (selective attention and interface awareness) and realism (visual scene realism, information realism and meaningfulness). Alexander et al. (2005) suggested, the more real a simulation appears, the more serious the learner will take it. This is an interesting insight on evaluating PC-based simulation devices as it suggests that poor physical fidelity (which may result in a lower degree of immersion) could hamper motivation and attention to details, trumping the overall effectiveness of the experience. Other researchers argue however, that the type of fidelity and the task to be trained are most important (Liu, Macchiarella, & Vincenzi, 2009).

This brings up a recurrent issue in flight simulation based training and use: illusory reality versus realism. Simulation in general attempts to mimic reality to produce a sense of experiencing a situation as if one was actually there, and the issue is whether the user experiences the same level of anxiety, stress, joy, and motivation in a simulated environment as opposed to the actual environment. In simulation, the issue becomes a matter of distinguishing between the perception of reality and the perception of realism and for training, the importance or unimportance of this distinction (Stroffregen et al., 1999). The two issues are inherently
different. Perception of realism is the perception of what is being simulated and perception of
reality is the perception of that which is being simulated (Stroffregen et al., 1999). In the case of
flight simulation based training, a perception of reality would be erroneous since the person is
aware of not being in a real system. Stating that something seems "real" essentially assumes the
person already knows the environment is simulated. For example, Microsoft Flight Simulator
(10.0) allows the user to experience a bird strike and is forced to avoid the birds in the same way
one would avoid the birds in an actual flying situation (because birds naturally drop in altitude
when approached by an airplane, the pilot is trained to pull up). Based on what Stroffregen et al.
(1999) suggested, the simulated environment of a bird strike would not produce the same
behavior since the user is consciously aware of being in a simulated environment (and failure to
avoid the birds would not produce the same consequences). However, would the user react the
same way in a real situation with a flock of birds if he or she did not receive the simulation
training? Higher levels of simulation fidelity will allow the user to experience more variability in
the environment. Regardless of whether or not the user is consciously aware that a simulator is
not real, the practice with a particular situation will ultimately improve the user's performance if
he or she were to encounter that particular situation (such as a bird strike) in an actual
environment. This enriched experience may serve as a motivating factor for student to invest in a
PC-based flight simulator (e.g., Microsoft Flight Simulator) for training purposes.

Gaming and motivation.

Since PC-based flight simulation could fall under the definition of a "game," a brief
review of game-based learning will be addressed. Garris, Ahlers, and Driskell (2002) looked at
the issues associated with game-based learning as a means of understanding a complex subject
matter and making learning more active. This is based on the notion that video games are
intrinsically motivating. Garris et al. (2002) addressed the difference between 'video games' and 'simulation.' Simulations represent a real-world system that can also incorporate aspects of reality for users. Games on the other hand contain rules and strategies and the costs of losing can be consequential but is contained within the game world. Although both share many similarities, the main difference between the two is that simulations propose to represent reality and games do not. Some researchers argue PC-based flight simulation do not use the rules and strategies seen in current in many video games. The structure, rules, and strategies present in video games are both intrinsically motivating and extrinsically motivating, a concept known as identified regulation (Garris et al., 2002).

A key advantage to identified regulation in game play is that it attracts the user into the game over and over, a behavior triggered by a 'game cycle.' The game cycle is comprised of three components: input, process, and outcome. Input contains two key components: instructional content and game characteristics. Instructional content concerns the information of the task at hand. Game characteristics are the various components that make the game unique. This includes fantasy (allows the users to interact in situations that are not part of normal experience), rules and goals, sensory stimuli, challenge, mystery, and control (ability to regulate, direct, and command something).

The process component of the game cycle concerns the characteristics that make a game motivating. Motivation in gaming is generally referred to as 'flow,' a state of optimal performance, enjoyment, and control at a task, where skills are matched to the challenges faced (Garris et al., 2002; Ricci, Salas, & Cannon-Bowers, 1996). There are four elements to the process component of the game cycle. The first is user judgment which is characterized by the user's interest in the game, enjoyment, task involvement, and confidence. The second element is
user behavior or the components of the game that produced sustained involvement (also referred to as persistent reengagement). System feedback is the third element of the process component and addresses the need to provide the user with an assessment of progress toward a goal that drives the learner to expand more effort on a task. This element cannot be fulfilled without the last process component, debriefing. Debriefing provides a link between what is represented in the simulation or gaming experience and the real world (Garris et al. 2002). It provides the learner with an analysis of his or her performance along with motivational information that encourages the learner to fix his or her mistakes in the future. The ‘debrief’ provides the learner with the necessary motivation to continue training in the future.

The last component of the game cycle concerns learning outcomes. Learning outcomes include skill-based learning (basic motor and technical skills), cognitive learning (declarative, procedural and strategic knowledge), and affective learning (attitudes towards the task). All of these outcomes are critical components of the game cycle as they represent a cyclical description of the major influences on human learning. Computer-based gaming devices are capable of producing all three of these components, particularly declarative and procedural knowledge.

The critical components of the gaming cycle shares almost the exact outcomes as provided by Kraiger, Ford, and Salas (1993). These outcomes include (a) cognitive outcomes, (b) skill-based outcomes, and (c) affective outcomes (motivation and self-efficacy). The major components of the cognitive outcome were addressed in the first section of this literature review and make-up the basic structure of acquiring a new skill. Skilled-based learning concerns the transition from declarative knowledge to procedural knowledge, marking the ability for the learner to perform tasks quickly while maintaining parallel activities. Finally, affective based learning is centered on the learner’s attitude which is the internal state that influences the
learner’s choice or personal action. This is primarily addressed through motivational outcomes and self-efficacy. Self-efficacy captures an individual’s personal understanding of how he or she is performing and influences the learner’s willingness to continue a particular task. It is also based on the learner’s attitudes developed during training and the level of motivation to continue training. Self-efficacy is another important part of the training paradigm because it provides the instructor with a general direction of the learner’s sense of accomplishment and confidence in the learned material. Measuring self-efficacy will be another component to this research study.

In summary, PC-based simulation shares many of the features seen in actual aircraft as well as high-fidelity full motion simulators. This includes adequate instrument instruction, realistic cockpit displays, accurate aerodynamics, high functional and psychological fidelity, and environmental realism. These improvements are significant and provide a good opportunity to revisit PC-based flight simulation research. One possible setback of PC-based flight simulation however, is that it does not provide the user with the same level of intrinsic motivation that is prevalent in gaming systems (Garris et al., 2002; Stroffregen et al., 1999). However, the newest version of Microsoft Flight Simulator (version 10.0) has a feature that may compensate for the insufficient level of motivation. This feature is known as the “shared cockpit” and allows users to operate the same aircraft over the internet, from different geographical locations. With the use of this feature, the gap between motivation and PC-based flight simulation could be closed. Specifically, the “shared-cockpit” has potential to be used as part of a web-based instruction strategy.

**Web-Based Training**

Web-based training is training that occurs via the internet without an instructor physically present. Web-based training has been used in many disciples and is a new concept in the training
and learning literature, but the real efficacy of training of this nature has yet to be determined.

The motivational issues addressed with PC-flight simulation training could be mitigated by incorporating live, web-based instruction. Although not all tasks can benefit from this form of instruction, it is likely certain tasks could be taught from a distance, allowing the learner and instructor to precede instruction without leaving the comfort of their homes.

Baker and O’Neil (2006) described nine types of web-based learning experiences: formal course (traditional classroom setting), blended course (live and computer-supported instruction), technology supported courses (live instruction is still utilized but materials and resources are available on the web), technology-enriched environments (practice and simulations are available on the web, but instruction is still live), discretionary web activity (activities that support computer literacy skills), tool use (activities that promote the practice of computer functions), focused games and simulations (goal enriched environments learning a series of expectations in a simulated environment), exploratory games and simulations (goal-focused yet unpredictable learning environment with opportunities for the learner to investigate relationships among procedures, constraints, and processes), and domain specific incidental learning (learning rules and rewards using commercial websites). Exploratory games and simulations is the primary web-learning device to be used in this study.

Many web-based training programs are asynchronous (e.g. online classes) where the learner and the teacher do not have to be connected at a specific time for a specific purpose (Hamilton & Cherniavsky, 2006). Synchronous programs, on the other hand, have coordinated communication as well as whatever is being manipulated via the personnel computer. Shotsberger (2000) proposed if synchronous learning is distributed over the internet, it must be efficient in terms of feedback, particularly in situations where the material being instructed
requires direct feedback. This is especially true in situations where the learner has to discuss the newly acquired information and apply this information in some fashion. Asynchronous learning would be cumbersome in this situation as feedback can be delayed and sometimes even non-existent. Unfortunately, the vast majority of web-based learning programs is asynchronous and leaves out the direct feedback component.

Another issue with web-based training is motivation. Piccoli, Ahmad, and Ives (2001) argued that a major advantage of web-based training is that it is self-regulated, but without proper motivation to complete the work, unmotivated students may not benefit from this form of training. Thus, two difficulties with web-based learning are the lack of feedback and learner motivation. Since feedback is necessary for learning and can also act as a motivator, incorporating feedback in web-based training interventions is crucial. One method to include feedback in web-based training is by using a mentor.

Mentoring is the process that brings together experienced individuals with students in the hope that the student develops critical knowledge, skill, and self-confidence needed to complete a task or series of tasks (Colky & Young, 2006). There are four phases of mentoring: (1) initiation; (2) cultivation; (3) separation; and (4) redefinition. The most critical phases in terms of conveying essential skills, knowledge, and self-confidence are the initiation and cultivation phases. The initiation phase concerns the mentor and mentee becoming acquainted with each other and addressing shared goals and objectives. In a virtual environment, individuals need to be self-motivated and committed for mentoring to work, especially if it is distributed over the internet. The cultivation phase is where the learner develops a sense of self-confidence through accomplishment from the task as well as trust and respect for the mentor. The separation phase is when the learner begins to complete a task and grow independent of the mentor, leading to the
final phase of mentoring, redefinition which is when the learner establishes an identity apart from the mentor and is able to apply what was learned in a way that is molded to the learner's own personal characteristics.

Web-based mentoring is a relatively new form of mentoring, relying on computer mediated communication (CMC). In many instances, mentoring thrives on emotion generated from face-to-face communication and it is this component that makes web-based mentoring different from traditional forms of mentoring since CMC is slower than face-to-face communication and most forms of CMC is transferred via the internet (Derks, Boss, & Grumbkow, 2007; Silvester, Anderson, Haddleton, Cunningham-Snell, & Gibb, 2000; Reynolds & Brannick, in press). Despite differences between mentoring via the web and face-to-face, incorporating live communication and feedback may address some of the issues with motivation deficits demonstrated in past web-based training literature (e.g. Piccoli, Ahmad, & Ives, 2001; Blickensderfer, Johnston, Paris, & Wilson, 2003). Thus, this study was designed to bring together aviation training with web-based instruction, and by using current PC-based flight simulation technology in conjunction with a web-based mentor.
Focus of Study

Statement of Problem

This research study presents a new approach to flight instruction using a PC-based flight simulator. So far, several important aspects of instruction were covered in the introduction which are: 1) capturing the learner's attention, 2) building both declarative and procedural knowledge to enable the learner to proceed through the three phases of skill acquisition and 3) including adequate practice and feedback. Simulation based training is useful for accomplishing all of these facets. Furthermore, PC-based flight simulation may be the vehicle for affordable practice and feedback in future flight training. PC-based flight simulation products such as Microsoft Flight Simulator 10.0 have yielded promising improvements in fidelity and functionality over the past 10 years. The motivational criticisms associated with PC-based flight simulation for training in the past could be resolved through using Microsoft Flight Simulator's (10.0) "shared cockpit" feature with a mentor. This feature resembles synchronized web-based communication and may be the missing link to motivational setbacks from older versions of PC-based flight simulators. Little empirical research exists that examines web-based instruction for flight training. In particular, little, if any, research examines the use of web-based instruction for pilots unfamiliar with a conventional instrument display. Thus, the purpose of this research study was to examine the efficacy of web-based instruction for instrument rated pilots in a Cessna 172 equipped with a conventional cockpit display.

Statement of Hypotheses

It was predicted that training using a low fidelity PC-based flight simulator in conjunction with a distant mentor (not face-to-face) would yield a higher percentage of flight within practical test standards (PTS) compared to those who did not receive distance mentoring.
Specifically,

Hypothesis: Participants using web-based instruction would exhibit greater knowledge, performance, and self-efficacy regarding the operation of a Cessna 172 equipped with a conventional cockpit (six-pack) display under the following tasks: 1) triangulating aircraft position using an ADF radio, 2) attitude flight in instrument meteorological conditions, 3) attitude flight with a vacuum failure in instrument meteorological conditions, and 4) executing an NDB approach with a vacuum failure under instrument meteorological conditions.

Hypothesis a: Web-based participants would exhibit greater declarative knowledge about the tasks as assessed with a knowledge test.

Hypothesis b: Web-based participants would perform the tasks with fewer errors.

Hypothesis c: Web-based participants would exhibit greater self-efficacy about using the conventional (six-pack) display.

Design

The following study is a Solomon’s Four Group Design (see Table 1). This design was implemented as a means to control for possible effects on the dependent variable from a pre-post design. This stems from previous research which suggests that pre-testing sensitizes and influences participants’ post-test performance (Goldstein & Ford, 2002). There are four groups: two experimental groups and two control groups. The experimental groups received training, but differ in terms of pre-post evaluation. Group A (pre-and-post-test with training) is an experimental group that received a pre-training evaluation and post-training evaluation. Group C (post-test with training) was also an experimental group but did not take a pre-training evaluation prior to training followed by a post-training evaluation. Group B (pre-and-post-test without training) is a control group which received a pre-training evaluation followed by a distracter test
consuming an equivalent amount of time as the training, and a post-training evaluation. Group B is similar to Group A with the exception that Group B received a distracter task. Group D (post-test without training) is the second control group which only required one evaluation.

Table 1.

List of groups in the Solomon four-group design.

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-Training Evaluation</th>
<th>Training</th>
<th>Post-Training Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>B</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Methods

Participants

Embry-Riddle Aeronautical University students (33 males and 2 females, age range = 18-30 years) were randomly assigned into one of four conditions: 7 participants in the pre-and-post-test with training condition, 7 participants in the pre-and-post-test without training condition, 7 participants in the post-test with training condition, and 7 participants in post-test without training condition. Four participants were used for pilot testing and the performance from three other participants yielded unrecognizable data and was not used in the analysis. Participants were required to have at least an instrument rating but no higher than a commercial rating. Selected participants also had no more than 10 hours of instrument time (simulated and actual) in an aircraft equipped with a conventional cockpit display. A total of 35 participants were used in this research study. All individuals who took part in this study received a stipend of 70 dollars for participation and they were guaranteed compensation if they completed the entire participation
session. All participants were informed as to the length of the study, what to expect, and were advised they could terminate participation if they felt uncomfortable during the study. Participants signed an informed consent document after being presented with this information (see Appendix A).

Materials

Microsoft Flight Simulator 10.0 was used in this study. The personal computer hardware and software requirements were based from the manufacturer’s recommendations. These requirements include Windows XP SPS2 (256 mb) or Vista (512 mb), a processor speed of at least 1.0 GHz, hard drive space of 15 GB, DirectX 9, and a video card compliant with DirectX 9 with at least 32 mb of ram (Microsoft, 2006). These are the minimal requirements to run Microsoft Flight Simulator 10.0. The computers used in this study were three Dell XPS 710s, with Intel Core 6600 2.40 GHz, 2.00 GB RAM. Two of these computers were used for the researcher and one was used for the participant. Two Platronics Digital Signal Processing (DSP) headsets were used for communication. Saitek Pro Flight System with control yoke, rudder pedals, and throttle quadrant was used. The Saitek Pro Flight System is a device tailored for Microsoft Flight Simulator (10.0 and earlier versions) and includes a fully functional flight control yoke with features including aileron and elevator control, trim, and a throttle quadrant with throttle, mixture and propeller angle control.

The shared-cockpit feature in Microsoft Flight Simulator 10.0 was used for web-based instruction. This feature was used to administer training in the distance-learning conditions where the instructor and the participant were flying the same aircraft but from different locations. For data collection (flight performance), two programs were used: FS Recorder and Fraps®. FS Recorder is a freeware package that allows users to rewind and fast-forward a flight simulator.
video. Fraps® is a program designed to allow video game users to record and convert video
game usage into video format. This program also comes with a screen shot function which the
researcher used to develop 10 sec slides for the independent raters in this study.

Demographics.

A demographics data document was used (see Appendix B). This document inquired the
participant's gender, age, list of certifications, number of total hours flown, number of
instrument flight hours flown, number of hours flown in a conventional six-pack display under
VFR and IFR conditions, number of hours using Microsoft Flight Simulator a week, number of
hours using a simulated air traffic control environment (e.g. VATSIM, IVAO), number of hours
using the "shared-cockpit" feature in Microsoft Flight Simulator 10.0 or FS-Copilot for earlier
versions of Microsoft Flight Simulator, number of NDB approaches flown, and number of
vacuum failures experienced. The demographics document did not specifically inquire for
simulated and actual time so the researcher verbally indicated to each participant that all flight
times specified should include both simulated and actual time.

Flight related documents.

Five flight related documents were used in this study and consisted of three NDB
approach plates and two low-altitude enroute IFR charts (see Appendix C). The low altitude
enroute IFR charts were used for the situation awareness tasks of the performance evaluation and
the NDB approach plates were also used for the performance evaluation. A NDB-B approach
plate was used for the training condition of this study. Appendix C specifies when each flight
related document was used.
Performance measures

Performance was measured based on the number of deviations from practical test standards (PTS) during flight. These deviations are considered errors and two independent raters measured the number of errors made during all phases of flight. The researcher used FS recorder to video record the entire post-training evaluation (pre-training evaluations for the pre-and-post-test with training condition and pre-and-post-test without training condition were not measured due to the nature of the Solomon's Four Group Design; any practice effects caused by the pre-training evaluation would appear in the post-training evaluation). Once the participant finished the evaluation, the researcher used Fraps® to take 10-second screenshots of all phases of flight. These screenshots were used for raters to evaluate performance.

Tasks.

There were three primary tasks in this study: situational awareness task, attitude flight task, and an NDB approach. The purpose of the first two tasks were to separate the use of navigational equipment, specifically the ADF radio, from actual flight in instrument meteorological conditions. The situational awareness tasks required participants to triangulate his or her position (in pause mode) using only an ADF radio and low-altitude enroute IFR chart. The amount of time for each participant to locate his or her position was recorded. The attitude flight task only measured the participants’ ability to fly using a conventional cockpit display in instrument meteorological conditions (no navigation). Half of this task was performed under normal operating cockpit conditions and the other half was performed with a “vacuum failure.” In this situation, participants lost two pertinent instruments in the cockpit: the attitude indicator and heading indicator. The final tasks combined the use of navigational equipment and attitude flight by requiring the participant to execute an NDB approach with a “vacuum failure.” Table 2
lists all tasks and the type of measurement used for each task. For the two phases of flight, all subsequent sub-phases are also listed. The researcher categorized the tasks into three flight evaluation categories: non-vacuum failure attitude flight, vacuum failure attitude flight, and NDB approach.

Table 2.

List of tasks and sub-tasks measured and the type of measurement used for all tasks.

<table>
<thead>
<tr>
<th>Task</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Situational Awareness</td>
<td>Time to locate position</td>
</tr>
<tr>
<td>Attitude Flight</td>
<td>Number of errors</td>
</tr>
<tr>
<td>Non-vacuum failure flight</td>
<td></td>
</tr>
<tr>
<td>Straight-and-level flight</td>
<td></td>
</tr>
<tr>
<td>Right turn</td>
<td></td>
</tr>
<tr>
<td>Descent</td>
<td></td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td></td>
</tr>
<tr>
<td>Straight-and-level flight</td>
<td></td>
</tr>
<tr>
<td>Left turn</td>
<td></td>
</tr>
<tr>
<td>Climb</td>
<td></td>
</tr>
<tr>
<td>NDB Approach</td>
<td>Number of errors</td>
</tr>
<tr>
<td>Straight-and-level flight</td>
<td></td>
</tr>
<tr>
<td>Right turn; intercepting NDB bearing</td>
<td></td>
</tr>
<tr>
<td>Straight-and-level flight; tracking</td>
<td></td>
</tr>
<tr>
<td>NDB</td>
<td></td>
</tr>
<tr>
<td>Descent; reverse sensing</td>
<td></td>
</tr>
<tr>
<td>Straight-and-level; reverse sensing</td>
<td></td>
</tr>
</tbody>
</table>
Raters.

A total of three independent raters scored participant performance in this research study. Only two raters were utilized for each participant and a third rater was used as a substitute for rater two for the last five participants. All raters were licensed private pilots and the third rater was a licensed private pilot with an instrument rating. The researcher trained all raters on how to determine if a participant is within practical test standards by focusing on three pertinent instruments: altimeter, airspeed indicator and heading indicator. Raters were responsible for viewing 10 second screenshots of participants’ evaluation flight and determined if each participant was within practical test standards for each slide. The raters used a spreadsheet which labeled each phase and sub-phase of the evaluation in chronological order (see Appendix D). If a participant was outside of the practical test standards for a specific slide, the rater indicated this error by writing a checkmark in the specific box of the violated standard. The raters added the number of errors for each practical test standard within the sub-phase, phase, and the total number of errors. All raters were blind as to the condition of each participant.

Practical Test Standards (PTS).

The practical test standards issued by the Federal Aviation Administration for the use of judging pilot proficiency were adopted in this study. There are three primary measures used: altitude (+/- 100), heading (+/- 10°), and airspeed (+/- 10 knots of 100 knots). Some of these measures were not used in specific phases of flight (i.e., when a participant is turning an aircraft, it would be illogical to measure headings as this is constantly changing). Appendix D specifies the practical test standards implemented for specific phases of flight. This was the primary measured used to judge performance in this research study.
Data Transformation.

The frequency of errors was initially calculated for each participant by the raters. Since it can be argued that frequency counts are not representative of continuous data, rater scores were converted to percentages. More specifically, the researcher subtracted the total number of errors for each sub-phase and phase of flight by the total number of practical test standards measured. For instance, the first phase of the non-vacuum failure attitude flight consisted of straight-and-level flight. For this phase, there are three practical test standards the participant must abide by: altitude, heading, and airspeed. This phase lasted two minutes creating a total of 12 slides. Since there are three practical test standards measured for this specific phase, there are a total of 36 standards measured for this phase (three standards multiplied by 12 slides). The researcher subtracted the number of errors for this phase from 36 and divided the resultant by 36. This created a percentage score of the portion of flight within practical test standards (e.g. 87% of flight within practical test standards; 13% of flight outside of practical test standards). Appendix E is an example of rater error frequency transformed to percentage of flight within practical test standards. Each rater had a separate data transforming scoring sheet as depicted in Appendix E.

Inter-rater reliability.

Once frequency data was transformed into percentages, the researcher compared the reliability of both raters’ scores for each participant. Inter-rater reliability was calculated for the three flight evaluation categories using a Pearson’s correlation for each (as depicted in Table 3). There are strong correlations for all five categories with very little disagreement in participant performance (see Table 3). Since all categories yielded strong correlations, the researcher averaged the percentage scores from both raters to create a single composite score for each participant (percentage of flight within PTS).
Knowledge Assessment

A written knowledge test was administered to all participants after the post-training evaluation. In addition, participants in conditions the pre-and-post-test with training condition and the pre-and-post-test without training condition also received a knowledge test in the pre-training conditions. Both of these written knowledge tests covered the same material but with different questions (see Appendix F). The pre-training knowledge evaluation was not analyzed for its purpose was to test for practice effects in the Solomon's Four Group Design. If any effects were found, it would be detected in the post-training evaluation. Both evaluations consisted of nine questions. Questions covered NDB navigation, ADF usage, magnetic variation, conventional cockpit system failures (e.g., vacuum and static failures), and six-pack instrument identification. All participants received a final score based the number of correct answers.

Self-efficacy and reaction evaluations

The self-efficacy and reaction evaluations address the participants’ attitude toward their interaction and training in the conventional cockpit (see Appendix G). There are 16 questions, eight of which pertain to self-efficacy and eight pertaining to participant reaction to their training.
and cockpit display. All questions from both questionnaires were positively skewed and answers were selected based on a seven-point Likert Scale selection (i.e., rating scale: 1 = To no Extent; 7 = To a Great Extent).

*Training Manual*

A training manual for this study was developed that describes all of its components (see Appendix H). This manual was written exclusively for the researcher (and instructor’s dialog for the training intervention) to use throughout the entire study and includes the dialog between the participant and the researcher from the introduction of the study (e.g., informed consent) through all flight tests and ending at the debriefing. The manual was designed to allow the researcher to read the information to the participant verbatim as a means of ensuring all participants were accurately trained and assessed. The training was designed in collaboration with a subject-matter expert who also served as the certified flight instructor for this study.

*Pre- and post-flight training evaluations*

Each pre-and post flight training scenarios took approximately 25 minutes to complete. The meteorological conditions for both flight evaluations were the same (1/4 mile visibility up through 9000 ft). As mentioned previously, there are three tasks participants were responsible for: situational awareness task, attitude flight task (non-vacuum failure and vacuum failure), and a NDB approach. For both scenarios, participants were briefed on all three tasks. Briefing included instruction on the situational awareness task which required the participant to locate his or her position using only an ADF radio. This task was accomplished in “pause mode.” The participant was also informed as to what to expect in the attitude flight task. This task consisted of the researcher giving the participant vectors in instrument meteorological conditions. Participants were also informed that a vacuum failure would occur five minutes into the attitude
flight task. In essence, half of the attitude flight took place in a normal operating aircraft and the other half took place in an aircraft with a failed vacuum. The task took approximately 8 minutes to complete. Both attitude flights took place in separate locations in the Midwest region of the United States and (pre-and-post) started in the location of situational awareness task (i.e., once the participant located his or her correct position in the situational awareness task, the simulator was “unpaused” and the attitude flight commenced).

For the NDB approach, participants were briefed on all pertinent information required to execute the approach. This information included the starting location, distance, and, heading from the initial fix, altitude procedures, and circling procedures. Both approaches were executed with an inoperative vacuum pump and participants in both scenarios were informed of this. The pre-training evaluation took place in Worchester, MA. The starting location took place 7 nautical miles from the SPENO intersection at an altitude of 2,900 ft and heading of 145°. The participant was informed to maintain present heading and altitude until crossing the SPENO intersection. This point was also the point for the participant to track the 109° bearing inbound to the DUNCA NDB (as published in the NDB RWY 11 approach plate; see Appendix C). Participants were informed to maintain 2,900 ft until crossing the NDB where they descended to an altitude of 1,700 ft (approximate circling minimum). Once reaching 1,700 ft, the participant was asked to maintain straight-and-level flight for one minute. After one minute, the flight was terminated. The post-training NDB approach followed similar procedures but in different a location of the United States. This approach took place in White Plains, NY. The starting location shared the same heading and distance from the initial fix as the pre-training evaluation: 7 nautical miles from the FARAN intersection at a heading of 145°. The starting altitude for this approach was 2,000 ft since the circling minimums were lower for this approach. Both approaches had an
altitude differential between the starting altitude and circling minimums of 800 ft. Once the participant crossed the FARAN intersection, he or she was informed to track the 162° bearing inbound to the HESTER NDB. After crossing the NDB, the participant was informed to descend to 1,200 ft (approximate circling minimum). After reaching this altitude, the participant flew a straight-and-level course for one minute. All of this information was briefed to the participant prior to both evaluations.

**Web-based Instruction**

Participants received web-based instruction where the researcher and participant sat at different locations utilizing the "shared-cockpit" feature in Microsoft Flight Simulator 10.0. Instruction covered four primary sections: developing an instrument scan (e.g. box method and hub and spoke method), attitude flight with the learned scan, vacuum failure, and an NDB approach with a vacuum failure. All sections included formal instruction by a certified flight instructor and practice after each section. Instruction was administered in the same order as it appears in Appendix H. This was important since each section was predicated on the previous section (i.e., in order to fly an NDB approach with a vacuum failure, it is critical the participant understands how to fly the aircraft with a failed vacuum pump prior to executing an approach).

**Instruction.**

Conventional cockpit instruction covered in detail the four primary components discussed previously: developing an instrument scan, attitude flight with the learned scan, vacuum failure, and an NDB approach with a vacuum failure. Before initiating the training intervention, the researcher first linked three computers from separate locations. Two of the computers were used by the flight instructor, one of which was used to view the conventional cockpit and the other was used as an ATC function for the instructor to accurately identify the aircrafts position. The
instructor also used a GPS function when the ATC function was inoperative (the GPS function was not available to the participant). The participant sat at a separate location from instructor using a third computer. The instructors and participant’s computers were linked via Microsoft Flight Simulator 10.0’s shared cockpit feature, found in the multiplayer section of this software. Platronics Digital Signal Processing (DSP) headsets were used for communication between the participant and instructor. The shared-cockpit feature does have the capability of voice communication, but there is a miniscule delay between what is transmitted through the microphone and what could be heard in the room (since the participant and instructor were in the same room). Consequently, this was distracting so the DSP headsets were utilized to dampen any outside sound and to execute direct communication.

The training took place 10 nautical miles south of the Carisle, PA airport over the PIFER intersection at a heading of 360°, 4,000 ft, and 100 knots. Winds were calm and the visibility was ¼ mile. Once the training intervention was ready for the participant and instructor, the participant sat down at his or her location and the instructor was seating at his location shortly after. The instructor avoided face-to-face contact with the participant until after the training intervention. Once seated, the instructor introduced himself through the DSP headsets and training commenced. Both the instructor and participant were able to transfer controls via the Shift + B function in Microsoft Flight Simulator 10.0. The participant had control of the aircraft for most of the training but the instructor did take control on occasion to demonstrate a specific maneuver.

Flight instructor qualifications.

A certified flight instructor was hired to administer the training intervention in this study. His licenses are the following: PPL, instrument, CSEL, CMEI, CFI, CFII. The instructor
qualification must be through certified flight instructor (instrument-CFII) since the training intervention is strictly instrument related.

**Distracter Tasks**

For participants in a control conditions, a distracter task was administered. The distracter tasks included a FAA IFR written examination (Aviation Supplies & Academics, 2007). These distracter tasks were administered for those participants who did not receive training and/or a pre-training evaluation. For participants in pre-and-post-test without training condition, only one IFR written examination was administered. For those in post-test without training condition, two separate examinations were administered. Each participant was required to answer as many questions as he or she could within 30 minutes. All subsequent charts associated with the exam(s) were provided and the researcher insured none of the questions were used in either knowledge evaluations.

**Procedures**

There are six components to the current research study: participant introduction (e.g., demographical information and informed consent), basic manual flight instruction, flight evaluations (pre-and-post), conventional cockpit instruction, knowledge evaluations, self-efficacy and reaction evaluations, and debriefing. All participants received participant introduction, basic manual flight instruction, flight evaluation(s), knowledge evaluation(s), and a debriefing (self-efficacy and reaction evaluations, participant contact information for payment). Conditions differed based on whether they received a pre-training evaluation and conventional cockpit instruction (see Table 4 for a chronological list of events per condition).
Table 4.

*List of participation events per condition.*

| Condition A | Participant Introduction  
| Basic Manual Flight Instruction | Pre-Training Evaluation Flight  
| Knowledge Evaluation | Conventional Cockpit Instruction  
| Post-Training Evaluation Flight | Knowledge Evaluation  
| Self-Efficacy Evaluation |

| Condition B | Participant Introduction  
| Basic Manual Flight Instruction | Pre-Training Evaluation Flight  
| Knowledge Evaluation | Distracter Task  
| Post-Training Evaluation Flight | Knowledge Evaluation  
| Self-Efficacy Evaluation |

| Condition C | Participant Introduction  
| Basic Manual Flight Instruction | Distracter Task  
| Conventional Cockpit Instruction | Post-Training Evaluation Flight  
| Knowledge Evaluation | Self-Efficacy Evaluation |

| Condition D | Participant Introduction  
| Basic Manual Flight Instruction | Distracter Task  
| Distracter Task  
| Post-Training Evaluation Flight | Knowledge Evaluation  
| Self-Efficacy Evaluation |

*Participant introduction.*

Flyers were distributed through Embry-Riddle’s mailing system to solicit participation.

Upon arrival at the experimental site, all participants were first given a brief description of the
nature of the research and were informed that participation in the research study was voluntary. Participants were advised that compensation for participation would be given in the amount of 70 dollars upon completion to the study and participants were asked to sign an informed consent document. Upon signing the informed consent document, participants were given a demographic questionnaire which took approximately five minutes.

**Basic manual flight instruction.**

After the completion of the questionnaire, the participant was than seated at a computer with Microsoft Flight Simulator 10.0 open. The flight simulator was in “pause” mode at 2,000 ft in a Cessna 172. This purpose of this instruction was to familiarize the participant with Microsoft Flight Simulator and to allow participants to acclimate to the sensitivities of the flight controls. It was not intended to provide participants with formal instruction. In addition, this portion of the study was administered using a Garmin 1000 to avoid any possible practice effects with a conventional cockpit. The instruction addressed altitude, airspeed, and heading changes. Altitude corrections were manipulated through a control yoke and trim tab. The trim tab was located on the upper left side of the control yoke and is pertinent for maintaining pitch stability, especially in Microsoft Flight Simulator. The participant was also responsible for airspeed adjustments and was allowed practice with the throttle quadrant located next to the control yoke. Mixture and propeller angle controls were not manipulated during the study and the participant was advised of this. Rudders pedals were also accessible to the pilot if he or she felt it was necessary to use them in order to maintain coordinated flight.

The researcher briefly showed the participant the necessary components of the yoke and throttle quadrant. Once this was administered, the researcher sat directly behind the participant to monitor his or her progress. The introduction began in visual meteorological conditions directly
over the Daytona International Airport. All participants first maintained straight-and-level flight at 2,000 ft for two minutes at a heading of 360° and 100 knots. After two minutes, the participant was asked to climb-and-maintain 3,000 ft at a heading of 360° and 100 knots. Upon reaching 3,000 ft, the participant was advised to descend back to 2,000 ft at the same heading and airspeed. At 2,000 ft, the participant made a left turn to 270° and a right turn back to 360°. After the heading exercise, the participant was asked to decelerate to 90 knots and accelerate back to 100 knots. Finally, the participant made a climbing right turn to an altitude of 3,000 ft and a heading of 090°. Once completed, the researcher transitioned to the next phase of experimentation.

*Flight evaluations.*

Flight evaluations were administered according to which condition participants were randomly assigned to (see Table 4). For participants in the pre-and-post-test with training condition and the pre-and-post-test without training condition (control), a pre-and-post-training evaluation was given. For participants in the post-test with training condition and post-test without training condition (control), only a post-training evaluation was administered. All flight evaluations took place at one computer. The researcher stored the necessary flight for the specific condition and task (attitude flight or NDB approach) in Microsoft Flight Simulator (the flight simulator allows users to save flights). Once the flight was called, the researcher activated FS Recorder to record the flight.

The researcher sat behind the participant during the evaluations. This allowed the researcher to determine the correct stage of flight. Both evaluations started with the situational awareness task directly over the specific intersection the participant was required to find using NDB triangulation. This task was performed in “pause mode.” The researcher started a
stopwatch immediately after the participant started to input NDB frequencies. Upon completion of the task, the participant was asked to identify the specific waypoint. The exact names and coordinates for all waypoints and starting positions are listed in the training manual (see Appendix H). After correctly identifying the waypoint, the participant started the attitude flight task. This was executed simply by "unpausing" the flight. The first portion of the attitude flight consisted of straight-and-level flight, a turn, and a descent. The second portion of the attitude flight consisted of straight-and-level flight, a turn, and a climb. Both portions were separated by normal cockpit operations (first portion of flight) and vacuum failure flight (second portion of flight). The vacuum failure automatically occurred at five minutes into the flight (see Appendix H for specific instructions). All participants were verbally instructed by the researcher when to execute the next task (e.g., turn left, descend). For instance, upon the completion of the two minute straight-and-level non-vacuum failure attitude flight, the participant was asked to turn right to a heading of 090°. Once he or she reached this heading, the participant was asked to descend to 3,000 ft. After reaching this altitude, the participant flew a straight-and-level course for approximately 30 sec until a vacuum failure occurred. As soon as this occurred, the straight-and-level vacuum failure portion of the attitude flight began. The portion of time between when the participant leveled-off at 3,000 ft and the onset of the vacuum failure was not evaluated in this study.

Upon the successful completion of the attitude flight, the researcher saved the flight in FS Recorder and loaded the appropriate NDB approach. Once the flight was loaded, the researcher activated FS Recorder. Unlike the attitude flight task, the NDB approach did not require any dialog between the researcher and the participant. The participant was briefed on the specifics of the approach prior to the flight evaluation.
Debriefing.

Upon completion of the post-training flight evaluation, all participants completed the knowledge evaluation. Once finished, participants completed the self-efficacy and reaction questionnaire. Once all paperwork was completed, the researcher informed the participant about the anonymity of his or her performance data, and obtained contact information for participation payment.
Results

The purpose of this study was to evaluate the efficacy of web-based instruction for instrument rated pilots transitioning to an aircraft (Cessna 172) equipped with a conventional (six-pack) cockpit display (see table 5 for demographics results). It was hypothesized that participants who received web-based instruction would yield greater knowledge, performance, and self-efficacy regarding the operation of an aircraft equipped with a conventional cockpit display. Based on the structure of the Solomon’s Four Group Design, performance between experimental groups (pre-and-post-test with training and post-test with training) should differ significantly from the control groups (pre-and-post-test without training and post-test without training). Performance within the experimental and control groups should not differ significantly.

With respect to performance evaluations, there were three primary tasks implemented: situational awareness task, attitude flight task, and NDB approach task. With the exception of the situational awareness task, performance was measured based on the percentage of flight participants flew within practical test standards. The three practical test standards used were airspeed, altitude, and heading. Table 6 provides a correlation matrix for all dependent measures used in this study. The following section will report each evaluation in its respective order, including all sub-phases discussed in the previous section. Performance evaluation will be followed by analysis of knowledge and self-efficacy, and reaction evaluations.
Table 5.

Descriptive statistics from demographics evaluation.

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Hours</td>
<td>141.39</td>
<td>52.56</td>
<td>70.00</td>
<td>290.00</td>
</tr>
<tr>
<td>Total Instrument</td>
<td>40.43</td>
<td>16.85</td>
<td>35.00</td>
<td>120.00</td>
</tr>
<tr>
<td>Six-Pack Instrument Time</td>
<td>1.82</td>
<td>2.94</td>
<td>0.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Six-Pack Time-VMC</td>
<td>43.90</td>
<td>42.46</td>
<td>0.00</td>
<td>190.00</td>
</tr>
<tr>
<td>FS Time per Week</td>
<td>1.68</td>
<td>1.68</td>
<td>0.00</td>
<td>6.00</td>
</tr>
<tr>
<td>Total VATSIM Hours</td>
<td>48.27</td>
<td>234.98</td>
<td>0.00</td>
<td>1200.0</td>
</tr>
<tr>
<td>VATSIM Use per Week</td>
<td>1.79</td>
<td>0.41</td>
<td>0.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Total Shared-Cockpit Hours</td>
<td>0.07</td>
<td>0.26</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Total Number of NDB Approaches</td>
<td>2.19</td>
<td>2.41</td>
<td>0.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Number of Vacuum Failures</td>
<td>1.89</td>
<td>0.31</td>
<td>0.00</td>
<td>2.00</td>
</tr>
</tbody>
</table>

Table 6.

Correlation Matrix for all dependent measures.

<table>
<thead>
<tr>
<th></th>
<th>Non-Vac</th>
<th>Vacuum</th>
<th>NDB</th>
<th>Know</th>
<th>Self</th>
<th>Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Vac</td>
<td>r</td>
<td>n</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vacuum</td>
<td>r 0.222</td>
<td>n 28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDB</td>
<td>r 0.257</td>
<td>n 28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Know</td>
<td>r 0.227</td>
<td>n 28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self</td>
<td>r 0.039</td>
<td>n 28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reaction</td>
<td>r 0.269</td>
<td>n 21</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*denotes significance at .05  **denotes significance at .01
Performance Evaluations

The following analysis will cover the situational awareness task, attitude flight task, and NDB approach task respectively. Table 7 provides a descriptive analysis for all performance evaluations. There are only two actual dependent measures: time (situational awareness task) and percentage of flight within practical test standards (attitude and NDB flight tasks). However, since both the attitude flight task and NDB approach task are divided into phases, each phase is its own evaluation. In this case, the measure used is this same (percentage of flight within practical test standards) with the exception of the situational awareness task, but each phase is compared separately. More specifically, each phase measures a separate aspect of the participants' overall ability. For example, the attitude flight task is subdivided into two phases: non-vacuum failure flight and vacuum failure flight. Both of these phases contain the same performance measure (percentage of flight within practical test standards), but evaluate performance under separate conditions (no vacuum failure and vacuum failure). Therefore, each phase is considered a separate evaluation even though all of the phases share the same measure.
Table 7.

*Means and standard deviations for all evaluations in all conditions.*

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Condition</th>
<th>( n )</th>
<th>( M )</th>
<th>( SD )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Situational Awareness</td>
<td>A</td>
<td>7</td>
<td>90.3 sec</td>
<td>48.0 sec</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>97.6 sec</td>
<td>61.1 sec</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>123.1 sec</td>
<td>57.0 sec</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>211.6 sec</td>
<td>124.4 sec</td>
</tr>
<tr>
<td>Non-vacuum failure flight</td>
<td>A</td>
<td>7</td>
<td>98.6 %</td>
<td>1.6%</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>94.9%</td>
<td>4.0%</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>96.8%</td>
<td>3.3%</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>96.8%</td>
<td>4.5%</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>A</td>
<td>7</td>
<td>93.1%</td>
<td>5.8%</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>86.9%</td>
<td>9.7%</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>82.4%</td>
<td>12.0%</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>56.9%</td>
<td>26.3%</td>
</tr>
<tr>
<td>NDB approach</td>
<td>A</td>
<td>7</td>
<td>86.3%</td>
<td>11.5%</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>84.1%</td>
<td>13.7%</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>83.4%</td>
<td>12.1%</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>65.4%</td>
<td>22.7%</td>
</tr>
</tbody>
</table>

A one-way multivariate analysis of variance (MANOVA) was used for this study. A Box's \( M \) test was not significant, \( F(30, 1583.66) = 1.17, p < .240 \), indicating homogeneity.

Subsequently the multivariate test showed a significant difference, Wilks' Lambda = .324, \( F(12, 55.85) = 2.12, p < .016 \), partial \( \eta = .303 \), observed power = .872 (table 8 illustrates all statistical tests for all evaluations). The following subsections will cover the results of all four evaluations.
Table 8.

*F-test results for situational awareness task, non-vacuum failure attitude flight task, vacuum failure attitude flight task, and NDB approach.*

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>$F$</th>
<th>$p$</th>
<th>$\eta$</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Situational awareness</td>
<td>3.53</td>
<td>.030*</td>
<td>.306</td>
<td>.711</td>
</tr>
<tr>
<td>Non-vacuum failure flight</td>
<td>1.23</td>
<td>.299</td>
<td>.139</td>
<td>.301</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>7.32</td>
<td>.001*</td>
<td>.478</td>
<td>.965</td>
</tr>
<tr>
<td>NDB approach</td>
<td>2.65</td>
<td>.071</td>
<td>.249</td>
<td>.574</td>
</tr>
</tbody>
</table>

*Denotes significant results

**Situational awareness task.**

The situational awareness task measured the amount of time it took each participant to triangulate his or her position using only an ADF radio and a low-altitude enroute IFR chart. A graphical analysis of this measure indicates an increase in average time and standard deviation across conditions (see figures 1 and 2). It was hypothesized that participants who received web-based training would perform better than participants who did not receive web-based training. Significant differences were found for this evaluation, $F(3, 24) = 3.53, p = .030$, partial $\eta = .306$, observed power = .711. A LSD post hoc test for this dependent measure revealed when the pre-and-post-test with training condition ($p = .008$), pre-and-post test without training condition ($p = .012$), and post-test with training ($p = .046$) condition were compared to the post-test without training condition, all comparisons yielded significant differences. Since the control conditions did not differ from the experimental conditions, the results do not support the hypothesized claim for this evaluation.
Figure 1. Line graph of mean time (sec) as a function of all conditions.
Figure 2. Boxplot of means scores measured in seconds as a function of all conditions.

Non-vacuum failure attitude flight task.

The non-vacuum failure attitude flight task measured participants' ability to fly in instrument meteorological conditions with no instrument failures (e.g. vacuum failure). No significant differences were detected as all participants in all conditions performed the same, $F(3, 24) = 1.26, p = .299$, partial $\eta^2 = .139$, observed power = .301. This indicates that under normal conditions, participants can fly an aircraft equipped with a conventional cockpit display in instrument meteorological conditions with little experience and practice. Unfortunately it was hypothesized that participants who received web-based training would perform better on all evaluations than those participants who did not receive training. For instance, in this specific evaluation, pilots randomly assigned to either control groups should have performed worse than participants in either experimental groups. This is not the case as participants across all groups performed statistically the same (see figure 3). In addition, the range of the percentage scores
across all groups was rather compacted, where even the lowest score across all conditions performed reasonably well (see figure 4). Therefore, performance in this evaluation does not support the hypothesized claim that participants who received web-based training would perform better.

Figure 3. Line graph of percent of flight within practical test standards as a function of all conditions for the non-vacuum failure flight task.
Figure 4. Box-plot of means percentage scores for the non-vacuum failure attitude flight task as a function of all conditions.

Vacuum failure attitude flight task.

The implementation of a vacuum failure during attitude flight significantly affected participant performance for this evaluation, $F(3, 24) = 7.32, p = .001$, partial $\eta = .478$, observed power = .965. This task resembled the non-vacuum failure attitude flight task with the exception of the loss of the attitude and heading indicators. The results however, do not reflect what was hypothesized. The structure of the Solomon's Four Group Design tests for practice and as mentioned throughout this manuscript, the experimental groups together should perform better than control groups combined. A graphical depiction of participant performance during the vacuum failure flight task reveals a distinct difference between post-test without training condition and the other three conditions (see figure 5). An LSD post hoc test statistically confirms this observation as the first three conditions differed significantly from the post-test
without training condition (pre-and-post-test with training, $p = .0001$; pre-and-post-test without training, $p = .001$; post-test with training, $p = .005$). Both experimental conditions were statistically similar ($p = .212$), however the pre-and-post-test without training condition was also statistically similar to both experimental conditions (pre-and-post-test with training, $p = .467$; post-test with training, $p = .593$). In addition, variance seems to increase with a decrease in practice opportunities. Figure 6 represents this observation as the pre-and-post-test with training condition shows the least variability between scores, pre-and-post-test without training and post-test with training share similar variability, while the post-test without training reveals the greatest variability. It is clear from this observation that practice decreases participant variability that instruction alone does not influence. Therefore, the hypothesis that web-based instruction would improve participant performance is not supported.
Figure 5. Line graph of percent of flight within practical test standards as a function of all conditions for the vacuum failure flight task.
Figure 6. Box-plot of means percentage scores for the vacuum failure attitude flight task as a function of all conditions.

Non-vacuum failure and vacuum failure flight task evaluations.

The purpose of the non-vacuum failure attitude flight task was to compare changes in performance after the onset of a vacuum failure. In this instance, it is necessary to statistically compare performance before and after a vacuum failure. A repeated measure one-way MANOVA was used to evaluate participant performance before and after a vacuum failure for the attitude flight task. A Box’s M test was not significant, $F(9, 6600.85) = 1.95, p = .042$, indicating heterogeneity. Subsequently the multivariate test for the before and after vacuum failure performance scores showed a significant difference, Wilks’ Lambda = .401, $F(1, 24) = 35.87, p = .0001$, partial $\eta = .599$, observed power = 1.00. For the before and after vacuum failure performance scores by training condition interaction, a significant difference was found, Wilks’ Lambda = .507, $F(3, 24) = 7.78, p = .001$, partial $\eta = .493$, observed power = .973. A Greenhouse Geisser repeated measures analysis for the before and after vacuum failure
performance scores revealed significant differences, $F(1, 111.62) = 35.87, p = .0001$. The before and after vacuum failure performance scores by training condition interaction also revealed significant differences for the Greenhouse Geisser repeated measures analysis, $F(3, 111.62) = 7.78, p = .001$. A significant main effect was found for the training condition, $F(3, 24) = 6.44, p = .002$.

Using paired-independent samples t-tests (one for each condition) for simple effects analysis, the post-test with training condition, $t(6) = 3.49, p = .013$, and the post-test without training condition, $t(6) = 4.14, p = .006$ yielded significant results. The pre-and-post-test with and without training conditions did not yield significant differences (see table 9). This indicates depreciation in performance before and after the onset of a vacuum failure in attitude flight. This also suggests that when practice is limited, the ability to fly an aircraft with a vacuum failure in instrument meteorological conditions decreases.

Table 9.

*Paired-independent samples t-tests comparing participant performance during non-vacuum failure and vacuum failure attitude flight.*

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean difference</th>
<th>SD</th>
<th>$t$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5.50</td>
<td>6.28</td>
<td>2.32</td>
<td>.060</td>
</tr>
<tr>
<td>B</td>
<td>7.93</td>
<td>9.20</td>
<td>2.28</td>
<td>.063</td>
</tr>
<tr>
<td>C</td>
<td>14.36</td>
<td>10.90</td>
<td>3.49</td>
<td>.013*</td>
</tr>
<tr>
<td>D</td>
<td>39.86</td>
<td>25.50</td>
<td>4.14</td>
<td>.006*</td>
</tr>
</tbody>
</table>

*Denotes significant results*
NDB approach.

The NDB approach task required participants to execute an approach using only an ADF radio in instrument meteorological conditions. The flight task was also performed with a vacuum failure. The results of this task yield similar results with the vacuum failure attitude flight task (see figure 5 and figure 7). However, no significant differences were detected, $F(3, 24) = 2.65, p = .071$, partial $\eta = .249$, observed power = .564. The variability issues of the vacuum failure attitude flight task are also present in the NDB approach task. Figure 8 illustrates this notion as variability between conditions increases as practice decreases. Since significant differences were not detected, the results from this task do not support the hypothesized claim that web-based training improves pilot performance.

Figure 7. Line graph of percent of flight within practical test standards as a function of all conditions for the NDB approach flight task.
Figure 8. Box-plot of means percentage scores for the NDB approach flight task as a function of all conditions.

Implications of a two-group design.

The Solomon’s Four Group Design in this particular research study calls for a one-way MANOVA to be used. However, its composition is only comprised of two conditions: training condition (experimental condition) and a control condition. Although combining both control and experimental groups would provide neither statistical nor methodological merit (since the distribution of practice is not equal within both control and experimental conditions), it still may provide some interesting insight if conditions (experimental and control) are compared separately based on an equal number of evaluations received (practice). In this instance, experimental pre-and-post-test with training condition is compared to pre-and-post-test without training condition (control) and the post-test with training condition is compared to the post-test
without training condition (control). In essence, this would require the use of multiple independent samples t-tests (four for both comparisons).

Using multiple independent samples t-test comparing the pre-and-post-test with training condition and the pre-and-post-test without training condition, it is determined there is no statistical difference for any of the four evaluations (see table 10). This does not support the hypothesis that participants who received training would perform better. Based on these results, when the number of evaluations (practice) is equal, practice alone yields the same performance as practice with instruction. However, limited practice does impede flight performance. This is demonstrated when the post-test with training and the post-test without training conditions are compared statistically (see table 11). Multiple independent samples t-tests for this comparison reveals significant findings only for the vacuum failure attitude flight task, \( t(8.39) = 2.33, p = .047 \) (homogeneity not assumed). For this task, the experimental group \((M = 86.42, SD = 12.0)\) remained within practical test standard for a significantly larger percentage of flight than the control group \((M = 56.93, SD = 26.33)\). This suggests that under limited practice conditions, instruction significantly increases the percentage of flight within practical test standards.
Table 10.

*t-test results for situational awareness task, non-vacuum failure attitude flight task, vacuum failure attitude flight task, and NDB approach for conditions the pre-and-post-test with training and the pre-and-post-test without training conditions.

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>t</th>
<th>p</th>
<th>df_</th>
</tr>
</thead>
<tbody>
<tr>
<td>Situational awareness</td>
<td>.252</td>
<td>.806</td>
<td>12</td>
</tr>
<tr>
<td>Non-vacuum failure flight</td>
<td>2.29</td>
<td>.052</td>
<td>7.94*</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>1.44</td>
<td>.176</td>
<td>12</td>
</tr>
<tr>
<td>NDB approach</td>
<td>.327</td>
<td>.749</td>
<td>12</td>
</tr>
</tbody>
</table>

*Denotes homogeneity not assumed

Table 11.

*t-test results for situational awareness task, non-vacuum failure attitude flight task, vacuum failure attitude flight task, and NDB approach for the post-test with training and the post-test without training conditions.

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>t</th>
<th>p</th>
<th>df_</th>
</tr>
</thead>
<tbody>
<tr>
<td>Situational awareness</td>
<td>.171</td>
<td>.113</td>
<td>12</td>
</tr>
<tr>
<td>Non-vacuum failure flight</td>
<td>.0001</td>
<td>1.00</td>
<td>12</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>2.33</td>
<td>.047**</td>
<td>8.39*</td>
</tr>
<tr>
<td>NDB approach</td>
<td>.185</td>
<td>.089</td>
<td>12</td>
</tr>
</tbody>
</table>

*Denotes homogeneity not assumed; **denotes significant results
The practical test standards used to measure performance in this study are reflected by a combined composite score unifying all practical test standards for each phase of flight. The scores represented previously provide no insight as to which practical test standard(s) may have reduced or improved pilot performance. In this section, practical test standards are measured separately for each phase of flight (e.g., altitude across all three phases). In order to accomplish this, three one-way MANOVAs were performed for each practical test standard (altitude, heading, airspeed).

The airspeed practical test standard yielded results which reflect the composite performance scores of previous reported analyses. Table 12 illustrates the mean differences for all three evaluation phases across all conditions exclusively for the airspeed practical test standards. Using a one-way MANOVA for the airspeed practical test standard, a statistically significant Box’s $M$ test was reported, $F(18, 2035.43) = 3.49, p = .0001$, suggesting equal variance and covariance across levels of the independent variable (condition) indicating heterogeneity. Subsequently the multivariate test did not show a significant difference, Wilks’ Lambda = .562, $F(12, 55.85) = 1.59, p = .141$, partial $\eta = .175$, observed power = .553. No significant results were found for the non-vacuum attitude flight task, $F(3, 24) = .718, p = .516$, partial $\eta = .089$, observed power = .192, or the NBD task was found, $F(3, 24) = 1.17, p = .339$, partial $\eta = .128$, observed power = .276. Significant results only for the vacuum failure attitude flight task were found, $F(3, 24) = 4.44, p = .013$, partial $\eta = .357$, observed power = .815. Using a LSD post hoc test, the pre-and-post-test with training condition ($p = .005$), pre-and-post test without training condition ($p = .005$), and post-test with training ($p = .012$) condition were compared to the post-test without training condition, all comparisons yielded significant
differences, indicating potential practice effects. Although no significant differences were found for the other two phases (non-vacuum failure attitude flight task), it is important to mention that a graphical depiction of the flight performance results for airspeed during the NDB approach does mimic what was hypothesized. Figure 9 illustrates this notion as the pre-and-post-test with training condition post-test with training condition are distinctly different from pre-and-post-test without training condition (control) and post-test without training condition (control).

Table 12.

Airspeed means and standard deviations for all flight evaluations across all conditions.

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Condition</th>
<th>n</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-vacuum failure flight</td>
<td>A</td>
<td>7</td>
<td>99.67%</td>
<td>0.89%</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>96.76%</td>
<td>6.33%</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>95.90%</td>
<td>3.97%</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>93.86%</td>
<td>12.31%</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>A</td>
<td>7</td>
<td>95.69%</td>
<td>5.21%</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>95.83%</td>
<td>7.15%</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>97.48%</td>
<td>10.69%</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>68.76%</td>
<td>29.68%</td>
</tr>
<tr>
<td>NDB approach</td>
<td>A</td>
<td>7</td>
<td>94.01%</td>
<td>4.68%</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>80.99%</td>
<td>23.70%</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>91.10%</td>
<td>7.07%</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>76.63%</td>
<td>31.21%</td>
</tr>
</tbody>
</table>
The observation of the mean differences seen with the airspeed practical test standard during the NDB approach was also observed for the altitude practical test standard. Using a one-way MANOVA, no significant results were found for the altitude practical test standard (non-vacuum failure attitude flight task, $F(3, 24) = .238, p = .869$, partial $\eta = .029$, observed power = .089, vacuum failure attitude flight task $F(3, 24) = 2.98, p = .052$, partial $\eta = .271$, observed power = .629, or NDB approach, $F(3, 24) = 1.60, p = .216$), partial $\eta = .166$, observed power = .365). However, a graphical depiction of the NDB approach altitude practical test standard resembles the results of the airspeed practical test standard (see figure 10). Table 13 demonstrates the mean differences for all three evaluation phases across all conditions exclusively for the altitude practical test standard. By applying the two-group method applied
earlier in this analysis for both the airspeed and altitude practical test standards, it may be possible for significant differences to be detected. If differences are found, it could be argued that training improved performance (independent of the amount of practice received) for both the airspeed and altitude practical test standards. This issue will be revisited shortly.

Table 13.

*Altitude means and standard deviations for all flight evaluations across all conditions.*

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Condition</th>
<th>$n$</th>
<th>$M$</th>
<th>$SD$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-vacuum failure flight</td>
<td>A</td>
<td>7</td>
<td>97.29 %</td>
<td>6.34%</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>92.75%</td>
<td>9.29%</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>95.71%</td>
<td>11.34%</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>95.21%</td>
<td>12.66%</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>A</td>
<td>7</td>
<td>90.57%</td>
<td>19.76%</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>76.29%</td>
<td>16.79%</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>84.68%</td>
<td>16.17%</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>53.96%</td>
<td>38.57%</td>
</tr>
<tr>
<td>NDB approach</td>
<td>A</td>
<td>7</td>
<td>68.43%</td>
<td>12.69%</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>56.20%</td>
<td>23.02%</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>79.66%</td>
<td>16.15%</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>62.71%</td>
<td>28.00%</td>
</tr>
</tbody>
</table>
The final practical test standard, heading, yielded significant results. Using a one-way MANOVA for the heading practical test standard, a non-significant Box’s $M$ test was reported, $F(18, 2035.43) = 1.33, p = .160$, indicating homogeneity of variance. Subsequently the multivariate test did not show a significant difference, Pillai’s Trace = .555, $F(12, 55.85) = 1.46$, $p = .180$, partial $\hat{\eta} = .154$, observed power = .648. Significant results only for the vacuum failure attitude flight task were found, $F(3, 24) = 5.67, p = .004$, partial $\hat{\eta} = .415$, observed power = .905, (non-vacuum failure attitude flight task, $F(3, 24) = .393, p = .759$, partial $\hat{\eta} = .047$, observed power = .116 or NDB approach, $F(3, 24) = 1.32, p = .292$, partial $\hat{\eta} = .141$, observed power = .305). Using a LSD post hoc test, the pre-and-post-test with training condition ($p = .0001$), pre-and-post test without training condition ($p = .012$), and post-test with training ($p =$
.027) condition were compared to the post-test without training condition. As indicated for the airspeed practical test standard, it does appear practice had a significant effect over training for this specific phase of flight (see figure 11). Table 14 demonstrates the mean differences for all three evaluation phases across all conditions exclusively for the heading practical test standard.

Table 14.

*Heading means and standard deviations for all flight evaluations across all conditions.*

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Condition</th>
<th>n</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-vacuum failure flight</td>
<td>A</td>
<td>7</td>
<td>97.29%</td>
<td>3.84%</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>96.21%</td>
<td>7.02%</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>96.57%</td>
<td>6.58%</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>92.71%</td>
<td>13.74%</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>A</td>
<td>7</td>
<td>89.07%</td>
<td>13.37%</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>74.04%</td>
<td>16.07%</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>69.65%</td>
<td>30.26%</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>42.40%</td>
<td>22.80%</td>
</tr>
<tr>
<td>NDB approach</td>
<td>A</td>
<td>7</td>
<td>78.25%</td>
<td>22.70%</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>77.96%</td>
<td>26.31%</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>79.91%</td>
<td>16.77%</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>57.25%</td>
<td>25.25%</td>
</tr>
</tbody>
</table>
Figure 11. Line graph of percentage of flight within the practical test standard heading as a function for all conditions for the NDB approach.

Two-group comparison for all practical test standards.

All practical test standards for the pre-and-post-test with training condition and pre-and-post-test without training condition (control) (see table 15) are compared separately from the post-test with training and the post-test without training condition (control) (see table 16) using multiple independent samples t-tests. The purpose of these tests is to investigate whether differences within each practical test standard exist when experimental and control groups are combined based on an equal number of evaluations (practice). Out of all the tests, only one comparison yielded significant results for the heading practical test standard in the vacuum failure attitude flight task for the post-test with training and the post-test without training condition comparisons, \( t(12) = 2.45, p = .031 \). Participants in the post-test with training
condition ($M = 73.79; SD = 27.54$) performed significantly better than those participants in the post-test without training condition ($M = 39.79; SD = 24.25$). These results should be interpreted with caution as the multiple t-tests increase the likelihood of a type I error. It appears that the statistical difference between the post-test with training and the post-test without training conditions was compounded by the number of heading errors.
Table 15.

*t*-test results for non-vacuum failure attitude flight task, vacuum failure attitude flight task, and NDB approach for the pre-and-post-test with and without training conditions.

<table>
<thead>
<tr>
<th>Evaluation for Airspeed</th>
<th>t</th>
<th>p</th>
<th>df</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-vacuum failure flight</td>
<td>1.20</td>
<td>.252</td>
<td>12</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>-0.43</td>
<td>.967</td>
<td>12</td>
</tr>
<tr>
<td>NDB approach</td>
<td>1.43</td>
<td>.129</td>
<td>12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Evaluation of Altitude</th>
<th>t</th>
<th>p</th>
<th>df</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-vacuum failure flight</td>
<td>1.07</td>
<td>.307</td>
<td>12</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>1.46</td>
<td>.171</td>
<td>12</td>
</tr>
<tr>
<td>NDB approach</td>
<td>1.23</td>
<td>.242</td>
<td>12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Evaluation of Heading</th>
<th>t</th>
<th>p</th>
<th>df</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-vacuum failure flight</td>
<td>.354</td>
<td>.730</td>
<td>12</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>1.90</td>
<td>.081</td>
<td>12</td>
</tr>
<tr>
<td>NDB approach</td>
<td>0.02</td>
<td>.983</td>
<td>12</td>
</tr>
</tbody>
</table>
Table 16.

$t$-test results for non-vacuum failure attitude flight task, vacuum failure attitude flight task, and NDB approach for the post-test with training and post-test without training conditions.

<table>
<thead>
<tr>
<th>Evaluation for Airspeed</th>
<th>$t$</th>
<th>$p$</th>
<th>$df$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-vacuum failure flight</td>
<td>1.05</td>
<td>.315</td>
<td>12</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>1.47</td>
<td>.166</td>
<td>12</td>
</tr>
<tr>
<td>NDB approach</td>
<td>1.33</td>
<td>.209</td>
<td>12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Evaluation of Altitude</th>
<th>$t$</th>
<th>$p$</th>
<th>$df$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-vacuum failure flight</td>
<td>.121</td>
<td>.905</td>
<td>12</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>1.81</td>
<td>.096</td>
<td>12</td>
</tr>
<tr>
<td>NDB approach</td>
<td>1.32</td>
<td>.211</td>
<td>12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Evaluation of Heading</th>
<th>$t$</th>
<th>$p$</th>
<th>$df$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-vacuum failure flight</td>
<td>.372</td>
<td>.716</td>
<td>12</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>2.45</td>
<td>.031</td>
<td>12</td>
</tr>
<tr>
<td>NDB approach</td>
<td>1.30</td>
<td>.222</td>
<td>12</td>
</tr>
</tbody>
</table>

Error frequency.

All data reported so far consisted of frequency data converted into percentages. The cumulative frequency consists of the number of deviations from specified practical test
standards. This section is designed to provide the reader with a different perspective regarding the number of errors occurred instead of percentage of flight within practical test standards.

Starting with the frequency of errors across all conditions and flight evaluations, a Kruskal-Wallis Test revealed a significant difference only for the vacuum failure attitude flight task, $x^2(3) = 10.20, \ p = .017$. Using a Mann-Whitney U Test for a post hoc analysis (all significant results calculated at $p < .01$ to reduce family-wise error rate), only groups A ($M = 4.57$) and D ($M = 10.43$) differed significantly, $Z = -2.14, \ p = .007$ (see table 17 for statistical analyses for all three flight evaluations). Figure 12 demonstrates a large increase in the number of errors for all participants during the NDB flight task compared to the vacuum failure and non-vacuum failure attitude flight tasks.

Focusing on the practical test standards, it is clear that many of the errors for each evaluation generally concerns heading errors. Tables 18, 19, and 20 demonstrate the number of errors by each practical test standard within separate flight evaluations. The NDB approach under practical test standards altitude and airspeed resemble results similar to what was hypothesized. More specifically, the results (average number of errors) indicate a higher number of errors for the control groups as opposed to the experimental groups.
Table 17.

Chi-squared results for non-vacuum failure attitude flight task, vacuum failure attitude flight task, and NDB approach for all conditions as a function of error frequency.

<table>
<thead>
<tr>
<th>Flight Evaluation</th>
<th>$\chi^2$</th>
<th>$p$</th>
<th>$df$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-vacuum failure flight</td>
<td>3.11</td>
<td>.374</td>
<td>3</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>10.21</td>
<td>.017</td>
<td>3</td>
</tr>
<tr>
<td>NDB approach</td>
<td>4.17</td>
<td>.244</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure 12. Frequency of errors for all conditions and flight performance evaluations as a function of number of deviations from practical test standards.
Table 18.

*Means and standard deviations for frequency of heading errors for all flight evaluations across all conditions.*

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Condition</th>
<th>$n$</th>
<th>$M$</th>
<th>$SD$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-vacuum failure flight</td>
<td>A</td>
<td>7</td>
<td>0.57</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>0.86</td>
<td>0.60</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>0.21</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>1.14</td>
<td>0.71</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>A</td>
<td>7</td>
<td>2.29</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>5.57</td>
<td>1.51</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>7.00</td>
<td>2.71</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>14.50</td>
<td>4.07</td>
</tr>
<tr>
<td>NDB approach</td>
<td>A</td>
<td>7</td>
<td>11.57</td>
<td>6.66</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>12.86</td>
<td>5.06</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>16.14</td>
<td>5.19</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>31.07</td>
<td>7.60</td>
</tr>
</tbody>
</table>
Table 19.

*Means and standard deviations for frequency of altitude errors for all flight evaluations across all conditions.*

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Condition</th>
<th>n</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-vacuum failure flight</td>
<td>A</td>
<td>7</td>
<td>0.29</td>
<td>0.18</td>
</tr>
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<td></td>
<td>B</td>
<td>7</td>
<td>1.29</td>
<td>0.75</td>
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<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>0.71</td>
<td>0.47</td>
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<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>0.86</td>
<td>0.86</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>A</td>
<td>7</td>
<td>1.57</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>3.86</td>
<td>1.03</td>
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<td></td>
<td>C</td>
<td>7</td>
<td>3.07</td>
<td>0.98</td>
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<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>9.57</td>
<td>3.50</td>
</tr>
<tr>
<td>NDB approach</td>
<td>A</td>
<td>7</td>
<td>14.93</td>
<td>2.95</td>
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<td></td>
<td>B</td>
<td>7</td>
<td>25.29</td>
<td>6.80</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>13.93</td>
<td>3.52</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>27.64</td>
<td>6.64</td>
</tr>
</tbody>
</table>
Table 20.

**Means and standard deviations for frequency of airspeed errors for all flight evaluations across all conditions.**

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Condition</th>
<th>n</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-vacuum failure flight</td>
<td>A</td>
<td>7</td>
<td>0.14</td>
<td>0.15</td>
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<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>1.21</td>
<td>0.71</td>
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<td></td>
<td>C</td>
<td>7</td>
<td>1.14</td>
<td>0.46</td>
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<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>0.57</td>
<td>0.49</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>A</td>
<td>7</td>
<td>1.21</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>1.07</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>2.43</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>12.00</td>
<td>4.07</td>
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<tr>
<td>NDB approach</td>
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<td>7</td>
<td>5.07</td>
<td>2.08</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>11.07</td>
<td>5.88</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>7.86</td>
<td>2.82</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>14.57</td>
<td>6.27</td>
</tr>
</tbody>
</table>

Unfortunately, the observed differences in the average number of errors for altitude and airspeed within the NDB approach did not yield significant differences. Due to the number of dependent measures, the alpha level was adjusted to .01 for all non-parametric comparisons. At this level, no significant differences were detected (see table 21).
Table 21.

*Chi-squared results for non-vacuum failure, vacuum failure, and NDB approach flight tasks for all conditions and separate practical test standards as a function of error frequency.*

<table>
<thead>
<tr>
<th>Flight Evaluation</th>
<th>PTS</th>
<th>$\chi^2$</th>
<th>$p$</th>
<th>$df$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-vacuum failure flight</td>
<td>Airspeed</td>
<td>3.49</td>
<td>.322</td>
<td>3</td>
</tr>
<tr>
<td>Non-vacuum failure flight</td>
<td>Altitude</td>
<td>1.20</td>
<td>.753</td>
<td>3</td>
</tr>
<tr>
<td>Non-vacuum failure flight</td>
<td>Heading</td>
<td>0.84</td>
<td>.841</td>
<td>3</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>Airspeed</td>
<td>5.50</td>
<td>.139</td>
<td>3</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>Altitude</td>
<td>5.90</td>
<td>.116</td>
<td>3</td>
</tr>
<tr>
<td>Vacuum failure flight</td>
<td>Heading</td>
<td>8.22</td>
<td>.042</td>
<td>3</td>
</tr>
<tr>
<td>NDB approach</td>
<td>Airspeed</td>
<td>0.87</td>
<td>.832</td>
<td>3</td>
</tr>
<tr>
<td>NDB approach</td>
<td>Altitude</td>
<td>3.45</td>
<td>.327</td>
<td>3</td>
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<tr>
<td>NDB approach</td>
<td>Heading</td>
<td>8.20</td>
<td>.042</td>
<td>3</td>
</tr>
</tbody>
</table>

*p-values adjusted for the .01 level*

Knowledge Evaluation

The knowledge evaluation consisted of nine questions which focused on NDB navigation, ADF usage, magnetic variation, conventional cockpit system failures, and six-pack instrument identification. Scores were based on the number of questions answered correctly (composite score; see table 22). Of the nine questions, four were answered correctly by a large majority of participants (questions 1, 7, 8, 9). Question three was answered incorrectly the most. This question concerned the indication of a magnetic compass during a standard rate turn from a south heading. All questions were evaluated for reliability (see table 23). Using Cronbach’s Alpha, the knowledge evaluation does not appear to have good internal consistency, $\alpha = .02$. This
may be because the majority of questions were not related to one another. An exception can be made with questions four and five because question five depends on the participants answer to question four. With regard to statistical analyses, comparing the independent variable to the composite scores using a one-way analysis of variance did not yield significant results, \( F(3, 24) = .667, p = .581, \eta = .017 \), observed power = .169. Figure 13 illustrates this issue clearly as there is no distinct pattern of performance between the experimental and control groups. In summary, the knowledge evaluation did not provide any insight into what participants learned from instruction compared to participants who received no web-based instruction.
Table 22.

*Frequency distribution for each question of the knowledge evaluation.*

<table>
<thead>
<tr>
<th>Question Number</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>Percentage Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>24</td>
<td>2</td>
<td>0</td>
<td>85.7%</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>16</td>
<td>5</td>
<td>5</td>
<td>57.0%</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>9</td>
<td>13</td>
<td>0</td>
<td>46.4%</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>2</td>
<td>19</td>
<td>9</td>
<td>67.9%</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>22</td>
<td>1</td>
<td>5</td>
<td>78.6%</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>3</td>
<td>20</td>
<td>5</td>
<td>71.4%</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>0</td>
<td>27</td>
<td>0</td>
<td>96.4%</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>0</td>
<td>28</td>
<td>0</td>
<td>100%</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>25</td>
<td>2</td>
<td>1</td>
<td>89.3%</td>
</tr>
</tbody>
</table>
Table 23.

Reliability correlations for knowledge evaluation.

<table>
<thead>
<tr>
<th>Question 1</th>
<th>Question 2</th>
<th>Question 3</th>
<th>Question 4</th>
<th>Question 5</th>
<th>Question 6</th>
<th>Question 7</th>
<th>Question 8</th>
<th>Question 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>N</td>
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<tr>
<td>r</td>
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<td>N</td>
<td>28</td>
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<td></td>
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<tr>
<td>r</td>
<td>0.241</td>
<td>0.302</td>
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<td>28</td>
<td>28</td>
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<td></td>
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<tr>
<td>r</td>
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<td>-0.219</td>
<td>-0.422</td>
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<tr>
<td>r</td>
<td>0</td>
<td>0.369</td>
<td>0.31</td>
<td>-0.735</td>
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<td>28</td>
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</tr>
<tr>
<td>r</td>
<td>-0.178</td>
<td>0.161</td>
<td>-0.43</td>
<td>0.011</td>
<td>-0.069</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>N</td>
<td>28</td>
<td>28</td>
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<td>28</td>
<td>28</td>
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<td></td>
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</tr>
<tr>
<td>r</td>
<td>-0.509</td>
<td>-0.119</td>
<td>0.061</td>
<td>-0.127</td>
<td>0.098</td>
<td>0.389</td>
<td></td>
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</tr>
<tr>
<td>N</td>
<td>28</td>
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<td>28</td>
<td>28</td>
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<tr>
<td>r</td>
<td>0</td>
<td>0.103</td>
<td>-0.184</td>
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<td>0.098</td>
<td>0.026</td>
<td>-0.037</td>
<td></td>
</tr>
<tr>
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<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>0.215</td>
<td>0.013</td>
<td>0.31</td>
<td>-0.255</td>
<td>-0.165</td>
<td>0.109</td>
<td>0.062</td>
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<tr>
<td>n</td>
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<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
</tr>
</tbody>
</table>

Question 1. On the basis of this information provided above, the magnetic bearing TO the station would be?

Question 2. If the magnetic heading shown in aircraft 6 is maintained, which ADF illustration would indicate the aircraft is on the 255 magnetic bearing FROM the station?

Question 3. What should be the indication of the magnetic compass as you roll into a standard rate turn to the left from a south heading in the Northern Hemisphere?

Question 4. What is the flight attitude? One system which transmits information to the instruments has malfunctioned?

Question 5. What system in the previous question failed?

Question 6. What is the relative bearing TO the station?

Question 7. The altimeter is located in box...?

Question 8. The turn coordinator is located in box...?

Question 9. What instrument(s) in the list below is NOT lost in a vacuum failure?
Self-Efficacy and Reaction Evaluations

The self-efficacy and reaction evaluations addressed participants' perception of their ability to handle an aircraft equipped with a conventional six-pack display after training as well as their reaction to the training. All participants received both of these evaluations regardless of whether they received training. Each evaluation consisted of eight questions. Tables 24 and 25 diagram inter-item correlations for all evaluations. Using Cronbach’s Alpha, self-efficacy does appear to have good internal consistency, \( \alpha = .08 \), but lesser internal consistency for the reaction evaluation, \( \alpha = .70 \). The reaction questionnaire also had some missing data entries, excluding seven cases, which reduced the N size. Nevertheless, since all questions were positively skewed, a composite score for self-efficacy and a score for reaction was developed.
These scores were an average rating for all eight questions in the self-efficacy evaluation as well as a separate score for the eight questions of the reaction evaluation.

Table 24.

*Reliability correlations for self-efficacy.*

<table>
<thead>
<tr>
<th>Question 1</th>
<th>Question 2</th>
<th>Question 3</th>
<th>Question 4</th>
<th>Question 5</th>
<th>Question 6</th>
<th>Question 7</th>
<th>Question 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question 1</td>
<td>r</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question 2</td>
<td>r</td>
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<td></td>
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<td>-0.054</td>
<td>0.435</td>
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<td>28</td>
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</tr>
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<tr>
<td>Question 7</td>
<td>r</td>
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<td>0.34</td>
<td>0.127</td>
<td>0.149</td>
<td>0.528</td>
<td>0.232</td>
</tr>
<tr>
<td>N</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
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<td></td>
</tr>
<tr>
<td>Question 8</td>
<td>r</td>
<td>0.331</td>
<td>0.37</td>
<td>0.266</td>
<td>0.464</td>
<td>0.395</td>
<td>0.43</td>
</tr>
<tr>
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<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
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<td>28</td>
</tr>
</tbody>
</table>

Question 1. I believe I can become unusually good at using a six-pack display
Question 2. I want to continue training on the six-pack display
Question 3. I feel I can solve any problem I encounter using a six-pack display
Question 4. I can accomplish a lot in the cockpit when I work hard
Question 5. No-six pack display equipped aircraft is too tough for me to operate
Question 6. I feel I am a more accomplished pilot after learning how to operate the six-pack display
Question 7. The six-pack display is an easy display to operate
Question 8. I have confidence in my abilities to use a six-pack display
Table 25.

*Reliability correlations for reaction questions.*

<table>
<thead>
<tr>
<th>Question 1</th>
<th>Question 2</th>
<th>Question 3</th>
<th>Question 4</th>
<th>Question 5</th>
<th>Question 6</th>
<th>Question 7</th>
<th>Question 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>0.463</td>
<td>-0.244</td>
<td>0.305</td>
<td>-0.232</td>
<td>0.533</td>
<td>-0.265</td>
<td>-0.244</td>
</tr>
<tr>
<td>N</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
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<tr>
<td>r</td>
<td>0.305</td>
<td>0.611</td>
<td>-0.226</td>
<td>0.292</td>
<td>0.266</td>
<td>0.615</td>
<td>0.396</td>
</tr>
<tr>
<td>N</td>
<td>28</td>
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</tr>
<tr>
<td>r</td>
<td>-0.058</td>
<td>0.263</td>
<td>-0.175</td>
<td>0.628</td>
<td>0.345</td>
<td>0.952</td>
<td>0.229</td>
</tr>
<tr>
<td>N</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>r</td>
<td>-0.205</td>
<td>0.533</td>
<td>0.078</td>
<td>0.628</td>
<td>0.345</td>
<td>0.952</td>
<td>0.229</td>
</tr>
<tr>
<td>N</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
</tr>
</tbody>
</table>

Question 1. I feel today’s six-pack display instruction was informative
Question 2. I feel the instructor was knowledgeable of the six-pack display
Question 3. I learned a lot about the six-pack display from today’s training
Question 4. I feel the training software was realistic
Question 5. I believe the flight controls were easy to use
Question 6. I had no difficulty communicating with the instructor and assistant
Question 7. I really enjoyed the shared-cockpit feature in MSFS
Question 8. The yoke control was comfortable and easy to use

For the self-efficacy evaluation, three question comparisons stood-out: questions one and two, questions one and four, and questions four and six. Questions one and four pertain to participants’ confidence regarding operating the six-pack and their desire to continue training in the future. The positive correlation, $r = .816$, suggests that as participants’ confidence with the six-pack increases, so does their desire to continue training in the future. Questions one and four pertain to participants’ confidence with operating the six-pack and their perception of accomplishment when working hard towards a goal. In this instance, participants’ confidence with the six-pack is elevated when they work hard towards a specific goal, $r = .721$. Lastly, questions four and six pertain to participants’ perception of accomplishment when working hard
towards a goal and participants' sense of accomplishment as a pilot after receiving web-based instruction. With this correlation, $r = .628$, participants who receive web-based training generally perceive themselves as more accomplished pilots if they work hard towards a specific goal. After transforming all eight questions into a single composite score, a one-way analysis of variance was used and no significant results were found, $F(3, 24) = 1.05, p = .390, \eta^2 = .116$, observed power = .248.

The reaction evaluation had more inconsistencies, primarily because the questions were designed for participants who received web-based instruction. The only questions applicable to all participants were questions four, five, and eight, which concerned participants' interaction with the training software and hardware. The inter-item correlations also yielded the highest correlations for these comparisons. Questions four and five concerned the realism of the training software and the easy-of-use of the flight controls. The correlations, $r = .633$, suggests the more realistic participants perceived the controls, the easier they were to use. Questions four and eight address the realism of the software and the comfort of the flight controls. The positive correlation between the two questions ($r = .615$) is similar to the last comparison as the software realism is associated with the comfort of the yoke control. Finally, questions five and eight concerns the overall ease-of-use of the flight controls with the comfort of the control yoke. In this instance, participants who rated the flight controls as easy to use also found the control yoke easy to use, $r = .952$. This comparison yielded the strongest correlation for all inter-item correlations. Like the self-efficacy evaluation, composites scores were developed. No significant results were found, $F(3, 17) = .083, p = .968, \eta = .014$, observed power = .062. Table 26 provides descriptive statistics for the knowledge, self-efficacy, and reaction evaluations.
Table 26.

*Descriptive statistics for knowledge evaluation, self-efficacy evaluation, and reaction evaluation.*

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Condition</th>
<th>n</th>
<th>M</th>
<th>SD</th>
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</thead>
<tbody>
<tr>
<td>Knowledge evaluation</td>
<td>A</td>
<td>7</td>
<td>79.37</td>
<td>14.94</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>80.95</td>
<td>8.40</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>69.84</td>
<td>7.94</td>
</tr>
<tr>
<td>Self-efficacy Evaluation</td>
<td>A</td>
<td>7</td>
<td>5.67</td>
<td>.63</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>4.90</td>
<td>1.16</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>5.42</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>5.07</td>
<td>1.09</td>
</tr>
<tr>
<td>Reaction Evaluation</td>
<td>A</td>
<td>7</td>
<td>5.73</td>
<td>0.58</td>
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<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>5.50</td>
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</tr>
<tr>
<td></td>
<td>C</td>
<td>7</td>
<td>5.70</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>7</td>
<td>5.80</td>
<td>0.86</td>
</tr>
</tbody>
</table>
Discussion

The purpose of this study was to investigate the effectiveness of web-based instruction for instrument rated pilots transitioning from a Garmin 1000 to a conventional six-pack display. More specifically, the form of web-based instruction proposed in this study was designed to mitigate some of the feedback and asynchronous communication issues common in computer mediated communication and web-based training programs. This was accomplished through the shared-cockpit feature of Microsoft Flight Simulator 10.0 which provided live synchronous communication. It was predicted that this form of training would improve instrument flight performance by capturing the learners’ attention, increasing procedural and declarative knowledge, and allowing the learner adequate practice and feedback opportunities. Ultimately, this study investigated a novel approach toward an affordable alternative to aviation training. An explanation of the previously reported results for this study is discussed below.

Pilot Performance

To reiterate, there were four evaluations: situational awareness, non-vacuum failure attitude flight, vacuum failure attitude flight, and NDB approach. With the exception of the situational awareness task, pilot performance was measured based on the percentage of flight within practical test standards. This section will cover the implications for the results of all four evaluations.

Situational awareness.

The situational awareness task evaluated the participants’ ability to triangulate his or her position using only an ADF radio and low-altitude enroute chart. It was hypothesized that participants who received web-based instruction regardless of practice (number of evaluations) would perform better than those participants who did not receive web-based instruction. In this
instance, participants in the training conditions would perform better than those participants in either control conditions. Unfortunately, this was not found to be as the only condition that performed poorly was the post-test without training condition. Since participants did receive some practice along with feedback during training, participants in the pre-and-post-test with training condition received the highest number of practice opportunities as these participants received both practice during the pre-test along with practice with an instructor. The post-test without training condition received no practice opportunities. Since the time-on-task increased (the less amount of time-on-task infers better performance) with a decrease in practice, it appears that practice caused the changes in this dependent measure. Although these results do not support the hypothesized claim, it does provide some evidence that with practice alone, performance on-task greatly improves. In other words, participants in the pre-and-post-test without training condition (control) did not receive training but performed statistically similar to those participants in both training conditions. Even with practice alone, participants appear to have performed well enough to be statistically similar to participants in the training conditions.

Non-vacuum failure attitude flight task.

The non-vacuum failure attitude flight task evaluated participants' ability to fly under instrument meteorological conditions using a conventional cockpit display. The task was designed to measure participant performance prior to an instrument related failure (e.g., vacuum failure). Since all participants had little to no prior experience with using the conventional cockpit display under instrument meteorological conditions, it was hypothesized that those participants who received training would perform better than participants in the control conditions. Unfortunately, this was not true since participants in all conditions performed similarly. This may be the result of a weak manipulation for this specific task. For instance,
when participants started this evaluation, the task began in straight-and-level flight. In this situation, the aircraft was already stabilized to maintain the present heading and altitude. Essentially, the participant was only responsible for locating the instruments pertinent to maintaining level flight in instrument meteorological conditions and flying within practical standards. There was no conflicting information in the cockpit that would have challenged participants without formal training. In essence, this task was easy enough for any instrument rated pilot to execute (develop an instrument scan).

*Vacuum failure attitude flight task.*

The vacuum failure attitude flight task evaluated pilot performance under instrument meteorological conditions with a vacuum failure. A vacuum failure typically results in the loss of the attitude indicator as well as the directional gyro in a conventional cockpit display. It was hypothesized that participants who received training would perform better than those participants who were in either control conditions. Participants in the pre-and-post-test with training condition, pre-and-post-test without training condition, and post-test with training condition performed statistically better than those participants in the post-test without training condition. Like the situational awareness task, these results are probably attributed to practice since practice alone appears to be enough for participants to learn how to overcome the challenges posed by a vacuum failure in instrument meteorological conditions.

*Non-vacuum failure and vacuum failure attitude flight tasks.*

The training intervention was expected to enable consistent flight performance between the non-vacuum failure and vacuum failure attitude flight task. In other words, the training intervention was expected to enable the participants to easily transition between normal operating conditions and a vacuum-failure emergency. Specifically, participants in the training
condition were expected to perform better and continue to perform better across both performance evaluations than both control conditions. This was not the case as during a vacuum failure emergency since performance worsened for participants in the post-test with training condition as well as the post-test without training condition (control). The reduction in performance from non-vacuum failure to vacuum failure attitude flight task suggests that the additional practice received in the pre-and-post-test without training condition played a significant role in regard to changes to the dependent measure. This is probably due to the researcher’s failure to determine a task that requires training exclusively in order to perform a task. More importantly, the researcher underestimated the role that the pre-test (i.e., practice) exclusively has on flight performance in aviation training. This issue will be revisited later in this section.

*NDB approach task.*

The NDB approach flight task is a combination of the situational awareness task which consisted of NDB usage and positioning and the vacuum failure task which focused on flying an aircraft without the use of two pertinent instruments (i.e., directional gyro and attitude indicator) which is necessary to safely fly an aircraft equipped with a conventional six-pack display in instrument meteorological conditions. Like the previous performance evaluations, it was hypothesized that participants who received training would perform better on this task than those participants in either control conditions. Unfortunately no significant results were found as all participants in all conditions performed statistically similar to one another. However, a graphical depiction of performance scores does illustrate a difference (not significant) between the post-test without training condition and the other three conditions.
Altitude, Airspeed, and Heading.

The FAA Practical test standards for instrument currency were used as a primary measure of pilot proficiency. The standards used in this study are a reflection of what is used in the real world. These standards measured pilot performance based on a specific altitude, airspeed, and heading. All standards were held constant and some were left out depending on the phase of flight (i.e., cannot measure heading during a turn since heading is constantly changing during that phase of flight). Overall, there appears to be more heading and altitude errors than airspeed errors across all conditions. However, only the heading practical test standard yielded significant results. Specifically, participants in the post-test without training condition during the vacuum failure attitude flight task committed more heading errors than participants in the other three conditions. In essence, under limited practice, a decrease in the amount of time within practical test standards (i.e., decrease in flight performance) seems to be compounded by the number of heading errors during the vacuum failure attitude flight task. This was reflected with the frequency error data where more practice alone (participants in the pre-and-post-test without training) decreased the number of heading errors that occur during flight evaluations, specifically the vacuum failure attitude flight task. These findings indicate that with practice, participants learn how to control bank-angle in Microsoft Flight Simulator. Although purely anecdotal, participants did complain of the difficulty with controlling heading in the simulator due to hypersensitivity. The researcher tried to dampen the sensitivities of the controls (through the sensitivities function in Microsoft Flight Simulator 10.0) but it appears that changes detected in the dependent measure can be partially attributed to the sensitive control surfaces. In essence, there appears to be a deficit in functional fidelity with respect to aircraft aerodynamic responses. If the control surfaces more closely mimicked the psychomotor responses of the actual Cessna
172, a greater separation of flight performance between the training and control conditions might have been detected. For instance, participants in the post-test with training condition may have performed better if those participants had more time to adapt to the control surfaces of the simulator.

The airspeed practical test standard for the NDB approach (all phases of the approach) yielded an interesting observation. Although not significant, the experimental conditions did appear to have a greater percentage of flight within practical test standards for airspeed then did either control conditions. This is a promising observation because it reflects the intended hypothesis.

Knowledge Evaluation

The results of the knowledge evaluation were inconsistent. Participants in all conditions appear to have scored similarly, and those participants in the treatment conditions scored rather low considering they received formal training. There are a number of possibilities for these results. First, there were simply not enough questions. Originally, 18 questions were developed, two for each question topic. The intended purpose of this was to build a level of redundancy as a means of verifying whether each participant was answering each question legitimately. These questions were later separated to form the pre-and-post knowledge evaluations. There is a small possibility participants were also familiar with some of the questions. Six of the nine questions were taken from the private pilot and instrument written exams. Some of the answer possibilities were changed to reduce this risk and an additional answer option was added (written exam only contains three possible answers). In addition, some of the questions could have been determined with just limited prior exposure to the conventional cockpit display. For instance, question seven of the post-knowledge evaluation asks the participant to locate the altimeter on a six-pack
display. Although none of the gauges contained the actual instrumentation, this is an important feature of the flight evaluations and participants may have learned where in the cockpit this instrument is located simply by performing the evaluation. In this instance, the flight evaluation prepared the participant to answer this question correctly since the instrument was used during the evaluation.

*Self-Efficacy Evaluation*

The self-efficacy evaluation was designed to evaluate participants’ perception of their ability to operate an aircraft equipped with a conventional six-pack display after participation. Participants across all conditions generally rated their ability to operate a conventional cockpit display equally. In general, participants who believe they can be proficient in operating the display also feel they can accomplish a lot in the cockpit if they put effort into their work. Participants were also willing to continue training on the six-pack display if they felt they could become unusually good at using the display. Lastly, participants feel more accomplished after learning how to use the display if they put hard work into training. Unfortunately, there were no significant differences between the control and experimental conditions, which does not support the hypothesis that participants who received training elicited greater self-efficacy after training than those participants in either control conditions. One explanation for these results is that there are simply not enough questions to detect significant differences (the original measure has been validated). Also, the evaluation did not incorporate both positive and negative questions, so it is difficult to determine whether participants truly feel what they actually reported on the evaluation (Likert-scale based) or if they were reporting their self-efficacy arbitrarily.
Reaction Evaluation

The reaction evaluation was less reliable in terms of internal consistency than the self-efficacy evaluation. This is primarily attributed to the design of the questions. Specifically, the questions were tailored for participants in the training conditions. Five of the nine questions were exclusively designed for participants in the training conditions (questions one, two, three, six, and seven). This resulted in numerous inconsistencies such as participants skipping questions not pertaining to them and participants in the control conditions mistaking the word instructor for the researcher. The latter issue explains why many participants in both control conditions answered questions not pertaining to them (i.e., training questions). The remaining questions which pertained to all participants addressed their experience with the training software and flight controls. Of those questions, only questions five and eight yielded the strongest relationship. In this instance, participants who were comfortable with the flight controls also found the yoke easy to use. As was an issue with the self-efficacy evaluation, the reaction evaluation also did not incorporate positive and negative questions. This would have strengthened the reliability of the reported results.

Limitations

The findings of this research study do not support the claim that synchronous web-based instruction is sufficient alone for instrument currency in a conventional cockpit display. There are several factors that may have contributed to this finding. First, there was a relatively small sample size. The researcher originally proposed for 40 participants, 10 in each condition. Unfortunately, this goal was not reached as the researcher had some difficulty with soliciting participation during the summer session at Embry-Riddle Aeronautical University. This issue was also compounded by poor participant flight performance which forced the researcher to
exclude three participants. In addition, four participants were used for pilot testing. In total, seven participants were excluded from the data analysis, decreasing the number of participants from 35 to 28. With a larger sample size, it may be easier to detect statistical significance.

Secondly, there needs to be a stronger differentiation between knowledge gained from verbal instruction and knowledge gained from practice. One of the important elements of training is effective practice (Oser et al., 1999). In aviation, practice is an essential element toward successful training. Some forms of learning in aviation cannot be achieved without accompanied practice (e.g., landing a plane). Furthermore, practice is generally followed by some form of verbal instruction (e.g., formal lecture). In an aviation training environment, this is usually accomplished in the cockpit, where the instructor demonstrates how to accomplish a specific task. The demonstration is then followed by practice. Therefore, there are two elements of instruction: lecture (verbal communication) and practice (physical manipulation). However, in this research study, these two elements were never partitioned. For example, in both treatment conditions, participants were provided a small lecture and presentation regarding a specific task (e.g., straight-and-level flight without the use of an attitude indicator and directional gyro) which was followed by practice. But from a research standpoint, how does one determine whether changes in the dependent measure are attributed to the lecture (verbal communication) portion of instruction, practice (physical manipulation), or both? The present design of this research study (Solomon’s Four Group Design) does not effectively partition the two elements. In this instance, even if significant results were detected, it would still be unclear as to which element (or both) caused the results. This is important because one cannot improve the quality of instruction without determining which element (or both) of instruction needs to be improved.
The Solomon’s Four Group Design was specifically implemented to partition potential exposure effects obtained from being evaluated. Specifically, the design detects whether changes in the dependent measure are a result of practice from pre-test or training. In this case, the design did detect this shortcoming as participants in the pre-and-post-test without training condition (control) performed equally as well as both training conditions. It was also used to test the effectiveness of web-based instruction, independent of practice. If practice alone is just as effective as web-based instruction, then there is no need for web-based instruction. Unfortunately, practice was never truly partition from instruction as both were interconnected in the training paradigm. Based on the findings in this study, it is just as likely that participants adjusted to the loss of a vacuum failure simply by adapting to other instrumentation in the cockpit (e.g. magnetic compass, altimeter, and turn coordinator). A potential solution to this issue is to create conditions where participants only receive web-based instruction (verbal instruction) or practice (physical manipulation). For instance, the first condition would receive instruction (verbal instruction) along with practice, the second condition would receive only instruction (verbal instruction), the third condition would receive only practice, and the last condition would not receive any practice or instruction. This new design is related to the Solomon’s Four Group Design with the exception that all groups are only evaluated after treatment (no pre-tests). From a research methodological standpoint, this design provides some clarity as to what element of the instruction caused changes to the dependent measure. In addition, it allows a training practitioner to more accurately improve any deficits of a specific training paradigm.

The third limitation concerns motivation. There was very limited focus on measuring participants’ motivation as a result of web-based mentoring. Many forms of web-based
instruction are asynchronous, where feedback is delayed or omitted. Feedback also serves as a
motivator which reinforces the learner's engagement in the training. Delayed feedback or no
feedback transfers the responsibility of interpreting performance to the learner, making it
difficult for the learner to maintain the motivation to stay engaged in the training program if
performance feedback is scarce or unreliable (Piccoli et al., 2001). The mentor in this study
served to fill this void through the use of the "shared-cockpit" by providing the learner with
timely feedback. However this notion assumes that the learner is motivated simply by feedback
alone. There were no measures addressing other factors which could have affected participant
motivation (e.g., personal goal, enjoyment of using simulators, and love for learning). The
questions related to motivation in the self-efficacy evaluations generally focused on participants’
perception of their ability to operate a conventional cockpit display but the questions did not
address participant motivation as a result of mentoring via web-based instruction. Besides
incorporating Likert-scale questions specifically addressing participant motivation after receiving
web-based instruction, future research should focus on evaluating mentoring over an extended-
period of time (i.e., several training sessions). It would also be interesting to measure motivation
over an extended period when coupled with the new design proposed previously. This would
provide further insight into the role of web-based instruction independent of practice.

The fourth limitation that may have contributed to the current findings is the difficulty of
the flight task, specifically the NDB approach. The approach route started seven nautical miles
from the initial approach fix. Once crossing the fix, the participant was responsible for tracking a
specific NDB bearing inbound as specified on their approach plate. This was the same procedure
for both pre-and-post training evaluations (both approaches took place from two separate regions
of the United States). However, the turn toward the inbound bearing differed between the two
evaluations. Specifically, the turn angle inbound for the post-training evaluation (which was the only evaluation analyzed) was 19 degrees shorter than the pre-training evaluation. This means that all participants turned for a shorter period of time, possibly making it easier for the participants to complete this phase of the NDB approach task. In relation to this issue, determining the exact phase of flight was never assigned to the independent raters. The researcher was responsible for creating the screenshot slides for the independent raters to score participant performance. On the other hand, there was never any consensus regarding when a participant transitioned into the next phase of flight. For example, during the NDB approach, the participant was instructed to make a right turn after crossing the initial approach fix to track the inbound NDB beading. However, the participant could have made a left turn due to a lack of familiarity with how to make a heading change only using a compass. In this instance the participant could have executed a left turn before realizing he or she was moving in the opposite direction of the inbound NDB bearing. In this situation, it would be easier to continue turning left until the participant tracked the correct bearing inbound. The participant could have also made the turn too soon (more than two nautical miles from the initial approach fix). Since this phase of flight is a turn, the only two practical test standards measured were airspeed and altitude (heading is not measured because it is constantly changing), but there is no measure as to whether the participant executed the correct procedure (i.e., left turn). In essence, the practical test standards are a good measure of a pilot’s ability to stabilize an aircraft and to fly within specific course with the exception of heading changes. For heading changes, additional measures need to be implemented to determine the correct direction of the turn (left or right) and the proper time or distance in which it was executed.
Lastly, it appears practice played a critical role not only in accomplishing the tasks in the evaluations but also with adapting to the sensitivities of the flight controls. The flight controls (specifically the control yoke) seemed to have been unrealistically sensitive, especially for heading changes. This may have required additional time for participants to adapt to the sensitivities of the flight controls beyond what was already provided. In addition, stress is another factor that was not measured in this research study. There is no way to determine if stress, either from flight controls alone, or from the tasks, had any influence on flight performance. Stress, particularly caused by a lack of training (or knowledge) and practice could have affected the participants' ability to attend to pertinent instruments necessary to stay within practical test standards in instrument meteorological conditions.

Future Recommendations

The limitations just discussed clearly demonstrated there is room for improvement in the study. Sample size was a significant problem in this study, as the number of participants did not match what was originally proposed. More participants are needed in the future in order to more accurately detect significant differences.

A more comprehensive knowledge evaluation, self-efficacy evaluation, and reaction evaluation should be implemented in future research. All three of these evaluations need to incorporate positively and negatively skewed questions in order to test the accuracy of each participant answers. In addition to these evaluations, a measure of perceived stress (e.g., NASA TLX) also should be addressed. As discussed previously, there are a number of factors which contribute to participant flight performance and stress is an important factor not addressed in this study. It would be interesting to differentiate perceived stress between those participants who received training and those who did not receive training.
With regard to the flight evaluation, the NDB approach should incorporate a larger degree turn to make it more challenging for participants who were not trained to accurately intercept and track the NDB bearing inbound. This could be achieved simply by changing the initial heading of the aircraft, seven nautical miles from the initial approach fix. In relation to heading changes, there needs to be more emphasis on dampening control sensitivities, primarily for turning. This issue can be resolved by purchasing software programs which specialize in adjusting the sensitivities of gaming controls (e.g., FSUIPC). In addition, participants should be allowed additional time to become more comfortable with these controls prior to training and evaluation. This may also alleviate some of the stress attributed to adapting to the sensitive controls.

As for the independent raters, additional information needs to be supplemented as a way to determine whether each participant properly transitioned into the next phase of flight. This is especially needed for heading changes which can be addressed by allowing the independent raters to determine the correct direction of the turn (left or right) and the correct time or distance for when the turn should be executed.

Lastly, there should be greater emphasis on investigating the fundamental elements of aviation instruction. As mentioned previously, the design used in this study provided no insight as to what element of instruction (verbal communication and/or practice) contributed to the changes in the dependent measure. The training paradigm was developed in conjunction with a subject-matter expert who argued that verbal instruction followed by practice is central to aviation training. This is also true for other forms of training as well (Picoli et al., 2001) such as driving a car, or learning how to solve a math problem. With this in mind, the researcher developed a paradigm that required verbal instruction, followed by practice, and that required
information from previously learned tasks (e.g., instrument scan) to accomplish new tasks (e.g., flying in instrument meteorological conditions). Unfortunately, verbal instruction and practice were never partitioned. The proposal presented in the limitation section provides a good research design foundation to investigate this issue.

Conclusion

The simplest explanation for the present results is that the training intervention was simply ineffective. This could be attributed to the tasks used to test the effectiveness of web-based instruction for flight training (e.g., attitude flight, NDB approach, vacuum failure) or because web-based instruction is an insufficient mode of aviation training in general. In either case, the methods used to test these claims were not incorporated as verbal instruction was never partitioned from practice (as was the case for the former claim) and non-verbal communication was never manipulated as a variable (as was the case for the latter claim). Regardless of the amount of effort put into the training intervention, it simply did not work.

Despite the many impediments associated with this research study, there is still some useful information to be gathered from the present findings. First, it appears simply using Microsoft Flight Simulator for practice (without instruction) improves performance, although this has been addressed in previous research (Talleur et al., 2003; Moroney et al., 1999; Koonce & Bramble, 1998; Ortiz, 1994). By allowing pilots to practice certain instrument procedures (e.g., NDB approach, attitude flight with a vacuum failure) using a very affordable and accessible PC-based flight simulator, pilots can improve their flight proficiency on a specific instrument task. This is encouraging to those who want to reduce the cost of training by replacing some instruction with practice on an ordinary personal computer. This is also
encouraging for those who fly in parts of the world where navigational aids such as NDBs are more common than VORs, and in instances where an aircraft is not equipped with more recent technology such as GPS. These two examples are common for new flight instructors (particularly at Embry-Riddle and other prestigious aviation training institutions) who have very limited experience with older technology. For example, many smaller flight schools in the United States and throughout the world have not upgraded their fleets with newer forms of technology (e.g., Garmin 1000). This poses a small dilemma for students who attend institutions such as Embry-Riddle where the majority of instrument time is in a Garmin 1000. These pilots are familiar with instrument flight but have limited or no exposure to older forms of technology (e.g., conventional cockpit display). In this instance, these pilots can acclimate themselves to the older technology simply by practicing on PC-based flight simulator. This can also work for pilots who are unfamiliar with a specific approach procedure (e.g., NDB approach). Like in the previous example, the pilot does not have to spend hundreds of dollars renting an aircraft or flight training device (FTD) when they can simply familiarize themselves on a PC-based flight simulator. The only caveat to this advice is that the training task cannot consist of learning new psychomotor techniques, as this form of training has been discussed as ineffective in previous PC-based flight simulation training research (Dennis and Haris, 1998).

Additionally, this study provided a better understanding of the difference between verbal instruction and practice in aviation training. It was determined that some of the research tools used to investigate training programs in other domains is not necessarily appropriate for aviation training research (e.g. Solomon’s Four Group Design). In previous aviation training studies which investigated instrument flight and PC-based flight simulation (Talleur et al., 2003; Taylor et al., 1999; Ortiz, 1994), none of them focused on the effectiveness of verbal instruction and
practice through a PC-based flight simulation. Most of these studies were concerned with practice alone or instruction and practice. Although this study also did not make that distinction, the issue was never addressed in previous research (however the researcher may have missed the issue being addressed in previous aviation research). Therefore, the findings from this study lead to an awareness of the issue along with a solution to be used in future research.

Overall, there is still a lot of room for improvement in this research study as there were a variety of problems not addressed prior to data collection. Regardless, this study made an attempt to investigate an encouraging form of training that is accessible and affordable. In addition, past PC-based flight simulation research only addressed some forms of instrument training (e.g., attitude flight). This study investigated other forms of PC-based flight simulation training that has not been investigated, such as NDB approach and emergencies (e.g., vacuum failure). There are still other instrument tasks that can be used in PC-based flight simulation training and more research is needed to investigate its effectiveness.
References


Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, motivation and learning: A research and


Appendix A

Participant Information Statement

Distance Learning for Instrument Flight: Evaluating the Effectiveness of a Virtual Mentor

Conducted by Andrew S. Mendolia
Advisor: Dr. Elizabeth Blickensderfer
Embry Riddle Aeronautical University
600 S. Clyde Morris Blvd.
Daytona Beach, FL 32114

Purpose of Research
The purpose of the experiment is to investigate the effectiveness of personal computer-based flight simulation training and to examine a distance learning approach to flight training. The results from this study will provide for a better understanding of distance learning as an affordable alternative to aviation training.

Specific procedures to be used
Participants will operate Cessna 172 in Flight Simulator 10.0, learn and operate the conventional six-pack display, and will be evaluated.

Duration of Participation
A total commitment of 2.0 hours is required for participation.

Benefits to the Individual
You will be compensated for your participation. Participants who complete the research will be paid $70.

Risks to the Individual
A possible risk for this study is slight simulator sickness. In this study, however, the risk is considered low as the simulation is a desktop computer. Occasionally after operating a flight simulator, individuals do feel symptoms of simulator sickness. The symptoms of simulator sickness include eyestrain, mental disorientation, fatigue, dizziness, drowsiness, headache, and nausea. Symptoms generally do not last longer than six hours. If symptoms do persist, please seek medical help.

Confidentiality
Efforts will be made to maintain participants’ privacy. Each participant will be assigned a number, and only that number will be used while recording and reporting data. All data will be kept in a locked file cabinet in the Department of Human Factors and Systems at Embry-Riddle.

Voluntary Nature of Participation
Participants do not have to participate in this research project. Also, participants may terminate their participation at any time without penalty. Participants will still be paid for the time they have contributed.

Thank you for your participation (Phone: (386) 226-6790 or email: mendolia@erau.edu) or Dr. Blickensderfer (Phone: (386) 223-8065 or elizabeth.blickensderfer@erau.edu)
Statement of Consent

Embry Riddle Aeronautical University

I consent to participating in the research project entitled: **Distance Learning for Instrument Flight: Evaluating the Effectiveness of a Virtual Mentor.**

Researcher: Andrew S. Mendolia

The individual above has explained the purpose of the study, the procedures to be followed, and the expected duration of my participation. I have read the page labeled “Participant Information Statement” and agree to the conditions of the study. Possible benefits of the study have been described, as have alternate procedures, if such procedures are applicable and available.

I currently hold at least a valid Class III medical certificate indicating I am medically qualified to experience the physical challenges of flight. There will be no other medical screening and I further certify that I am not currently under taking any prescription medication nor undergoing any medical care.

I acknowledge that I have had the opportunity to obtain additional information regarding the study and that any questions I have raised have been answered to my full satisfaction. Furthermore, I understand that I am free to withdraw consent at any time and to discontinue participation in the study without prejudice to me.

Finally, I acknowledge that I have read and fully understand the consent form. I sign it freely and voluntarily. A copy has been given to me.

_________________________________________
Date

_________________________________________
Participant’s Name (please print)

_________________________________________
Participant’s signature

_________________________________________
Researcher signature

[ ] Yes, I would like to be contacted regarding the results of the study
Appendix B

Demographics Data

Please answer the following questions to the best of your ability.

1. Sex: M  F
2. Age: ________
3. List current flight licenses and certificates:
4. Approximate total number of hours flown: ____________
5. Approximate number of hours flown under instrument flight rules: ____________
6. Approximate number of hours flown using a six-pack display under IFR conditions: ____________
7. Approximate number of hours flown using a six-pack display under VFR conditions: ____________
8. How many hours a week do you use Microsoft Flight Simulator: ____________
9. Have you ever used VATSIM, IVAO, or other simulated Air Traffic Control environments?  
   Circle: Yes  No  
   If yes, approximately how many hours: ____________
10. Have you ever used the “shared-cockpit” feature in Microsoft Flight Simulator 10.0 or FS-Copilot for earlier versions of Microsoft Flight Simulator?  
    Circle: Yes  No  
    If yes, approximately how many hours: ____________
11. Have you ever flown an NDB approach? Circle: Simulated and/or actual?  
    Circle: Yes  No  
    If yes, approximately how many times: ____________
12. Have you ever experienced a vacuum failure in flight?  
    Circle: Yes  No  
    If yes, approximately how many times: ____________
Appendix C
Approach Plates

Figure Caption

Figure C1. Low-altitude enroute IFR chart of the Omaha sector used for the pre-training evaluation situational awareness task.

Figure C2. NDB approach plate for runway 11 into Worcester, MA used for the pre-training evaluation vacuum failure NDB approach.

Figure C3. NDB-B approach plate for runway 28 into Carlisle, PA used for the training portion of this study.

Figure C4. Low-altitude enroute IFR chart of the Omaha sector used for the post-training evaluation situational awareness task.

Figure C5. NDB approach plate for runway 16 into White Plains, NY used for the post-training evaluation vacuum failure NDB approach.
Figure C2
Figure C3

CARLISLE, PENNSYLVANIA

<table>
<thead>
<tr>
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<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<td>1260-1</td>
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<td>750 (800-2)</td>
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</table>

NDB-B
CARLISLE (N94)

LOM CX 219
APP CRS 286°
TDZE
Apt Elev 510

Use Harrisburg Intl altimeter setting.

MISSED APPROACH: Climbing right turn to 3000 direct CX LOM and hold.

HARRISBURG APP CON
124.1 273.525

UNICOM
122.8 (CTAF)

HARRISBURG
112.5 HAR
Chan 72

CARLISLE
Orig 08269
40°11'N - 77°10'W

GATSBY
750 (800-1)

LANCASTER
117.3 IAF
Chan 120

NE-4, 06 APR 2008 to 07 MAY 2009

285° 7.4 NM
from FAF

ELEV 510
Rwy 10 Ldg 3902'
Rwy 28 Ldg 3906'

40°11'N - 77°10'W
Appendix D

Rater Spread Sheets

Figure Caption

*Figure D1. Post-training evaluation attitude flight task.*

*Figure D2. Post-training evaluation NDB approach task.*
### Figure D1

**Attitude Flying Task**

**Straight-and-Level Flight**

- Heading (+/- 10)/360°
- Altitude (+/- 100)/4000 ft
- Airspeed (+/- 10)/100 kts

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<tr>
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**Right Turn 090°**

- Altitude (+/- 100)/4000 ft
- Airspeed (+/- 10)/100 kts

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**Descent to 3000 ft**

- Heading (+/- 10)/090°
- Airspeed (+/- 10)/100 kts

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**VACUUM FAILURE**

**Straight-and-Level Flight**

- Heading (+/- 10)/090°
- Altitude (+/- 100)/3000 ft
- Airspeed (+/- 10)/100 kts

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**Left Turn 360°**

- Altitude (+/- 100)/3000 ft
- Airspeed (+/- 10)/100 kts

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**Climb to 4000 ft**

- Heading (+/- 10)/360°
- Airspeed (+/- 10)/100 kts

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</table>
**Attitude Flying Task**

**Straight-and-Level Flight**
- Heading (+/-10)/360°
- Altitude (+/-100)/4000ft
- Airspeed (+/-10)/100kts

**Right Turn 090°**
- Altitude (+/-100)/4000ft
- Airspeed (+/-10)/100kts

**Descent to 3000 ft**
- Heading (+/-10)/270°
- Airspeed (+/-10)/100kts

**VACUUM FAILURE**

**Straight-and-Level Flight**
- Heading (+/-10)/090°
- Altitude (+/-100)/3000ft
- Airspeed (+/-10)/100kts

**Left Turn 360°**
- Altitude (+/-100)/3000ft
- Airspeed (+/-10)/100kts

**Climb to 4000 ft**
- Heading (+/-10)/360°
- Airspeed (+/-10)/100kts
Figure D2

**Post-Training Condition - White Plains**

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<tr>
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<tr>
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### Straight-and-Level Flight - to FARAN

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<th>170</th>
<th>180</th>
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</table>

- **Heading**: (+/- 10)/145°
- **Altitude**: (+/- 100)/2000ft
- **Airspeed**: (+/-10)/100kts

### Turn to 162°

<table>
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<tr>
<th>Time (sec)</th>
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<th>110</th>
<th>120</th>
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<th>150</th>
<th>160</th>
<th>170</th>
<th>180</th>
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</thead>
</table>

- **Altitude**: (+/- 100)/2000ft
- **Airspeed**: (+/-10)/100kts

### Straight-and-Level NDB Approach-16

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<tr>
<th>Time (sec)</th>
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<th>180</th>
</tr>
</thead>
</table>

- **Heading**: (+/- 10)/162°
- **Altitude**: (+/- 100)/2000ft
- **Airspeed**: (+/-10)/100kts

### NDB Approach-16 Descent from 2000 to 1200

<table>
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<th>Time (sec)</th>
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</table>

- **Heading**: (+/- 10)/162°
- **Airspeed**: (+/-10)/100kts

### NDB-Approach - Straight-and-level 162° for 1 min

<table>
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<tr>
<th>Time (sec)</th>
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- **Heading**: (+/- 10)/162°
- **Altitude**: (+/- 100)/1200ft
- **Airspeed**: (+/-10)/100kts
<table>
<thead>
<tr>
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**Straight-and-Level Flight to FARAN**
- Heading (+/- 10)/145°
- Altitude (+/- 100)/2000ft
- Airspeed (+/-10)/ 100kts

**Turn to 162°**
- Altitude (+/- 100)/2000ft
- Airspeed (+/-10)/ 100kts

**Straight-and-Level NDB Approach-16**
- Heading (+/- 10)/162°
- Altitude (+/- 100)/2000ft
- Airspeed (+/-10)/ 100kts

**NDB Approach-16 Descent from 2000 to 1200**
- Heading (+/- 10)/162°
- Airspeed (+/-10)/ 100kts

**NDB-Approach - Straight-and-level 162° for 1 min**
- Heading (+/- 10)/162°
- Altitude (+/- 100)/1200ft
- Airspeed (+/-10)/ 100kts
**Straight-and-Level Flight— to FARAN**
- Heading (+/- 10)/145°
- Altitude (+/- 100)/2000ft
- Airspeed (+/-10)/100kts

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**Turn to 162°**
- Altitude (+/- 100)/2000ft
- Airspeed (+/-10)/100kts

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**Straight-and-Level NDB Approach-16**
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- Altitude (+/- 100)/2000ft
- Airspeed (+/-10)/100kts

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**NDB Approach-16 Descent from 2000 to 1200**
- Heading (+/- 10)/162°
- Airspeed (+/-10)/100kts

<table>
<thead>
<tr>
<th>280 sec</th>
<th>290 sec</th>
<th>300 sec</th>
<th>310 sec</th>
<th>320 sec</th>
<th>330 sec</th>
<th>340 sec</th>
<th>350 sec</th>
<th>360 sec</th>
</tr>
</thead>
</table>

**NDB-Approach - Straight-and-level 162° for 1 min**
- Heading (+/- 10)/162°
- Altitude (+/- 100)/1200ft
- Airspeed (+/-10)/100kts

<table>
<thead>
<tr>
<th>280 sec</th>
<th>290 sec</th>
<th>300 sec</th>
<th>310 sec</th>
<th>320 sec</th>
<th>330 sec</th>
<th>340 sec</th>
<th>350 sec</th>
<th>360 sec</th>
</tr>
</thead>
</table>
### Straight-and-Level Flight - to FARAN
- **Heading**: $145^\circ$ (within $10^\circ$)
- **Altitude**: 2000 ft (within 100 ft)
- **Airspeed**: 100 kts (within 10 kts)

### Turn to 162°
- **Altitude**: 2000 ft (within 100 ft)
- **Airspeed**: 100 kts (within 10 kts)

### Straight-and-Level NDB Approach-16
- **Heading**: $162^\circ$ (within $10^\circ$)
- **Altitude**: 2000 ft (within 100 ft)
- **Airspeed**: 100 kts (within 10 kts)

### NDB Approach-16 Descent from 2000 to 1200
- **Heading**: $162^\circ$ (within $10^\circ$)
- **Airspeed**: 100 kts (within 10 kts)

### NDB-Approach - Straight-and-level 162° for 1 min
- **Heading**: $162^\circ$ (within $10^\circ$)
- **Altitude**: 1200 ft (within 100 ft)
- **Airspeed**: 100 kts (within 10 kts)
Appendix E

Data Transformation Sheet

**Attitude Flight**

*Non-vacuum failure*

<table>
<thead>
<tr>
<th></th>
<th>Total errors</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Straight-and-level</strong></td>
<td># of slides</td>
<td></td>
</tr>
<tr>
<td>Altitude</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td>Heading</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td>Airspeed</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td><strong>Right turn</strong></td>
<td># of slides</td>
<td></td>
</tr>
<tr>
<td>Altitude</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td>Airspeed</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td><strong>Descent to 3000 ft</strong></td>
<td># of slides</td>
<td></td>
</tr>
<tr>
<td>Heading</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td>Airspeed</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td><strong>Total Non-vacuum</strong></td>
<td># errors</td>
<td>%</td>
</tr>
</tbody>
</table>

*Vacuum failure*

<table>
<thead>
<tr>
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<th>Total errors</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Straight-and-level</strong></td>
<td># of slides</td>
<td></td>
</tr>
<tr>
<td>Altitude</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td>Heading</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td>Airspeed</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td><strong>Left turn</strong></td>
<td># of slides</td>
<td></td>
</tr>
<tr>
<td>Altitude</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td>Airspeed</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td><strong>Climb to 4000 ft</strong></td>
<td># of slides</td>
<td></td>
</tr>
<tr>
<td>Heading</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td>Airspeed</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td><strong>Total Vacuum</strong></td>
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</table>

**NDB Approach**

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</tr>
</thead>
<tbody>
<tr>
<td><strong>Straight-and-level</strong></td>
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</tr>
<tr>
<td>Altitude</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td>Heading</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td>Airspeed</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td><strong>Right turn</strong></td>
<td># of slides</td>
<td></td>
</tr>
<tr>
<td>Altitude</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td>Airspeed</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td><strong>Descent to 1200 ft</strong></td>
<td># of slides</td>
<td></td>
</tr>
<tr>
<td>Heading</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td>Airspeed</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td><strong>Straight-and-level</strong></td>
<td># of slides</td>
<td></td>
</tr>
<tr>
<td>Altitude</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td>Heading</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td>Airspeed</td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td><strong>Total NDB Approach</strong></td>
<td># errors</td>
<td>%</td>
</tr>
</tbody>
</table>

**Total Flight Evaluation**

<table>
<thead>
<tr>
<th></th>
<th>Total errors</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attitude Flight</strong></td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td><strong>NDB Approach</strong></td>
<td># errors</td>
<td>%</td>
</tr>
<tr>
<td><strong>Total Flight</strong></td>
<td># errors</td>
<td>%</td>
</tr>
</tbody>
</table>
Appendix F

Knowledge Tests

Pre-training knowledge test

Knowledge Evaluation

Participant Number

1. (Refer to figure above) On the basis of this information provided below, the magnetic bearing TO the station would be
   a. 175°
   b. 255°
   c. 355°
   d. 155°
2. (Refer to figure above) If the magnetic heading shown in aircraft 8 is maintained, which ADF illustration would indicate the aircraft is on the 090° magnetic bearing FROM the station?

   a. 3  
   b. 4  
   c. 6  
   d. 5
3. What should be the indication of the magnetic compass as you roll into a standard rate turn to the left from an east heading in the Northern Hemisphere?
   a. The compass will initially indicate a turn to the right
   b. The compass will remain on east for a short time, then gradually catch up to the magnetic heading of the aircraft
   c. The compass will indicate the approximate correct magnetic heading if the roll into the turn is smooth
   d. The compass will smoothly turn to the left regardless of the turn angle
4. (Refer to figure above) What is the flight attitude? One system which transmits information to the instruments has malfunctioned?
   a. Climbing turn to the left
   b. Climbing turn to the right
   c. Level turn to left
   d. Level turn to the right
5. What system in the previous question failed?
   a. Pitot-static
   b. Vacuum
   c. Hydraulic
   d. Electrical
6. (Refer to the figure above - ADF moveable card) What is the relative bearing TO the station?
   a. 260°
   b. 185°
   c. 240°
   d. 030°
7. (Refer to the figure above) The airspeed indicator is located in box...?
   a. 1
   b. 2
   c. 3
   d. 6

8. (Refer to the figure above) The vertical speed indicator is located in box...?
   a. 2
   b. 3
   c. 4
   d. 6
9. What instruments in the six pack display are lost in a vacuum failure?
   a. Altimeter, heading indicator, vertical speed indicator
   b. Attitude indicator, heading indicator, turn coordinator
   c. Attitude indicator, heading indicator
   d. Altimeter, heading indicator
Post-training knowledge test

Knowledge Evaluation

Participant Number

1. (Refer to figure above) On the basis of this information provided below, the magnetic bearing TO the station would be
   a. 060°
   b. 240°
   c. 270°
   d. 220°
2. (Refer to figure above) If the magnetic heading shown in aircraft 6 is maintained, which ADF illustration would indicate the aircraft is on the 255° magnetic bearing FROM the station?
   a. 2
   b. 4
   c. 5
   d. 3
3. What should be the indication of the magnetic compass as you roll into a standard rate turn to the left from a south heading in the Northern Hemisphere?
   a. The compass will indicate a turn to the right, but at a faster rate than is actually occurring
   b. The compass will initially indicate a turn to the left
   c. The compass will remain on south for a short time, then gradually catch up to the magnetic heading of the aircraft
   d. The compass will smoothly turn to the left regardless of the turn angle
4. (Refer to figure above) What is the flight attitude? One system which transmits information to the instruments has malfunctioned.
   a. Level turn to the right
   b. Level turn to the left
   c. Straight-and-level flight
   d. Level climb

5. What system in the previous question failed?
   a. Pitot-static
   b. Vacuum
   c. Hydraulic
   d. Electrical
6. (Refer to the figure above-ADF movable card) What is the relative bearing TO the station?
   a. 330°
   b. 240°
   c. 235°
   d. 175°
7. (Refer to the figure above) The altimeter is located in box...?
   a. 1
   b. 2
   c. 3
   d. 6

8. (Refer to the figure above) The turn coordinator is located in box...?
   a. 2
   b. 3
   c. 4
   d. 6
9. What instrument(s) in the list below is NOT lost in a vacuum failure?
   a. Attitude indicator
   b. Altimeter
   c. Heading indicator
   d. All of the above instruments are lost
Appendix G

Self-Efficacy and Reaction Evaluations

Self – Efficacy

1. I have confidence in my abilities to use a six-pack display.
   | To no Extent | 1 2 3 4 5 6 | To a Great Extent | 7 |

2. I believe I can become unusually good at using a six-pack display.
   | 1 2 3 4 5 6 | 7 |

3. I want to continue training on the six-pack display in the near future.
   | 1 2 3 4 5 6 | 7 |

4. I feel I can solve any problem I encounter using a six-pack display.
   | 1 2 3 4 5 6 | 7 |

5. I can accomplish a lot in the cockpit when I work hard.
   | 1 2 3 4 5 6 | 7 |

6. No six-pack display equipped aircraft is too tough for me to operate.
   | 1 2 3 4 5 6 | 7 |

7. I feel I am a more accomplished pilot after learning how to operate the six-pack display.
   | 1 2 3 4 5 6 | 7 |

8. The six-pack display is an easy display to operate.
   | 1 2 3 4 5 6 | 7 |
## Reaction Evaluation

<table>
<thead>
<tr>
<th></th>
<th>To no Extent</th>
<th></th>
<th>To a Great Extent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I feel today’s six-pack display instruction was informative.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2. I feel the instructor was knowledgeable of the six-pack display.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3. I learned a lot about the six-pack display from today’s training.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4. I feel the training software was realistic.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>5. I believe flight controls were easy to use.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>6. I had no difficulty communicating with the instructor and assistant.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7. I really enjoyed the shared-cockpit feature in Microsoft Flight Simulator.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>8. The yoke control was comfortable and easy to use.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
Participant Introduction

Group: All

Researcher/Assistant: Welcome and thank you for participating in this research study. I am first going to cover some of the details for today's study, payments for participation, and finally consent for participation. Today's instruction will focus on operating a conventional cockpit in a Cessna 172. The purpose of this study is to investigate the usefulness of web-based instruction for instrument flight training.

Your participation in today's study is completely voluntary and you may leave at anytime. However, payment for participation will only be awarded if you complete the study. All information regarding flight performance in today's study will be anonymous. Participation in this study will take approximately two hours to complete. In front of you is a participant information statement followed by an informed consent document. Please read through it carefully and print and sign your name on page two (see Appendix A).

[Allow the participant time to read through and sign the document]

Researcher/Assistant: Please fill-out the following demographics document. Take your time and be sure to fill-out everything to the best of your ability (see Appendix B). Note that all instrument times include both simulated and actual.

[Allow the participant time to read through and complete the document]

Basic Manual Flight Introduction

Group: All

[Make sure the G-1000 Cessna 172 is loaded; filename Basic Flight]

The basic manual flight instruction portion of the study is to allow the participant to become comfortable with operating an aircraft in Microsoft Flight Simulator 10.0. The objective is to allow the participant time to manage the control surfaces of the aircraft as well as power control. There will be an emphasis on the control yoke, trim, and throttle. This portion will take place in a Garmin 1000 equipped Cessna 172 in Microsoft Flight Simulator 10.0. This is to prevent any practice effects with the conventional cockpit. The basic manual flight instruction will take place in VFR conditions, also to avoid practice with instrument operations.
Researcher: Welcome to the Cessna 172 G1000 cockpit. The current display in front of you is the IFR panel view in Microsoft Flight Simulator Version 10.0. This will only be used for this portion of flight. The purpose of this introduction is to allow you time to become familiar with flying the Cessna 172 using manual flight control in Microsoft Flight Simulator.

Researcher: To begin, the simulation is currently “paused” at 2,000 ft. The autopilot is not engaged and will not be used throughout this session. In front of you is a control yoke, rudder pedals and throttle quadrant. You will need to use these items to control the aircraft. Let’s begin the flight!

[Unpause flight and make sure the participant has control of the aircraft]

Researcher: The aircraft is currently flying at 2,000 ft. To change altitude, simply push forward on the yoke to decrease altitude and pull-up on the yoke to increase in altitude. Notice the sensitivity. To release yoke pressure, use the up-down button on the left side of the control yoke. The upper portion of the trim button trims the aircraft downward and the lower portion of the trim button trims the aircraft upward. Remember; only make small adjustments as flight simulator is very sensitive.

Researcher: Fly straight-and-level for two minutes, heading 360°, 2,000 ft, and 100 knots.

Researcher: Now, climb to 3,000 ft using the control yoke and trim tab.

Researcher: Good, now descend back down to 2,000 ft.

Researcher: Now that we are at 2,000 ft, let’s practice turning. To turn, simply move the yoke in the direction you want the aircraft to go. Be sure to apply some back pressure to the yoke to avoid the aircraft’s natural inclination to descend. You can also prevent descent on a turn by properly trimming the aircraft. Be sure to also use rudder control when necessary.

[Note the heading and allow the participant to turn left 180°]

Researcher: Our current heading is 360°. Turn the aircraft to the left at a heading of 180°. Make sure the aircraft only turns left.

[Allow the participant to turn left]

Researcher: Good, now turn right to 360°.

[Allow the participant to turn right]

Researcher: Good, let’s now concentrate on power-adjustments. Find the left knob on the throttle quadrant. This is your throttle. We are currently at 2,000 ft at a heading of 270°. Reduce airspeed to 90 knots.
[Allow the participant to decrease airspeed]

**Researcher:** Good, now increase airspeed to 100 knots.

[Allow the participant to decrease airspeed]

**Researcher:** You have completed altitude, airspeed and heading changes successfully. Now let’s test your ability to perform all of these tasks at once. Your current heading is 360°. Turn right 090° and climb to 3,000 ft and maintain airspeed of 100 knots.

[Allow participant to perform this task. Once complete move on to the next section]

**Pre-Training Evaluation Flight**

**Group:** A and B only

*The pre-training evaluation will test the student’s ability to fly in IFR conditions using a conventional six-pack in a Cessna 172. There are three sections to this evaluation: SA task, attitude flight task, and NDB approach.*

**Section 1 - SA Task**

[Load filename pre-training flight evaluation-SA and Attitude]

**Researcher:** Welcome to the evaluation portion of this study. In a moment, we will begin the evaluation. There will be three components to this evaluation: a situation awareness task, an attitude flight task and a NDB approach. In front of you is a low-altitude enroute chart of the Omaha region. Your objective is to triangulate the correct intersection within the “boxed” perimeter using only your ADF radio. Once you have determined the correct intersection, please **name** the intersection out-loud. Your performance will be based on how long it takes you to complete the task. You can begin now!

[Time the participant. Once they have located the correct location move to the next section]

**Section 2 – Attitude Flight**

**Researcher:** Good, now let’s move to the second section of the evaluation. This section will evaluate your ability to fly in IMC. The flight will cover straight-and-level flight, climbs and descents, turns, and airspeed adjustments. Half of your flight will take place with a normal operating cockpit and the other half with a vacuum failure. Be sure to correctly identify the instruments that are affected by the failure.

[Make sure the flight recorder is active]
Researcher: You are currently flying at 4,000 ft and you have control of the aircraft. Approximately every two minutes I will give you new instructions. Be sure to read back ALL of my instructions as you would in real-life. Maintain straight-and-level flight at 4,000 ft, heading of 360°, and 100 knots for two minutes. Press “P” to “unpause” the flight when you are ready.

[After two minutes, move on to the next procedure]

Researcher: Turn left heading 270° at 100 knots.

Researcher: Descend and maintain 3,000 ft at 100 knots.

Researcher: Maintain straight-and-level flight at 3,000 ft, heading of 270°, and 100 knots.

[Note how long it takes between the time the participant reaches 3,000 ft and the onset of the vacuum failure. Once the vacuum failure occurs, start the stop-watch]

Researcher: Turn right heading 360° at 100 knots.

Researcher: Descend and maintain 4,000 ft at 100 knots.

[Once the participant reaches 4,000 ft terminate the flight and save it in FS recorder]

Researcher: We have now completed section two of the evaluation, let’s now move to the last phase of the evaluation.

[Load filename pre-training evaluation-NDB approach]

Section 3 – NDB Approach

Researcher: We have now made it to the last section of this evaluation. This section contains a NDB approach with a vacuum failure. You are to maintain 2,900 ft and a heading of 145° until you intercept the 109° bearing inbound to the DUNKA NDB. Once you cross the DUNCA NDB, descend and maintain 1,700 ft which simulates your circling altitude. Do not hold at the NDB. Once reaching 1,700 ft, fly straight-and-level for one minute.

[Allow the participant to look at the route for one minute; be sure FS Recorder is active]

Researcher: When you are ready, “unpause” the flight. Also be sure to input your correct NDB frequency and be advised that the entire approach shall be performed with a vacuum failure. In addition, you will not have access to your NAV1 and NAV2 radios.

[Once the participant finishes the flight, be sure to save it in FS Recorder]

Researcher: We have now finished the Pre-training evaluation flight, it’s now time to complete a short nine question written evaluation to test your instrument knowledge.
Knowledge Evaluation

Group: All

Researcher/Assistant: In front of you are questions which assess your knowledge of instrument flight. Please take your time and complete this evaluation.

[Allow participant to complete evaluation]

Conventional Six-Pack Display Training

Group: A and C only

The instructor (CFII) will conduct this portion of the flight. The researcher will introduce the participant to the instructor and the instructor will conduct the training. Training will cover an introduction to the six-pack scan, attitude flight with the scan, vacuum failures, and an NDB approach with a vacuum failure.

[Load the LAX flight for training.]

Instructor: Good afternoon, I will be your instructor today for this portion of the study. Today we will cover three topics for the conventional six-pack: scan, scan in all phases of flight, and VOR navigation.

[Below is the outline the instructor should follow]

A) Scan – is a way to analyze all pertinent flight data. While every person develops their own scan, there are two main methods that serve as good starting points.

a. Box method

i. Starting with the airspeed indicator, continually scan the “six pack” instruments in a box pattern making sure not to skip any.

b. Hub and spoke method

i. Imagine the six-pack as a wagon wheel where the attitude indicator is the central hub and the other instruments are connected by spokes. The scan starts with the attitude indicator then moves on to the other instruments. The scan is completed by scanning all instruments one a time and returning to the attitude indicator.

ii. At all times during flight (straight-and-level, turns, climbs, and descents) in instrument
meteorological conditions, it is necessary to continue scanning the instruments. When the scan stops, due to the omission or fixation of instruments, mistakes are made.

B) Attitude Flight

a. **Straight-and-level flight** – maintains altitude (+/-) 100 ft during level flight, headings (+/-) 10°, and airspeeds (+/-) 10 knots.
   i. Using the scan that works best for the student, simply maintain specified headings, airspeeds, and altitudes.
   ii. If any deviation is detected by the student, the student should only make small corrections to correct the deviation.
   iii. The attitude indicator can be used for primary pitch and bank information, but it should be cross referenced with the other instruments since it can fail.

*Allow the participant time to practice!*

b. **Turns** – maintain a bank angle (+/-) 15° during turn. No turn should exceed standard rate.
   i. Transition from straight flight into a turn using the turn coordinator to establish bank angle.
   ii. The airspeed indicator gives a good indication of climbs and descents because it lags less than the altimeter.
   iii. Roll out for a specified heading should begin prior to reaching the heading. Take the bank angle during the turn and divide it in half. This will give you the number of degrees before the heading where roll out should begin.
   iv. During roll out, rudder in the direction of roll out. This is required to help maintain heading and coordination.

*Allow the participant time to practice!*

c. **Climbs and Descent** – must be performed at a minimum of 500 fpm (feet per minute). If this is not possible, pilot must advise ATC.
   i. When climbs or descents are initiated it is necessary to adjust the power maintain airspeed.
   ii. The attitude indicator can be used for primary pitch and bank information.
   iii. If the climb of descent is made at a constant airspeed or rate the airspeed indicator or vertical speed indicator (respectively) can be used.
   iv. Level off should be done prior to reaching the designated altitude. Begin level off at 10% of the rate of altitude change (read of the VSI).
      1. 1200 fpm descent, begin level off 120 ft above altitude.
      2. 750 fpm climb, begin level off 75 ft below designated altitude.

*Allow the participant time to practice!*
C) **Vacuum Failure** – in a conventional six pack cockpit layout effect two primary flight instruments (attitude indicator and horizontal situation indicator - HSI), that are powered by the engine driven vacuum pump. When this pump fails, raw data from the remaining flight instruments must be processed by the pilot to accurately fly the aircraft.

a. **Compass** is the supporting bank instrument and the primary source of heading navigation, when the vacuum system fails. It leads or lags about turns based off bank angle and latitude. To determine when a roll-out should begin use the formula: Latitude + (bank angle/2) = roll out correction for headings 360°/180°. This only works for turns to north and south, not the other major headings, turns to these headings must be interpolated. Using 30° as max roll out correction, and turns to east (090°) needs no correction. Every 30° above or below east, the roll-out correction increases by 10°.

i. Heading, roll-out correction – 090, 0° - 060, 10° - 030, 20° - 000, 30°

   1. The same is true for westerly turns.

ii. **Leads** – when turning to southerly headings, the compass leads the turn (turns faster than the aircraft). Therefore it is necessary to roll-out past the desired heading.

   1. Left turn to 300° from heading of 060°, where 30° is max correction.

   a. Rollout should begin at heading of 310°.

iii. **Lag** – when turning to northerly headings, the compass lags behind the turn (turning slower than aircraft). Therefore it is necessary to roll-out prior to reaching the desired heading.

b. **Altimeter** is the primary pitch instrument.

c. **VSI** is used as supporting pitch when making altitude changes (unless they are made at constant vertical speed where it becomes a primary instrument). However, it really should not be considered a primary instrument because it lags behind the altimeter during large vertical speed changes due to its calibrated leak.

d. **Turn Coordinator** is the primary bank indicator. All turns should be made at standard rate, unless small heading changes need to be made, then half standard rate should be utilized.

e. **Airspeed Indicator** is a primary power setting instrument. It is important to maintain airspeed to as not to disrupt the trim characteristics.

f. **Timed Turns** – a standard rate turn produces a 360° turn in two minutes time. Extrapolating this information to other turning scenarios is a benefit for the pilot. At this same rate the aircraft will experience a 3° heading change every second. When making timed turns take the amount of heading change and divide it by three. This number will be the number of seconds in the turn until the desired heading change is achieved.

*Allow the participant time to practice!*
**D) NDB Approach** – NDBs are useful due to their simplicity.

a. There are two components to an NDB system. These are the NDB (Non-Directional radio Beacon) station which is on the ground and the ADF (Automatic Direction Finder) which is what is used in the aircraft.

b. When the ADF is tuned to the NDB, its needle will always point toward the station.

c. Once the station is tuned, its identifier needs to be monitored continuously.
   i. If the station goes out of service the identifier stops. This is the only indication that the NDB is unusable, and a missed approach must be conducted.

d. The formula to determine magnetic bearing to the station is \( MH + RB = MB \)

e. Magnetic Heading (MH) + Relative Bearing (RB) = Magnetic Bearing (MB)
   i. MH is read off the compass (or HIS if it has been slaved to the compass)
   ii. RB is read off the ADF card when North is up.
   iii. MB is the bearing that needs to be flown to go to the station.

f. The approach is simply conducted as instructed on the approach plates. *Allow the participant time to practice!*

**Post-Training Evaluation Flight**

**Group: All groups**

*The post-training evaluation will test the student’s ability to fly in IFR conditions using a conventional six-pack in a Cessna 172. There are three sections to this evaluation: SA task, attitude flight task, and NDB approach. This evaluation resembles the pre-training evaluation with the exception of different areas used.*

**Section 1- SA Task**

[Load filename post-training flight-SA and Attitude]

**Researcher:** Welcome to the evaluation portion of this study. In a moment, we will begin the evaluation. There will be three components to this evaluation: a situation awareness task, an attitude flight task and a NDB approach. In front of you is a low-altitude enroute chart of the region north of Omaha. Your objective is to triangulate the correct intersection within the “boxed” perimeter using only your ADF radio. Once you have determined the correct intersection, please **name** the intersection out-loud. Your performance will be based on how long it takes you to complete the task. You can begin now!

[Time the participant. Once they have located the correct location move to the next section]

**Section 2 – Attitude Flight**

**Researcher:** Good, now let’s move to the second section of the evaluation. This section will evaluate your ability to fly in IMC. The flight will cover straight-and-level flight, climbs and
descents, turns, and airspeed adjustments. Half of your flight will take place with a normal operating cockpit and the other half with a vacuum failure. Be sure to correctly identify the instruments that are affected by the failure.

[Make sure the flight recorder is active]

**Researcher:** You are currently flying at 4,000 ft and you have control of the aircraft. Approximately every two minutes I will give you new instructions. Be sure to read back ALL of my instructions as you would in real-life. Maintain straight-and-level flight at 4,000 ft, heading of 360°, and 100 knots for two minutes. Press “P” to “unpause” the flight when you are ready.

[After two minutes, move on to the next procedure]

**Researcher:** Turn right heading 090° at 100 knots.

**Researcher:** Descend and maintain 3,000 ft at 100 knots.

**Researcher:** Maintain straight-and-level flight at 3,000 ft, heading of 090°, and 100 knots.

[Note how long it takes between the time the participant reaches 3,000 ft and the onset of the vacuum failure. Once the vacuum failure occurs, start the stop-watch]

**Researcher:** Turn left heading 360° at 100 knots.

**Researcher:** Descend and maintain 4,000 ft at 100 knots.

[Once the participant reaches 4,000 ft terminate the flight and save it in FS recorder]

**Researcher:** We have now completed section two of the evaluation, let’s now move to the last phase of the evaluation.

[Load filename pre-training evaluation-NDB approach]

Section 3 – NDB Approach

**Researcher:** We have now made it to the last section of this evaluation. This section contains a NDB approach with a vacuum failure. You are to maintain 2,000 ft and a heading of 145° until you intercept the 162° bearing inbound to the HESTER NDB. Once you cross the DUNCA NDB, descend and maintain 1,200 ft which simulates your circling altitude. Do not hold at the NDB. Once reaching 1,200 ft, fly straight-and-level for one minute.

[Allow the participant to look at the route for one minute; be sure FS Recorder is active]

**Researcher:** When you are ready, “unpause” the flight. Also be sure to input your correct NDB frequency and be advised that the entire approach shall be performed with a vacuum failure. In addition, you will not have access to your NAV1 and NAV2 radios.
[Once the participant finishes the flight, be sure to save it in FS Recorder]

**Researcher:** We have now finished the Pre-training evaluation flight; it's now time to complete a short nine question written evaluation to test your instrument knowledge.

**Knowledge and Attitudes Evaluation**

**Group:** All

**Researcher:** You have now completed the majority of the study. You will now be given the knowledge evaluation. Make sure to take your time and answer every question to the best of your ability.

[After completion of the knowledge evaluation, have the participant complete the self-efficacy and reaction evaluations]

**Researcher:** Before leaving today, I ask for you to complete this self-efficacy evaluation. Like the rest of the documents you have completed today, be sure to take your time and to answer every question to the best of your ability.

**Debrief**

**Researcher:** Thank you for participating in this research study. The purpose of this study is to investigate the effectiveness of web-based training for instrument flight training. The results of this study could provide further insight into forming alternative forms of aviation training that are more productive and affordable to the student and trainee. If you are interested in the results of this study, we can provide you with that information once the study has been completed. Please contact Andrew Mendolia at andrew.mendolia@gmail.com or (703) 475-5574. Please leave your email address and phone number so we can provide you with your payment for participation. Your performance in today’s study will remain anonymous. Please refrain from revealing the true nature of this study as any disclosure could jeopardize the results. If you felt an emotional discomfort during today’s study, feel free to contact Health Services at (386) 226-7917.

**Researcher:** I once again thank you for participating in today’s study.

[Make sure the participant leaves his or her name and number]

[End of study]