Development and Assessment of a Novel Training Package For Basic Maneuvering Tasks on a Flight Simulator Using Self Instruction Methods and Above Real Time Training (ARTT)

FINAL TECHNICAL REPORT

By

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The reported work has not resulted in any invention

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4. SUMMARY OF THE COMPLETE REPORT

The report includes five research papers published in proceedings of various conferences and a Master of Science thesis. The research performed for the publications comprised three sets of experiments on training of novice pilots in a PC based flight simulator. The first set of experiments examined the use of Post-Flight Feedback (PFFB) and Above Real Time Training (ARTT) while training novice pilots to perform a coordinated level turn. The second and third sets of experiments investigated the effects of using out-of-the-window visual cues for training novice pilots to perform a basic flight maneuver. The flight maneuvers in the second and third sets were the straight-in landing approach and a coordinated level turn respectively. The out-of-the window visual cues in both sets consisted of visual hoops on the flight path through which a trainee would fly if maintaining the proper parameters.

In all three sets of experiments, we evaluated a training strategy by requiring every participant trained within an assigned strategy, to fly a similar but more challenging task without the use of Above Real Time Training or feedback or visual cues. To authenticate the computed performance measures for the training and evaluation flights, we compared them with the grades awarded by certified flight instructors on a prescribed number of selected flights.

For a comprehensive presentation of the training strategies covered in this research, a relatively small part of this report includes the work that is already reported on a preceding project performed by the same faculty members and sponsored by a NASA Dryden grant, NAG4-203 (At some places, by mistake, it was recorded as NAG4-209). Such material has sighted the appropriate reference in the enclosed publications.

The following paragraphs identify the six publications and provide the respective abstracts. The abstracts in these paragraphs are abridged versions of the abstracts and conclusions or results in the respective publications.

I. "An Evaluation of Training Interventions and Computed Scoring Techniques for Grading a Level Turn Task and a Straight in Landing Approach on a PC-Based Flight Simulator", MS thesis of Bruce E. Heath, Major Professor M. Javed Khan, at Tuskegee University, May 2007, 76 pages.

One result of the relatively recent advances in computing technology has been the decreasing cost of computers and increasing computational power. This has allowed high fidelity airplane simulations to be run on personal computers (PC). Thus, simulators are now used routinely by pilots to substitute real flight hours for simulated flight hours for training for an aircraft type rating thereby reducing the cost of flight training. However, FAA regulations require that such substitution training must be supervised by Certified Flight Instructors (CFI). If the CFI presence could be reduced or eliminated for certain tasks this would mean a further cost savings to the pilot. This would require that the flight simulator have a certain level of 'intelligence' in order to provide feedback on pilot performance similar to that of a CFI. The 'intelligent' flight simulator would have at least the capability to use data gathered from the flight to create a measure for the performance of the student pilot. Also, to fully utilize the advances in computational power, the simulator would be capable of interacting with the student pilot using the best possible training interventions.

This thesis reports on the two studies conducted at Tuskegee University investigating the effects of interventions on the learning of two flight maneuvers on a flight simulator and the robustness and accuracy of calculated performance indices as compared to CFI evaluations of performance. The intent of these studies is to take a step in the direction of creating an 'intelligent' flight simulator. The first study deals with the comparisons of novice pilot performance trained at different levels of above real-time to execute a level S-turn. The second study examined the effect of out-of-the-window (OTW) visual cues in the form of hoops on the performance of novice pilots learning to fly a landing approach on the flight simulator. The reliability/robustness of the computed performance metrics was assessed by comparing them with the evaluations of the selected number of the level turn flights by two CFIs and the landing flights by three CFIs.

Real Time Training (RT) with the post flight feedback resulted in the best performance on the evaluation flights for a level turn as compared to no feedback or training with ARTT. Above Real Time Training (ARTT) using a sequence of 1.5/2.0 with post flight feedback was observed to be the next best strategy for a level turn. The 1.5/2.0 ARTT implies that a trainee performed the first few flights with simulated events at a pace 1.5 times that of the actual, then flew with simulated pace 2 times that of the actual. The particular post flight feedback provided to the participants flying the level turn, consisting primarily of graphical feedback which showed the actual ground track superimposed over the target ground track, may be an effective form of feedback to implement in an "intelligent" flight simulator providing automated feedback.

For the landing task, no statistically significant difference was found between the group provided with visual out-of-the-window cues of hoops and the control group, perhaps because visual cues in the form of the runway and visual approach slope indicator lights were already available for this maneuver.

Poor correlations were observed between the evaluations by three different CFIs; improved correlations were, however, obtained for such flights on which the CFIs agreed on the best and worst controlled parameters. On those flights, the instructors' grades correlated well with the computed grades.

II. "An Experimental Study of the Effect of Out-of-the-Window Cues on Training of Novice Pilots on a Flight Simulator" by M. Javed Khan, Marcia

Rossi, Bruce Heath, S. Firasat Ali, Marcus Ward, Proceedings, Human Factors and Ergonomics Society Conference, San Francisco, California, October 2006, 5 pages.

The effects of out-of-the-window cues on learning a straight-in landing approach and a level 360° turn by novice pilots on a flight simulator have been investigated. The treatments consisted of training with and without visual cues as well as density of visual cues. The performance of the participants was then evaluated through similar but more challenging tasks. It was observed that the participants in the landing study who trained with visual cues performed more poorly than those who trained without the cues. However, the performance of those who trained with a faded-cues sequence performed slightly better than those who trained without visual cues. In the level turn study it was observed that those who trained with the visual cues performed better than those who trained without visual cues. The study also showed that those participants who trained with a lower density of cues performed better than those who trained with a higher density of visual cues.

III. "Correlating Automated and Flight Instructor Assessments of Straight-In Landing Approaches by Novice Pilots on a Flight Simulator" by Bruce E. Heath, M. Javed Khan, Marcia Rossi, Syed Firasat Ali, Proceedings, Huntsville Simulation Conference, Huntsville, Alabama, October 2005, 7 pages.

The research reported in this paper was conducted to evaluate various performance metrics of a straight-in landing approach by 33 novice pilots flying a light single engine aircraft simulation. These metrics were compared to assessments of these flights by three flight instructors to establish a correlation between the two techniques in an attempt to determine a composite performance metric for this flight maneuver. The performance measures investigated were the standard deviation of the errors in runway alignment, rate of descent, airspeed and linear combinations of these deviations. Pearson Product Moment Correlations were calculated between these measures and the three individual instructors' scores. The correlations ranged between 0.05 and 0.27. Correlations between the pairs of instructors' grades were calculated and found to be moderate (r^2= 0.4334, 0.5054, 0.4334). Seven of the 33 flights were identified for which all three instructors agreed on both best and worst controlled parameters. Correlations between the instructor grades and the composite error metric (a linear combination of the standard deviations of errors in runway alignment, rate of descent and airspeed) were calculated for these flights. Strong correlations were found for all three instructors (r^2 ranged between 0.63 and 0.82.) A composite error metric was used to provide the computed grades on all the training and evaluation flights.

IV. Using a Low Cost Flight Simulation Environment for Interdisciplinary Education by M. Javed Khan, Marcia Rossi, Syed F. Ali, Proceedings, ASEE Annual Conference and Exposition, Salt Lake City, Utah, June 2004, 6 pages.

A multi-disciplinary and inter-disciplinary education is gaining increasing recognition as an essential element in the undergraduate engineering education. However, often the focus is on interaction between engineering disciplines. This paper discusses the experience at Tuskegee University in providing inter-disciplinary research experiences for undergraduate students in both Aerospace Engineering and Psychology through the utilization of a low cost flight simulation environment. The environment, which is PC-based, runs a low-cost of-the-shelf software and is configured for multiple out-of-the-window views and a synthetic heads down display with joystick, rudder and throttle controls. While the environment is used to investigate and evaluate various strategies for training novice pilots, students were involved to provide them with experience in conducting such interdisciplinary research. On the global inter-disciplinary level these experiences included developing experimental designs and research protocols, consideration of human participant ethical issues, and planning and executing the research studies.

An interdisciplinary team of aerospace engineering and psychology majors was involved in the interdisciplinary research project. The research provided the students an opportunity to function as a closely-knit team. They gained experience in: (a) Participation and interaction as a research group, (b) establishing tasks for achieving research objectives, (c) time and effort management, (c) interdisciplinary academic areas, (d) literature searches, and (e) formal presentations of results. The team successfully met the objectives set forth by the faculty mentors. The main elements of success were a high level of motivation of the students due to the opportunity of learning of concepts not covered in their major areas, students' appreciation of responsibility of tasks with practical impact on the investigation and planning, and students' involvement in actual conduct of the experiments under minimal supervision. However, it is essential that for interdisciplinary student research teams, the faculty mentors have a well-structured research plan to minimize overwhelming of the students. Regular meetings to provide well-defined tasks are an important element of the structure.

V. Effect of Above Real Time Training and Post Flight Feedback in training of Novice Pilots in a PC-Based Flight Simulator by M. Javed Khan, Marcia Rossi, Bruce E. Heath, Syed Firasat Ali, Peter Crane, Tremaine Knighten, Christi Culpepper, Proceedings, Huntsville Simulation Conference, Huntsville, Alabama, October 2003, 8 pages.

We investigated the use of Post-Flight Feedback (PFFB) and Above Real-Time Training (ARTT) while training novice pilots to perform a coordinated level turn on a

PC-based flight simulator. Participants in six different groups obtained their training in the following respective sequences:

Group 2.0/1.5 ARTT no PFFB: Five missions in 2.0 ARTT then five missions in 1.5 ARTT with no PFFB. (2.0 ARTT and 1.5 ARTT imply that the simulated events in the training missions were performed respectively at the pace 2.0 times and 1.5 times the actual pace of events)

Group 2.0/1.5 ARTT with PFFB: Five missions in 2.0 ARTT then five missions in 1.5 ARTT with PFFB

Group 1.5/2.0 ARTT no PFFB: Five missions in 1.5 ARTT then five missions in 2.0 ARTT with no PFFB

Group 1.5/2.0 ARTT with PFFB: Five missions in 1.5 ARTT then five missions in 2.0 ARTT with PFFB

Group 1.0/1.0 RTT no PFFB (Control group): Ten missions in RTT then with no PFFB

Group 1.0/1.0 RTT with PFFB: Ten missions in RTT with PFFB

Immediately after the training missions, every participant conducted two challenging evaluation missions in real time with no feedback. The performance measure was based on the root mean squares of deviations in bank angle and altitude from their prescribed values.

The study suggested that for training of a coordinated level turn:

1. If ARTT is to be used:
   - (a) That it should be used as top-off training, i.e., after the pilot has experienced sufficient improvement in performance to have reached a plateau.
   - (b) That it should be used in conjunction with appropriate PFFB.
2. PFFB in a RTT is the most efficient combination

VI. Comparison of Different Methods of Grading a Level Turn Task on a Flight Simulator by Bruce E. Heath, Tomyka Crier, Proceedings, Huntsville Simulation Conference, Huntsville, Alabama, October 2003, 7 pages.

With the advancements in the computing power of personal computers, PC-based flight simulators and trainers have opened new avenues in the training of airplane pilots. It would be desirable to have the flight simulator make a quantitative evaluation of the progress of a pilot's training thereby reducing the physical requirement of the flight instructor who must, in turn, watch every flight.

In an experiment, University students conducted six different flights, each consisting of two level turns. The flights were three minutes in duration. Four kinds of grading have been used and compared for evaluating the flights. They are the following: (1) Instructor's grade that is awarded by a certified instructor. (2) Automated grade that is based on prescribed tolerances in bank angle, altitude and airspeed monitored at several instants of time during a flight. (3) The performance index (P.I.) that is created by using the square root of the sum of the squares of dimensionless deviations in altitude and bank angle. (4) Performance grade that is defined as 1 / (0.25 + P.I.) and provides a reasonable

4.0 grading scale. The comparison of performance grades with the other three performance measures suggests that they deserve further study for the evaluation of level turns in a simulator.

5. ACKNOWLEDGEMENTS FOR THE COMPLETE REPORT

NASA Dryden Flight Research Center sponsored this study through Grant Number NAG4-226. The sponsorship included financial support of three graduate students and ten undergraduates, who contributed in the study. Some of the students received partial financial support from the NASA Ames Award CTS-0320305. Jennifer Faulkner, Crystal Harris, Lakeshia King, SharHonda Kirksey and Yotadsha Stephens assisted the authors in the data collection and processing. The study used Lite Flite flight simulator procured from SDS International of Orlando, Florida and off the shelf purchased Microsoft Flight simulators 2002 and 2004. Dr. Dutch Guckenberger provided programming support for the Lite Flite Simulator. Asim Ali has done the formatting of the report. A total of about one hundred students registered in introductory psychology courses were voluntary participants as novice trainees under various training strategies. Three certified flight instructors independently graded selected flights on the simulator. The authors are pleased to acknowledge all the support and the help.

I

AN EVALUATION OF TRAINING INTERVENTIONS AND COMPUTED SCORING TECHNIQUES FOR GRADING A LEVEL TURN TASK AND A STRAIGHT IN LANDING APPROACH ON A PC-BASED FLIGHT SIMULATOR

By
Bruce E. Heath

A Thesis Submitted to the Graduate Faculty of Tuskegee University in Partial Fulfillment of the Requirements of the Degree:

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

TUSKEGEE UNIVERSITY
Tuskegee, Alabama 36088
May 2007

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AN EVALUATION OF TRAINING INTERVENTIONS AND COMPUTED SCORING TECHNIQUES FOR GRADING A LEVEL TURN TASK AND A STRAIGHT IN LANDING APPROACH ON A PC-BASED FLIGHT SIMULATOR

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ABSTRACT

AN EVALUATION OF TRAINING INTERVENTIONS AND COMPUTED SCORING TECHNIQUES ON A LEVEL TURN TASK AND A STRAIGHT IN LANDING APPROACH ON A PC-BASED FLIGHT SIMULATOR

By
Bruce E. Heath

One result of the relatively recent advances in computing technology has been the decreasing cost of computers and increasing computational power. This has allowed high fidelity airplane simulations to be run on personal computers (PC). Thus, simulators are now used routinely by pilots to substitute real flight hours for simulated flight hours for training for an aircraft type rating thereby reducing the cost of flight training. However, FAA regulations require that such substitution training must be supervised by Certified Flight Instructors (CFI). If the CFI presence could be reduced or eliminated for certain tasks this would mean a further cost savings to the pilot. This would require that the flight simulator have a certain level of 'intelligence' in order to provide feedback on pilot performance similar to that of a CFI. The 'intelligent' flight simulator would have at least the capability to use data gathered from the flight to create a measure for the performance of the student pilot. Also, to fully utilize the advances in computational power, the simulator would be capable of interacting with the student pilot using the best possible training interventions.

This thesis reports on the two studies conducted at Tuskegee University investigating the effects of interventions on the learning of two flight maneuvers on a flight simulator and the robustness and accuracy of calculated performance indices as compared to CFI

evaluations of performance. The intent of these studies is to take a step in the direction of creating an 'intelligent' flight simulator. The first study deals with the comparisons of novice pilot performance trained at different levels of above real-time to execute a level S-turn. The second study examined the effect of out-of-the-window (OTW) visual cues in the form of hoops on the performance of novice pilots learning to fly a landing approach on the flight simulator. The reliability/robustness of the computed performance metrics was assessed by comparing them with the evaluations of the landing approach maneuver by a number of CFIs.

CHAPTER I

INTRODUCTION

Motivation

One result of the relatively recent advances in computing technology has been the decreasing cost of computers yet increasing computational power. This has allowed high fidelity airplane simulations to be run on personal computers (PC). Thus, simulators are now used routinely by pilots to substitute real flight hours for simulated flight hours for training for an aircraft type-rating thereby reducing the cost of flight training. However, FAA regulations[1] (quoted below) require that such substitution training must be supervised by Certified Flight Instructors (CFI).

> ***5. AUTHORIZED USE.***
> ***a. Instruction by an Authorized Instructor.*** *Qualified PCATD's may be highly beneficial when used under the guidance of an authorized instructor to achieve learning in certain procedural tasks such as area departures and arrivals, navigational aid tracking, holding pattern entries, instrument approaches, and missed approach procedures. Accordingly, the FAA has determined to continue the policy that any time instruction is to be used to log time toward meeting any requirement of the regulations, an authorized instructor must have presented the instruction.*

If the CFI presence could be reduced or eliminated for certain tasks, this would mean a further cost savings to the pilot. This would require that the flight simulator have a certain level of 'intelligence' in order to provide expert feedback on pilot performance similar to that of a CFI. The 'intelligent flight simulator' (IFS) would have at least the capability to use data gathered from the flight to create a measure for the performance of the student pilot and provide expert feedback to the student pilot based on the computed performance index. Also, to fully utilize the advances in computational power, the simulator would be capable of interacting with the student pilot using the best possible training interventions.

Ludwig[2] et al. have referred to Mulgand's[3] main components of an Intelligent Tutoring System (ITS) to be the 'helper' and the 'advisor'. In their implementation of an IFS, the 'helper' assisted the pilot by making the helicopter, at first, easier to fly. As the student became more comfortable with the aircraft, the pilot received less help. The 'advisor' communicated directly with the pilot using text-to-speech software in four roles namely, tutorial, performance monitoring, monitoring flight control manipulation and advisory, verbalizing suggestions to control or correct flight.

Objective

The objective, however, of this study has been to investigate two important aspects of an IFS. These aspects being: (a) novel techniques to determine their efficacy in expediting the training of novice pilots and (b) reliability and robustness of computed performance indices in comparison to the CFI grading.

The two novel training techniques that were evaluated during the course of this investigation were:

(a) Above real time training (ARTT) for training a level S-turn with and without performance feedback.

(b) Out-of-window (OTW) visual cues based on "tunnel in the sky" for training a landing approach. Performance feedback was used.

Literature Review

Above Real Time Training (ARTT)

In 'above real time' (ART), or as it has been referred to in literature[4] as 'time compression', events are presented in a simulator as if they were happening in real time but are actually running faster than the same event in the real world. For example, an aircraft flying at 90 knots might look as though it is flying at 180 knots. However, any airplane flying at twice the speed would have, for a level-turn, a 4 times larger radius. In fact, lift and drag for the airplane at 180 knots would be different from an airplane flying at 90 knots. ART, therefore, means that in a simulator, the aircraft flying at 90 knots will have lift, drag and airspeed indications of an aircraft flying at 90 knots, except that time will pass at a multiple of actual clock time. Thus, for example, at 2.0 ART, the airplane flying at 90 knots will cover 90 nautical miles in one hour of computer clock time, but in real clock time it will take 30 minutes. Previous experiments[4, 5, 6] on training of pilots have indicated that real time training reinforced with ARTT could offer an effective training strategy for tasks which require significant effort at time and workload management. Kolf[5] documented that no matter how much pre-flight simulator training the pilot had undergone, the actual flight appeared, to the pilot, to take place in a much faster time frame. He chose pilots with experience flying the M2-F3 to fly experimental flights in the simulator and noted that by increasing simulator clock speed to 1.5 ART, the pilots felt that the simulator more closely resembled their actual flying experience. Kolf hypothesized that for ARTT an appropriate above real time factor would have to be chosen and would be a function of aircraft type, individual, task, and experience. Hoey[4] compared biomedical measurement data of test pilots flying remotely piloted vehicles, with data taken in past flights. He suggested that providing ARTT on a simulator could approximately simulate the mental state of pilots as if actually flying. His suggestion was that ARTT compared with real time training on a simulator, would lead to a smoother transition from simulator to airplane. Crane and Guckenberger[6] reference Schneider's[7] air traffic control study who proposed that "the primary effect of time compression is to allow more training trials within a given period of clock-time." Crane and Guckenberger[5] contrasted this study by giving two groups the same number of trials so that the above real-time participants receive less clock-time than the real-time participants while performing the task of tracking and shooting at a target in the air. The test trials were then performed in real-time. The results of that study showed that participants trained in above real-time performed better than participants trained in real-time.

However, this review of literature on ARTT determined that ARTT has not been exploited for the training of flight maneuvers.

Tunnel in the sky

The second training intervention investigated was the use of visual cues. This method is based on the concept of Tunnel in the Sky. The tunnel in the sky (Figure 1) which is a visual aid that shows the proposed path of flight for a maneuver in the sky is the subject of a number of studies.[8,9] The benefits of using tunnel in the sky for navigation versus flight path tracking with conventional instruments have been investigated in these studies.

Barrows, Alter, Enge, Parkinson, and Powell[10] compared the use of a tunnel display versus conventional instruments. In the simulator three different displays were offered:

1. The control group: conventional instruments, vertical speed indicator (non-instantaneous), horizontal situation indicator (HSI) with glide slope display, attitude indicator, altimeter, airspeed indicator, and turn coordinator,

2. First experimental group: Conventional instruments with a track symbol added to the HSI.

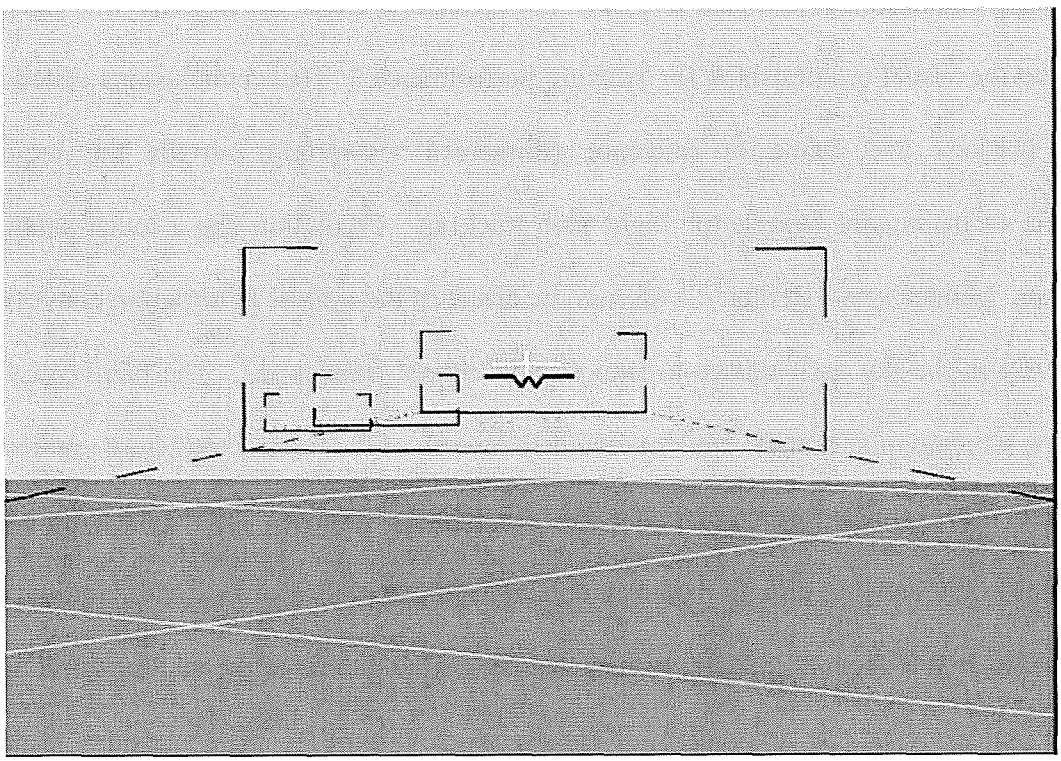

Figure 1. An example of tunnel in the sky.

3. Second experimental group: The HSI from the first experimental group and an additional symbol "glide slope predictor".

4. Third experimental display: a pathway-in-the-sky.

Using a simulator and actual flight, they found that the tunnel display offered significant improvements in horizontal and vertical flight precision and in workload reduction as compared to conventional instrumentation.[7]

Doherty and Wickens[9] looked at the effects of preview, prediction, frame of reference and display gain in tunnel in the sky displays. In short, preview allows a pilot to anticipate upcoming demands and prepare a response before actually starting a maneuver. They also used a flight predictor in their display that reduced the cognitive effort required by the pilot in determining future trajectory of the airplane. An egocentric frame of reference was chosen to "preserve the visual relationships for tracking performance." Their conclusions stated in part that preview and frame of reference (immersed viewpoint) provide the largest contribution to the tunnel benefit for flight path tracking. Prediction has a much smaller contribution. Mulder's two studies[11,12] discuss the effect of the optical information conveyed by a pathway-in-the-sky as it relates to straight and curved trajectories. The pathway was drawn using a rectangular tunnel. Mulder credits the worth of the tunnels to texture gradients that provide the useful information about the participants' motion. In Mulder's study, parallel lines to the viewing direction convey optical "splay angle" information or gradient of perspective (lines that meet at infinity). Lines that are perpendicular to the viewing direction convey an optical density or a "gradient of compression" (Figure 2). The study found that for a straight tunnel, optical splay and optical density were "essential for the pilot to perceive and control the aircraft position and motion with respect to the tunnel." Also, Mulder found that splay and density were complementary. A tunnel display without optical splay lines is not recommended and a tunnel display with the wrong number of frames could cause clutter.

For a curved trajectory, gradients have a much smaller use. First of all there is no vanishing point as can be seen in a straight tunnel. Second, only the gradients conveyed by the nearby elements of the tunnel provide valuable information about the aircraft movement.

Third, the presented curved trajectory does not convey actual position and attitude relative to the trajectory. These are presentation biases that lead the pilot to compensate for position and attitude errors that are not really there.

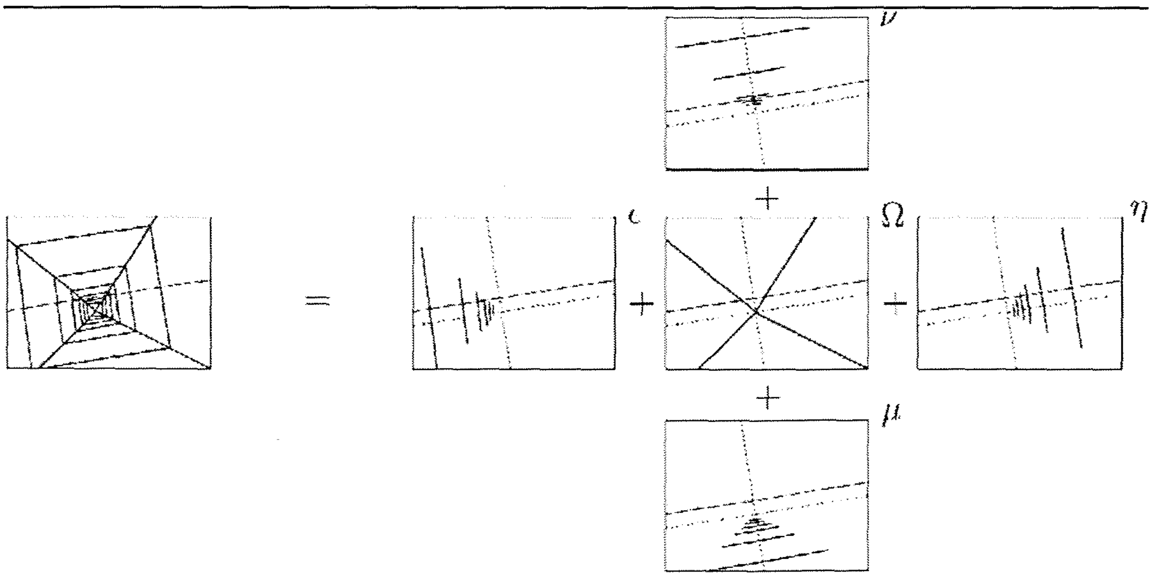

Figure 2. Straight tunnel components. Ω shows the optical splay angle, $\varepsilon, \nu, \eta, \mu$ show the perpendicular lines that convey optical density (Mulder[11]).

For a curved trajectory it was found that splay lines are substantially but not significantly useful. Presentation bias is greatest when the display shows only contour lines and decreases considerably when tunnel frames are used. Presentation bias leads to errors in the lateral position relative to the center circle. Participants found it difficult to tell when they were flying on the center of the path. Also, Mulder recommends use of a greater number of rings to reduce presentation bias.

Performance Feedback

As mentioned above, the cost component associated with the requirement of a CFI to be present during every simulation can be minimized if the flight simulator is able to emulate expert feedback of a CFI. Vruels and Obermayer[13] emphasize the need of automated performance measures on modern simulators as a substitute for direct evaluation of performance by an instructor. Rantanen and Talleur[14] have suggested the following five primary measures for pilot performance from the flight data recorder for nine flight parameters: (1) Standard deviation. A small standard deviation is indicative of good performance. (2) Root mean square error (RMSE) which summarizes the overall error. (3) Number of deviations, which is a measure of occurrences of the aircraft staying outside the prescribed tolerances. (4) Time outside tolerance is the cumulative time the aircraft spends outside prescribed tolerances. (5) Mean time to exceed tolerance is computed from the rate of change between successive data points and the aircraft's position relative to a given tolerance. Heath and Crier[11] used computerized scoring and certified flight instructors (CFI) to attempt to devise a computed performance measure for a level turn. A performance index based on deviations from the required heading, altitude and airspeed was compared with the instructors' letter grades. One of the challenges of such comparisons is inter-rater reliability of the flight instructors. In a study about crew resource management (CRM) in a simulated helicopter, Brannick, Prince, and Salas[15] evaluated three items: "(a) specific crew behaviors in response to scenario events (e.g., whether the crew kept out of icing conditions), (b) valuations of crew responses to scenario events (e.g., overall handling of the icing problem), and (c) crew resource management (CRM) dimensions for the entire scenario (e.g., evaluations of decision making)."

They were able to show that "respectable levels of both interjudge agreement and internal consistency were achieved for items dealing with the evaluation of crew performance in response to items in events embedded in the scenario". Interjudge agreement was low but internal consistency was high on CRM items and scales. Interjudge agreement was high but internal consistency low for specific observable behaviors.

An attempt to correlate instructors' grades with a performance metric by Heath and Crier[16] showed the same result. The instructors did not agree on how to measure performance. Discrepancies between instructors may be due partially to the fact that instructors normally give a pass/fail type of evaluation and not the type of A, B, C, D, E grade requested for the current study.

In a follow-up study the instructors were asked to identify the parameter they thought the student best controlled and the parameter they thought was worst controlled. Performance metrics were graphed against the grades given by the three instructors for the flights where they were in agreement of the best and worst controlled parameters. Using that kind of selection, a better correlation was found between instructor grades.

CHAPTER II

LEVEL TURN EXPERIMENT

This chapter describes a study which compared Above Real Time Training (ARTT) versus Real Time Training to investigate the performance of 32 novice trainees using a Level Turn Maneuver. The turn flight maneuver is one of the basic flight maneuvers required for a pilot in pre-solo training. According to the Federal Aviation Regulations other basic flight maneuvers include takeoff and landing, straight and level flight, climb and descent. (FAR 2002; §61.87) The purpose of this experiment is to investigate the effect of different levels of ARTT on novice pilots and to attempt to create a performance metric that will allow the comparison of the various groups of students flying at different levels of ART.

Setup

Hardware

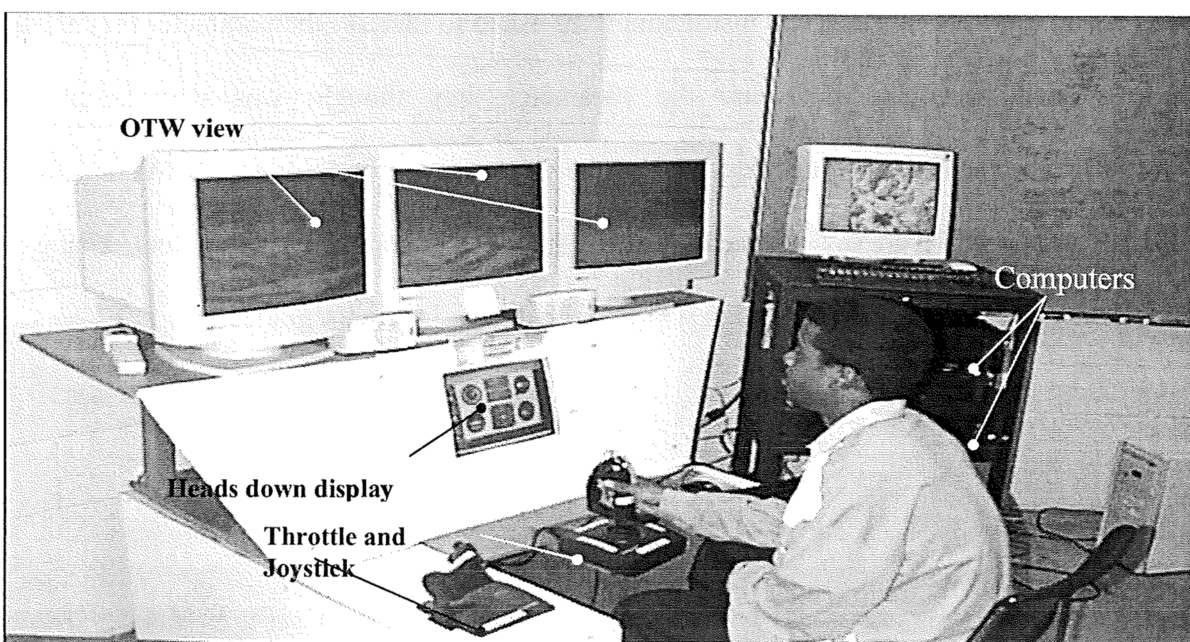

Figure 3. LiteFlite partial mock cockpit setup shows heads down display and OTW.

The experiment was performed in the Flight Vehicle Design Lab at Tuskegee University. The "simulator" consists of a mock setup of a partial construction of a cockpit. Three 19" monitors create a panoramic, outside of the window (OTW) view. The center monitor contains a heads up display (HUD) superimposed on the forward view. The HUD displays a composite of several relevant instruments including: altimeter, airspeed indicator, horizontal situation indicator (HSI), turn and slip coordinator, and heading indicator as shown (Figure 4).

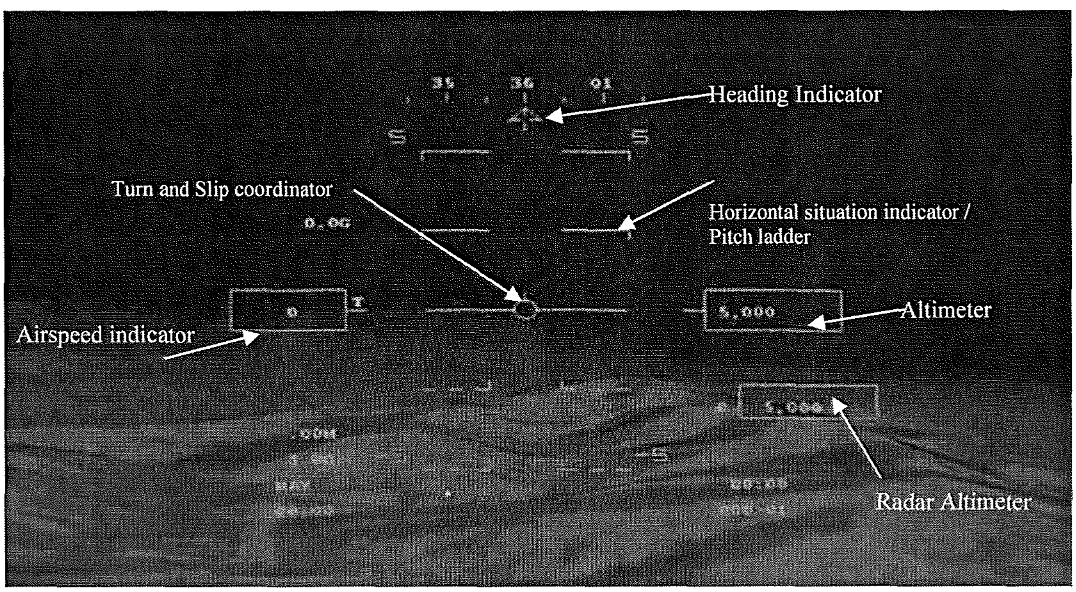

Figure 4. HUD for the LiteFlite software is superimposed on the center monitor of the OTW view.

The mock setup had an inside the cockpit "instrument panel" view displayed on a 15" monitor as shown (Figure 5).

The joystick used was a Saitek X36F and the throttle was a Saitek X35T controller. Rudder pedals used were from CH products. The PCs for the simulator were two Heavy Metal computers made by Quantum 3D.

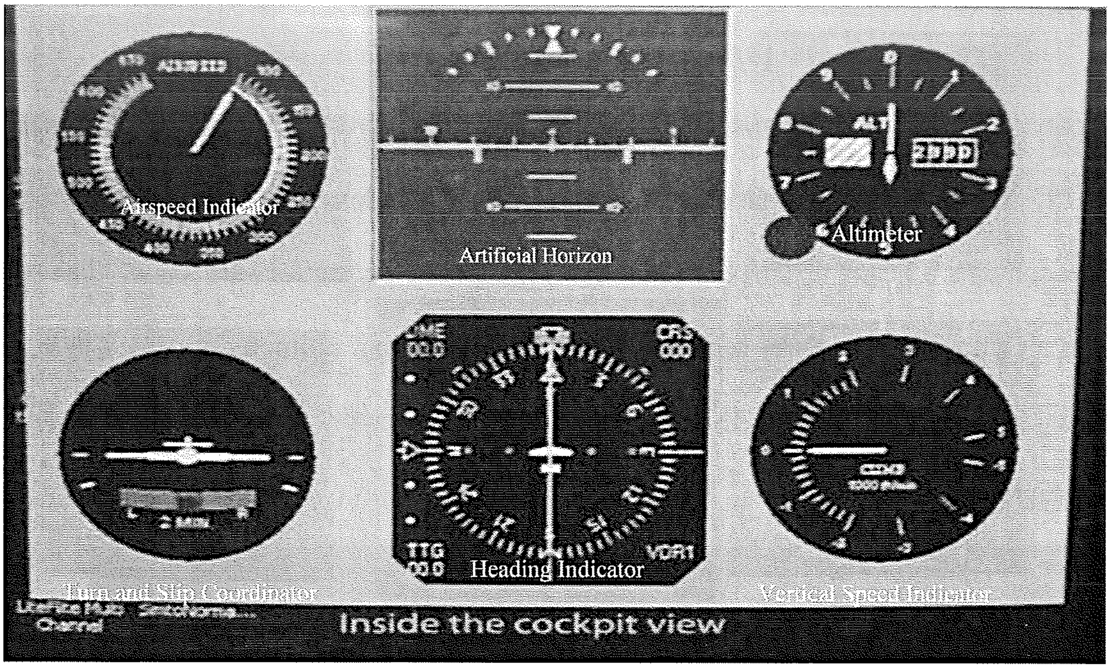

Figure 5. LiteFlite Head down display (HDD).

Each computer has 2 Pentium II processors running at 400Mhz, 400MB RAM, and has three extra video cards for the Out of the Window (OTW) view. Figure 3 also shows a moving map display monitor on the right of the picture. The moving map display was not used in this experiment. Additional details can be found in Williams[17].

Software

Flights were conducted using the LiteFlite version 3.3 flight simulation software developed by SDS International, Orlando, Florida. LiteFlite offers the Predator (UAV) simulation which was used in these studies. LiteFlite has an internal facility to capture flight data using Visual Basic. The same feature exports the data to *.csv files that are readable by Microsoft's Excel spreadsheet program.

Method

Participants

The student participants for this study were 36 undergraduate freshmen at Tuskegee University who had little or no prior experience with an airplane simulator. All participants enrolled in an Introductory Psychology class. The student participants were offered extra course credit in their psychology course for their participation. Our acceptance of a participant into the experiment, beyond the familiarization phase, was based upon their adherence to the flight parameters described in Table 1. Participants who achieved a score of 2.0 (grade based on comparing parameter values in the flight with the parameter values and tolerances required) on at least one familiarization flight were allowed to continue into training. The grading scheme is explained in Table 1. Thirty two participants who achieved the passing grade continued on to the training phase. Each of the participants who achieved a score of 2.0 was randomly placed in one of six groups.

Table 1. Grading Criteria for Straight and Level Flight

Nominal Altitude = 10000 ft	Nominal Speed = 129 knots	Nominal Bank angle = 0 degrees	Grade
Deviation(Δ in altitude)	Deviation(Δin speed)	Deviation(Δ in degrees)	
$\Delta = \pm 50$	$\Delta = \pm 5$	$\Delta = \pm 3$	A = 4.0
$+50 \leq \Delta \leq +100$	$+5 \leq \Delta \leq +10$	$+3 \leq \Delta \leq +6$	B = 3.0
$-100 \leq \Delta \leq -50$	$-10 \leq \Delta \leq -5$	$-6 \leq \Delta \leq -3$	
$+100 \leq \Delta \leq +150$	$\pm 10 \leq \Delta \leq \pm 15$	$+6 \leq \Delta \leq +9$	C = 2.0
$-150 \leq \Delta \leq -100$	$-15 \leq \Delta \leq -10$	$-9 \leq \Delta \leq -6$	
$+150 \leq \Delta \leq +200$	$\pm 15 \leq \Delta \leq \pm 20$	$+9 \leq \Delta \leq +12$	D = 1.0
$-200 \leq \Delta \leq -150$	$-20 \leq \Delta \leq -15$	$-12 \leq \Delta \leq -9$	
$+200 < \Delta$ or $\Delta < -200$	$+20 < \Delta$ or $\Delta < -20$	$+12 < \Delta$ or $\Delta < -12$	E = 0.0

Experimental Design

This experiment used a 3X2 factorial design. There were three types of training used: all flights flown in real time (RT), the first half of the flights flown in 1.5 above real time and the second half flown at 2.0 above real time (ART), or the first half of the flights flown at 2.0 ART and the second half of the flights flown at 1.5ART. Half of the participants in each group were randomly assigned to receive feedback or no-feedback during training. Feedback for this study took the form of the student instructors making suggestions to the participant as to how to improve the handling of the airplane. For the feedback group, students were given a picture representation of their performance in the form of a ground track on the second, fourth, sixth, eighth, and tenth flights. For the study conducted on the flight simulator, all participants experienced the following segments: Orientation to Simulator Controls and Functions, 2 Demonstration Flights, 3 Familiarization Flights, 8 Training Flights, and 2 Evaluation Flights. The evaluation flights were all conducted in RT.

Procedure

All participant pilots experienced the following sessions: Orientation to flight controls and aircraft instruments, familiarization flights, training flights and evaluation flights.

The instructors individually attending the participants in this experiment were the author, from the Aerospace Science Engineering Department, and three other juniors and seniors in the Psychology Department at Tuskegee University. The undergraduate instructors had, for the most part, no flying or simulator experience so they spent a good deal of time becoming comfortable with the controls and functions of the simulator. The graduate instructor has 10 hours of flight time in a Cessna 172 and numerous hours using Microsoft Flight Simulator.

Orientation to Flight Controls and Aircraft Instruments

A protocol was formulated to introduce the novice subjects to the flight controls. Such a protocol was considered essential so as to ensure standardized briefing to all participants thereby minimizing the influence of different instructors. During the orientation process, participants were shown a model airplane and informed of the basic control surfaces of the aircraft, their functions, and the movements associated with each control surface. The participants were then given an overview of the locations and functions of the joystick, rudder pedals, and the throttle located in the mock cockpit. Then, participants were instructed in the location and functions of the following displays on the HUD (head up display): altimeter, radio altimeter, airspeed indicator, heading tape, artificial horizon, pitch ladder, and clock.

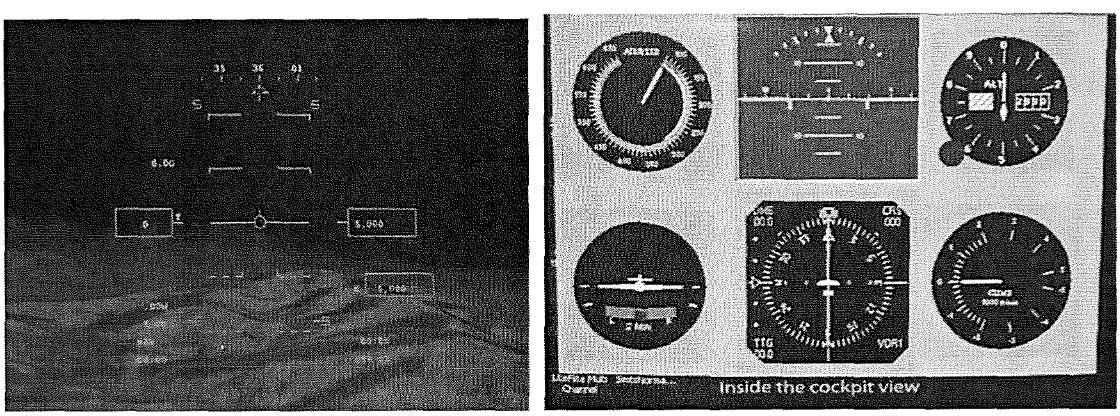

Figure 6. LiteFlite HUD and HDD.

Participants were also instructed on the location and functions of the following instruments on the HDD (head down display): artificial horizon and the vertical velocity indicator. Because the turn-and-slip indicator on the HDD was not functioning properly, participants were explained the use of the HUD to determine if the aircraft was making a coordinated turn.

Familiarization Flights

Participants observed the experimenter flying one 3-minute straight and level flight while explaining the controls and operation of the aircraft. Participants flew four flights of 3-minutes duration each in which they were told to maintain airspeed of 129 knots, a heading of 360 degrees, and an altitude of 10,000 feet. The participants were coached on all but the last of the flights. On the first flight, the experimenter asked the student to focus on altitude maintenance primarily. On the second flight the experimenter asked the student to focus on altitude and heading. For the third flight the experimenter asked the student to maintain altitude, heading and speed. The experimenter assisted with the controls, if needed. At the end of each of the flights participants were shown their actual course and given feedback on how well they performed. On the last flight, the participant was to maintain altitude, heading and airspeed without being coached.

During the familiarization flights, participants were graded on a 4.0 grade scale. The grades were calculated by a program written in visual basic by SDS.

Training Flights

The experiment consisted of a training phase and an evaluation phase. In the training phase pilots flew a mission consisting of a coordinated 180° turn with a 10° bank angle while the evaluation task was an S-turn with a bank angle of 30°. Each group conducted their training in the following sequence immediately followed by two evaluation flights in real time. Participants in Groups II, IV and VI were given post-flight feedback (PFFB).

Group I: Five missions in 1.5 ARTT then five missions in 2.0 ARTT with No-PFFB,

Group II: Five missions in 1.5 ARTT then five missions in 2.0 ARTT with PFFB,

Group III: Five missions in RTT then five missions in RTT with No-PFFB,

Group IV: Five missions in RTT then five missions in RTT with PFFB Feedback,

Group V: Five missions in 2.0 ARTT then five missions in 1.5 ARTT with No-PFFB,

Group VI: Five missions in 2.0 ARTT then five missions in 1.5 ARTT with PFFB.

Training Flights Briefing Scenario

To provide some realism to the training, the participants were briefed on their task according to the following scenario:

"You're the flight leader of a combat air patrol on a routine mission at 5000 ft altitude, 129 knots and heading in a 360° direction. An unidentified low-speed aircraft is being tracked by radar moving towards a no fly zone. Despite repeated requests, the aircraft fails to identify itself and continues towards the no fly zone. The Air Defense Radar Controller assigns the interception to your flight in order to make a visual identification. You are asked to initiate a right hand turn, maintain a bank angle of 10 degrees, an altitude of 5000 ft and a speed of 129 knots. Exactly after two minutes (as recorded on your heads up display), you should level out. Your heading should be 180°, putting you right behind the target, close enough for visual contact. You will complete a number of these missions. Do your best, because once you have finished the practice missions, you will be required to complete a test mission with a slightly more difficult task."

Feedback in Training

Participants in the No-PFFB groups received no feedback during or after flights. If they asked questions about the task, they were re-read the relevant instructions. Participants in the PFFB groups received verbal feedback after each flight. In verbal feedback, the experimenter told the participant the errors in manipulating the controls and in focusing on the wrong instruments. After the second, fourth, sixth, eighth, and tenth flights, participants in the PFFB groups were also shown a screen printout of the desired ground track and the pilot's actual ground track for comparison. Then, the experimenter explained possible reasons for the deviations in performance.

Evaluation Task

The evaluation flight was an S-turn. Pilots were instructed to make a 30° banked right turn to 180° or south and then an immediate 30° banked turn to 0° or north. The participants were told that they would fly two more flights having a different and more challenging task. Both flights were conducted in real-time for all participants and lasted for three minutes each. No feedback or coaching was provided during testing. Participants were read the following scenario before each flight. The participants were to fly an S-Turn with 30° bank angles, maintain 5,000 ft. and a speed of 164 knots.

However, a loss of situational awareness was observed in most of the participants after the first leg of the S-turn during evaluation. Those people who lost situational awareness could be seen doing some of the following: continuing the turn in the same direction, banking the plane and then pulling the stick back to increase the rate of turn, or continuing in a straight line after the first turn. Thus, only the first leg of the S-turn was evaluated for analysis purposes.

Testing Scenario

The participants were given the following scenario for evaluation flights:

"As part of a Combat Air Patrol, the Air Defense Radar Controller notifies you that a hostile aircraft is being tracked heading towards a vulnerable point (VP). Your instructions are to initiate a right hand turn in order to pursue the aircraft while maintaining a bank angle of 30°, an altitude of 5000 ft., and a speed of 164 knots. Exactly 48 seconds after the instructions to initiate the turn you should level out. You will now be exactly behind the target on a heading of 180°. You are then informed of a second target. You should fire your missile and immediately initiate a left turn with a 30° bank maintaining 5,000 ft. altitude and a speed of 164 knots in pursuit of the second target assigned. Exactly 48 seconds after initiating the second turn you should level out. Your heading should be 360°, putting you right behind the second target. Launch your missile. Mission accomplished." (It should be noted that no missile function was provided in the simulation).

Performance Metrics

Familiarization flight performance metric

The performance metric for the level turn was a letter-grade scheme based essentially on grading scheme of Williams.[17] The same scheme was used for selecting participants for the study (Table 1).

Turn Task Performance Metrics

The performance metric to track learning was calculated. This performance measure was based upon an aggregate of non-dimensional altitude error and the error, in radians, for the bank angle. The two measures were then squared, and the square root was taken of that result. Hence:

Error = $\sqrt{(\Delta H / \Re)^2 + \Delta\phi^2}$

where the radius of turn 'Y' was calculated for the flight parameters to be maintained by the pilot using the following relation[16]:

$Y = \dfrac{V^2}{g \cdot \sqrt{n^2 - 1}}$; $n = \dfrac{1}{\cos\phi}$, g = acceleration due to gravity for the **V** = airspeed,

and: ϕ = turn bank angle

Here, altitude error (ΔH) is non-dimensionalized by the theoretical radius (Y) of the turn made by the simulated airplane. If H is not divided by Y small changes in altitude overwhelm any contributions by possible large changes in bank angle (ϕ). Also, error in speed was not used in this calculation because the pilots did not make use of the throttle. Hence, as altitude decreased, speed increased and vice versa. The effect of speed changes was thus captured in the error in altitude as can be clearly seen in Figure 7.

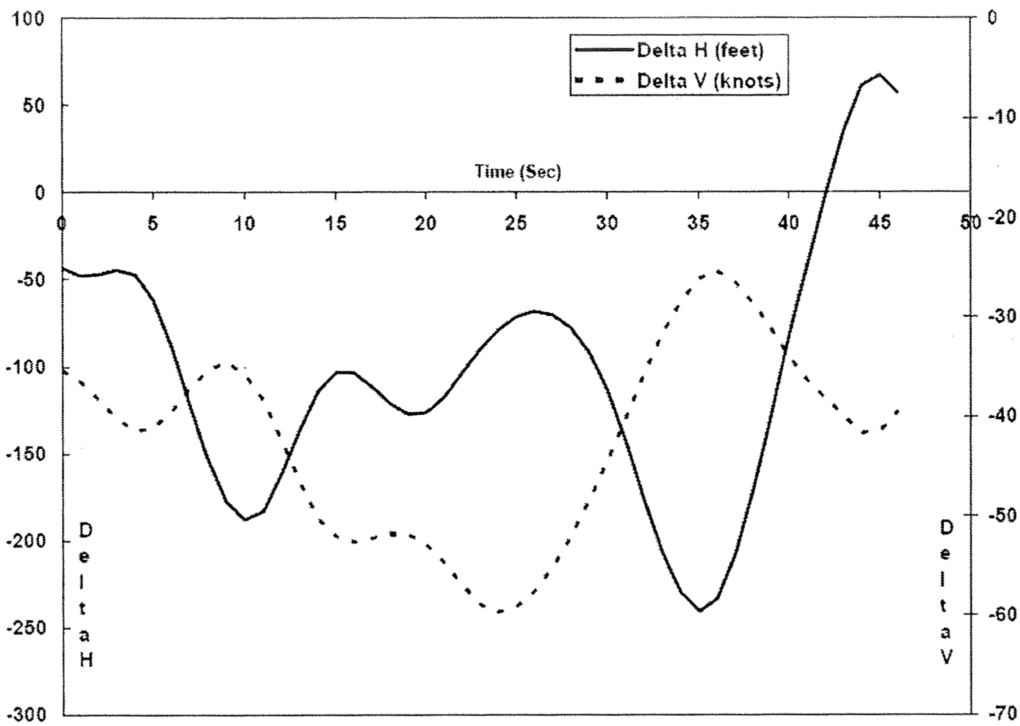

Figure 7. Deviations of altitude and speed (typical for a single flight).

Results And Discussion

The graph in Figure 8 shows the average errors for each group during training and evaluation flights. For the ART training regimen the first five flights and last five flights were at either 1.5 above real time or 2.0 above real time. In either case after the fifth flight the one level of above real time was changed to the other.

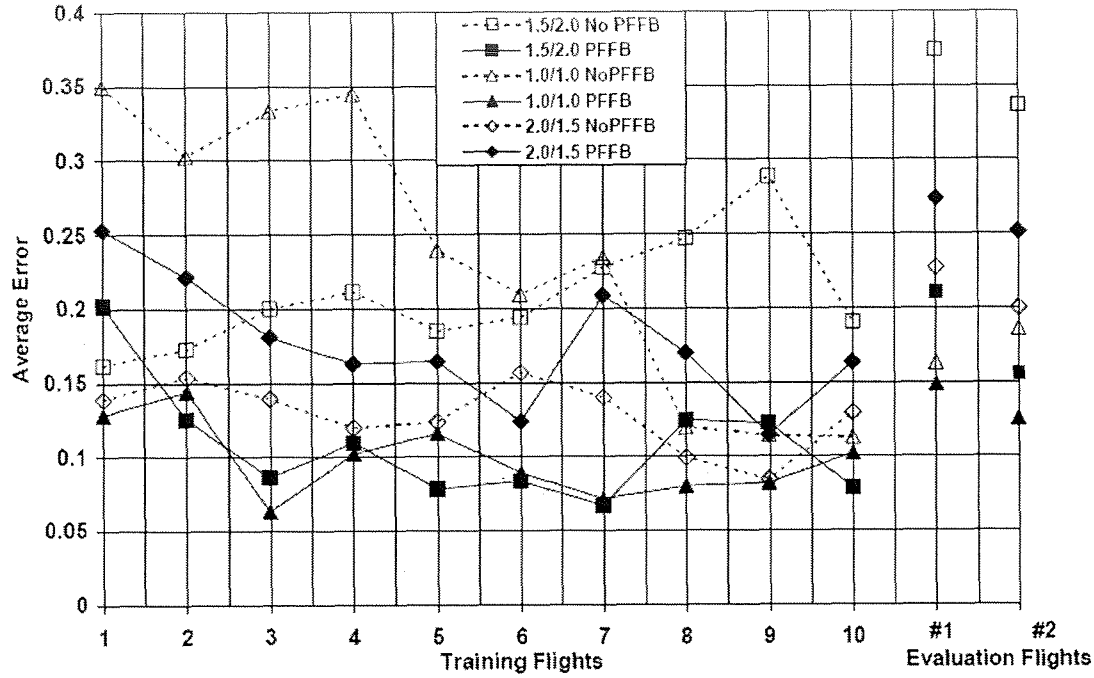

Figure 8. Average errors during training and evaluation flights.

In terms of post flight feedback or no post flight feedback, the graph shows that for both 1.5/2.0 ART and 1.0/1.0 RT, the No-PFFB group did worse than the corresponding PFFB group. This was expected because each participant in the PFFB group was given the advantage of knowing how well or poorly he was doing. For the 2.0/1.5 group the No-PFFB group actually did better than the corresponding PFFB group. This second result was unexpected in that feedback should provide extra help for the participant to understand what is going wrong. This may be due to the fact that the PFFB started the experiment with a worse performance; thus perhaps there was a difference between the two groups from the start of the experiment.

It might be expected that for the PFFB and No-PFFB groups, the performance of the 1.5/2.0 group should be similar to the 2.0/1.5 group performances at the very beginning as no advice was given to either group. For 1.0/1.0 No-PFFB, this was not the case. At the start of training with no feedback given, average performance by flight number for the No-PFFB group was much worse than the PFFB group. This continued throughout the training phase.

The transition between flights 5 and 6 for the 2.0/1.5 flights showed that for one flight, the PFFB group did better than the No-PFFB group and then proceeded to do worse for the rest of the training. This could have been from a loss of confidence in what the instruments were showing the participant and in the instructions given from the instructor. For the No-PFFB group they only relied on the instruments and scripted instructions from the experimenter.

CHAPTER III

LANDING TASK EXPERIMENT

This chapter presents an experiment in which the effect of Out-of-the Window (OTW) visual cues for training of novice pilots for a straight in landing approach on a flight simulator was studied. A performance metric based on RMS errors in the landing flight parameters was used. To validate the chosen computed metric, the computed grades for a few selected landing flights were compared with grades determined independently by three certified flight instructors by viewing the flight video of the approaches.

Setup

Hardware

The Landing Study was performed in the Flight Vehicle Design Lab at Tuskegee University. The experimental setup consisted of one computer with 15" monitor used as the instrument panel or heads-down-display (HDD); three other computers with monitors were used for OTW. The physical setup, shown in Figure 9, is a mock setup of a partial cockpit.

The three OTW view computers are all Gateway E series computers with the following specifications: Pentium 4 2.60GHz processor Hyper-Threading Technology with 512KB cache, 512 MB ram, bus speed 800 MHz and memory speed of 333 MHz; NVIDIA's GeForce FX5200 is the video card used for the three OTW view computers. The "master" computer, which includes the HDD, is a Dell with following specifications: Pentium 4 2.4GHz processor with 512 KB cache, 512 MB ram, bus speed 133 MHz. The video card is a NVIDIA GeForce Ti 4600 with 128MB memory. A KVM (keyboard, video, and mouse) switch was used to provide keyboard and mouse service to all computers. Three 19" monitors were used to provide the 135 degree out of the window (OTW) view Figure 9. The fourth monitor is a 15" monitor used to view the instrument panel. All of the four computers use 100 megabit Ethernet cards for LAN access. The computers are physically connected using a 5-port100 megabit switch. CH rudder pedals and Thrustmaster Cougar HOTAS stick and throttle were used for flight and engine controls.

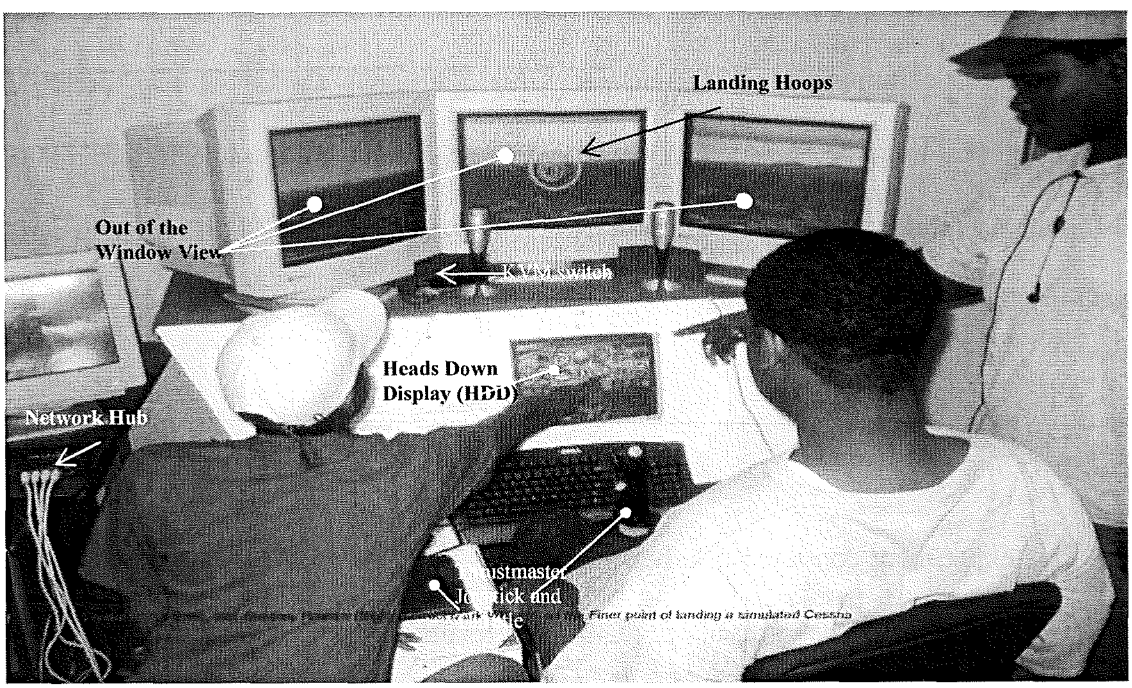

Figure 9. Partial mock cockpit. MSFS2002 shows the hub (switch) OTW view, HDD, switch and Thrustmaster joystick and throttle (partially hidden)

Software

The operating system for each computer is Microsoft Windows XP. Microsoft Flight Simulator (MSFS) 2002 was installed in the default location on each PC. In order to create the panoramic OTW view, Wideview's *.dll file was installed. Wideview[17] is a program that will allow multiple instances of Flight Simulator to be controlled by a "master" computer so that a panoramic view can be attained. Using Wideview, it would be conceivable to have a 360° display, given enough computers. As a prerequisite for Wideview's capability to synchronize OTW view displays, FSUIPC.dll and the IPX/SPX protocol (for Windows) were installed. FSUIPC[18] is a pathway for programs like Wideview to talk to MSFS 2002. The flight recorder software module FLTREC.dll[19] was installed to record the data to a *.dat file. FLTREC's output is configurable through a settings menu item. The data in the *.dat file is in XML format. A sample spread sheet was used to translate the fltrec.dat file into Microsoft Excel workbook columns for a spreadsheet. An additional worksheet was created to determine the performance (based on a 4.0 scale). The 4 point grade scale for straight and level flight was similar to that used by Williams[17]. The grade was based on values in certain ranges for parameters of level flight.

Method

Experimental Design

This experiment consisted of a between groups design with the independent variable being the type of visual cues presented. The three levels of the variable were: all training flights with OTW cues, all training flights without OTW cues, and a few training flights with OTW cues while others without OTW cues.

Participants

The student pilots participating in the experiment were all freshmen attending Tuskegee University. As an incentive, extra credit in an Introductory Psychology course was awarded to every participant. The volunteers that were selected had little or no prior experience with flight simulators or piloting an airplane. Every volunteer, after filling in consent and background forms (Appendix C), attended a brief orientation session and conducted five familiarization flights. The orientation session introduced the various controls and instruments that the participant would use during the experiment. Three of the familiarization flights required the student to fly straight and level. Any volunteer who scored a 3.0 or better on at least one of the familiarization flights was selected for the training and evaluation sessions. The grading matrix is given below in Table 2. The excel Visual Basic module that calculated the grades is shown in Appendix A.

Throughout the experiment, every participant was individually attended by at least one of the three available experimenters. The experimenters were the author, and two other undergraduate senior Psychology students. None of the senior Psychology students had any experience on a flight simulator, so they spent a good deal of time becoming familiar with the equipment by asking questions and teaching each other the operating procedures.

Procedure

Orientation to Flight Controls and Aircraft Instruments

For the Orientation session, pilots were shown the relevant instruments: airspeed indicator, vertical speed indicator, artificial horizon, gyroscopic compass and RPM gage shown in Figure 10. Appendix D includes the set of instructions that were given to every volunteer in the orientation session. The pilot controls introduced were: Joystick, throttle, and rudder pedals. Instructions were given on how to operate the controls and the consequences of operating them. For example, 'pulling back on the joystick pitches the nose up'.

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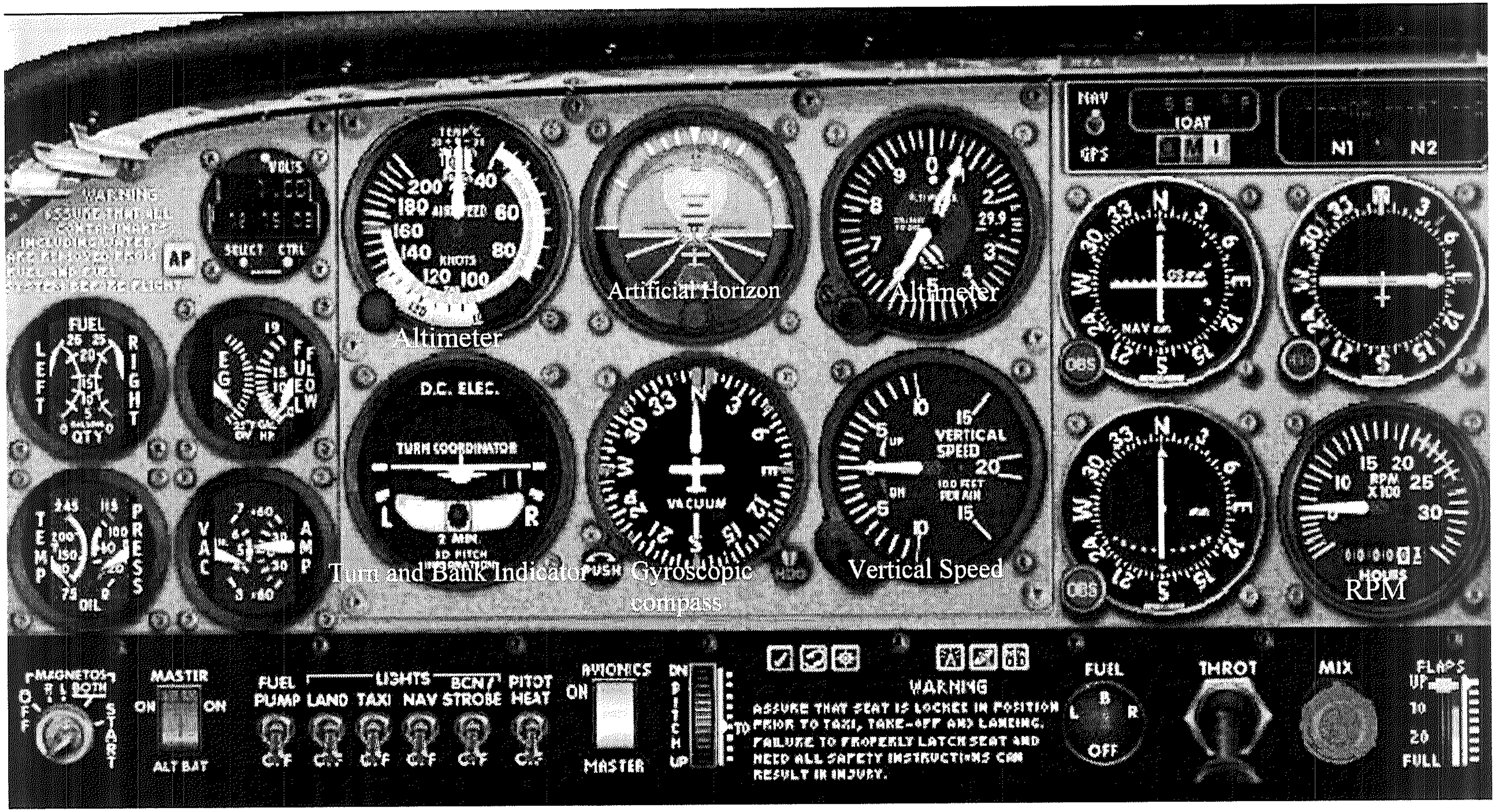

Figure 10. Instrument panel from Microsoft Flight Simulator 2002. Instruments are shown with labels.

Familiarization Flights

Each participant flew 5 familiarization flights. The first three familiarization flights were straight and level flights of three minutes duration each. If necessary the experimenter could provide hands on help to steady the airplane in flight. During the straight and level familiarization flights, participants were graded on a 4.0 GPA scale. The scores were computed using a Visual Basic 6.0 code that compared the parameter values in flight recorded every second with pre-determined parameter values and tolerances. The pilot was required to fly 5,000 ft, 75 knots, 0 degree bank angle. For each flight a score was calculated based on the following criteria:

Table 2. Grading Criteria for a Straight and Level Flight

Nominal altitude = 5000 ft	Nominal Speed = 75 knots	Nominal Bank angle = 0 degrees	
Deviation(Δin altitude) feet	Deviation(Δin speed) knots	Deviation(Δ in bank angle) degrees	Grade
Δ = ± 50	Δ = ± 5	Δ = ± 3	A
+50 ≤ Δ ≤ +100	+5 ≤ Δ ≤+10	+3≤ Δ ≤ +6	B
-100 ≤ Δ ≤ -50	-10 ≤ Δ ≤ -5	-6 ≤ Δ ≤ -3	
+100 ≤ Δ ≤ +150	±10 ≤ Δ ≤ ±15	+6≤ Δ ≤ +9	C
-150 ≤ Δ ≤-100	-15 ≤ Δ ≤ -10	-9 ≤ Δ ≤ -6	
+150 ≤ Δ ≤ +200	±15 ≤ Δ ≤ ±20	+9 ≤ Δ ≤ +12	D
-200≤ Δ ≤-150	-20 ≤ Δ ≤-15	-12 ≤ Δ ≤ -9	
+200 < Δ or Δ < -200	+20 < Δ or Δ < -20	+12 < Δ or Δ < -12	E

Those participants achieving a score of 3.0 or greater continued with the training. The fourth and fifth flights familiarized the pilot with making a straight-in landing initiated approximately from an altitude of 2860 ft with 500 ft/min rate of descent without any OTW cues. In both flights, the experimenter provided verbal feedback to the pilot to assist in making appropriate corrections. In the fifth flight, the experimenter gave instructions to the pilot to listen to the voice from the simulator and where necessary, make appropriate corrections. After each of the familiarization flights, a graphical record was shown to the pilot using Microsoft's Flight Analysis Tool. This graphical record showed a trace of the altitude and heading of the aircraft.

Training Flights

The training session required every pilot to fly eight straight-in landing flights from an altitude of approximately 2860 ft and at a heading of 192 degrees thus aligned with the centerline of the runway. The task given to the pilots was to maintain 75 knots airspeed, descend at 500 feet per minute (by reading both the vertical speed indicator and by looking at the V.A.S.I (Visual Approach Slope Indicator) lights on the left side of the runway, and head towards and line up with the centerline in a straight-in approach to the Bremerton International Airport in the Seattle, Washington area. Each pilot was asked to land on the centerline of the runway. The aircraft being flown was a Cessna 172. The flight scenario was a modified version of a landing lesson from the "flight school" portion of Microsoft Flight Simulator, MSFS 2002. Participants selected for training were randomly assigned to the three groups named HH, NH and FH. A trainee in group HH was required to conduct all of the eight training flights with hoops as OTW cues. The flights with the hoops were a modified version of the 'Landing Lesson II' of the MSFS 2002. The hoops in this lesson are placed on the glide-slope. It was explained to the participants that if they maintained the required flight parameters, they would automatically pass through the hoops. For the NH group a trainee conducted all of the flights without the OTW cues. A trainee in group FH was required to conduct eight flights some of the flights had hoops and the remaining flights had no hoops. The selected density was '5 hoops in sight at a time', which was the lowest setting in Microsoft Simulator.

Feedback in Training Flights

After each training flight, participants were able to look at the flight analysis provided by Microsoft Flight Simulator 2002. In the analysis the student could see a quick playback of a trace of the flight and see whether the airplane was on the centerline of the runway and whether it was descending at a constant rate. MSFS2002 also provided a computerized voice for training a landing task.

Evaluation Flights

After the training flight two evaluation flights were flown. The same scenario as the training flights was used. The only difference was that all trainees had to fly the glide slope without hoops. The sound was turned off so that the trainee could not hear the computer voice. Also, Microsoft's version of mild turbulence was added to make the task more challenging. No feedback was given after each of the flights. The total duration to complete the three phases for each participant was approximately 2-1/2 hours.

Observation

At the end of the experiment, it was noted that all participants in the FH group were given two distinctly different sequences of hoop flights. Therefore, the FH group was dropped from the study. However, the evaluation flights were used for the CFI study reported in Chapter IV.

Performance Metrics

Metric Definition

Data were gathered using third party flight recorder software Fltrec9.0 software. This software writes its data to an .xml file and was interpreted by a shareware spreadsheet into MSExcel for each flight. The analysis originally included data from the time the simulator was un-paused to the time the pilot should have touched down. This was not really accurate in that sometimes before the runway threshold, pilots must reduce power; change the airplane rate of descent (and airspeed) to make a landing. We decided to calculate the time it should have taken an airplane descending at 500 ft/min to hit the ground (which is what would happen) and compare this to the actual flight. Most of the flights exceeded this time.

The following parameters were taken into consideration for determining the landing task performance metric: rate of descent, runway alignment, and airspeed. Thus error in speed is ($\Delta V = V_r - V_f(t)$), and error in rate of descent is: ($\Delta ROD = H_f(t) - H_r(t)$)

where $H_r = H_{start} - 8.333 ft/sec * t$

The performance metric used assumed the airplane was on the extended centerline of the runway. For each second an airplane has a heading and speed. Then for each second, the airplane will have a distance Δx that it will move laterally from or toward the centerline. The distance the airplane travels, in a straight line, is: = V*t.

Error in the heading, ($\Delta\psi$) of the airplane is the difference between the runway heading and the current heading.

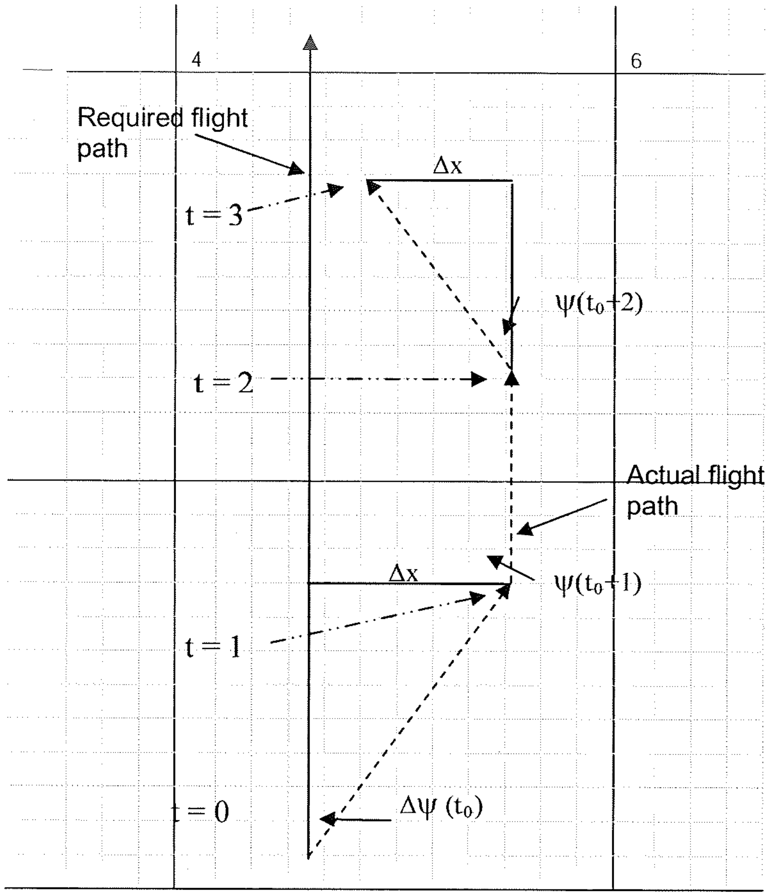

Figure 11. Runway Alignment.

The straight-line distance and the $\Delta\psi$ heading, lead to the distance

$\Delta x(t) = V(t)*t*\sin(\Delta\psi(t-1))$

Error in heading ($\Delta\psi = \psi(t_0) - \psi(t_0+1)$), $\psi(t)$ heading at time t is in radians

Since velocity is in knots conversion to feet was necessary

ΔV ft/s = 1.687809 * (ΔV knots)

Variables Lat1 through Lat5 (Figure 12) were Degrees from the Prime Meridian and converted to radians for calculation. Error in each of these parameters was determined for every second of the flight by taking the difference between the required value of the parameter and the value of the parameter during the flight.

V_r is the required velocity	$V_f(t)$ is the velocity at time t
ψ_r is the heading in radians	$\psi_f(t)$ is the heading at time t
H_r is the required altitude	$H_f(t)$ is the altitude at a time t.
H_{start} is the starting altitude	Δx is the lateral error from centerline

$H_r(t)$ is the altitude at time t assuming a descent rate of 8.333 ft/s

The errors, ΔV, Δx, and ΔROD are calculated for each second of a flight which could vary from 300 – 420 seconds. The RMS errors for ΔV, Δx, and ΔROD were computed for the entire flight. A linear combination of the RMS errors was used as the metric for evaluating the performance of the segment of the flight where the airplane should have constant airspeed, rate of descent and heading.

Starting Error

The airplane however, did not start out on the centerline. So each participant had to align the airplane and descend at the proper rate and the correct speed. This slight offset was barely discernable on the monitor but very noticeable in the data. To identify this problem, Latitude and Longitude data were gathered and used as "Cartesian coordinates." The straight line distance between the current Lat/Long and the centerline Lat/Long would then be the Δx. Using this method it was determined that the flight started out about a third of a mile 1600 ft left of the centerline.

The method used to calculate the distance from the centerline Δx starts with the figure shown in Figure 12. The latitude and longitude for the point on the centerline was determined with the method below. The straight line distance in kilometers from the centerline (Δx) was determined using equation 6 below[15] that comes from the Spherical Law of Cosines[15] and using 6371km as Earth's radius (R).

$$d = acos(sin(lat_1).sin(lat_2)+cos(lat_1).cos(lat_2).cos(long_2-long_1)).R$$

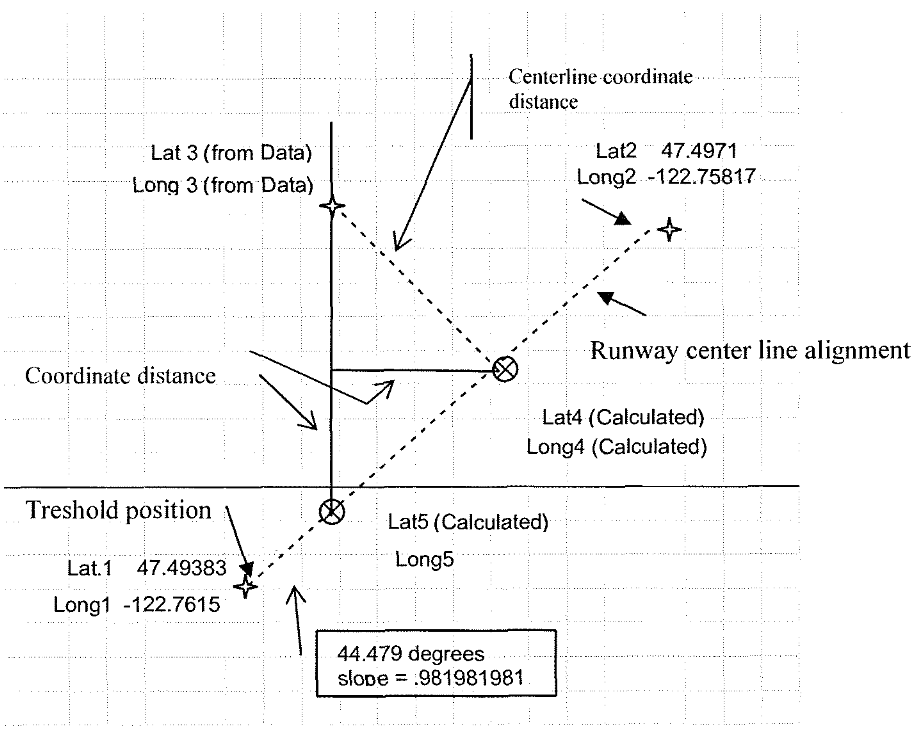

Figure 12. Runway alignment error geometry.

Lat5 = .981981(Long3) +168.043 ----------(Eq. 3.1)

Centerline_coordinate_distance = (Lat3 – Lat5)Cos($\tan^{-1}$(.981981981))----------(Eq. 3.2)

longitude_coordinate_distance = Centerline_coordinate_distance*Cos($\tan^{-1}$(-1/.981981981))

-----(Eq. 3.3)

Long4 = Long3+longitude_coordinate_distance ----------- (Eq. 3.4)

Lat4 = .981981(Long4)+168.043--------------(Eq. 3.5)

Alignment Error

Δx **(km)**= ArcCos(sin(Lat3)*sin(Lat4) + Cos(Lat3)*Cos(Lat4)*Cos(Long3-Long4))* 6371 (ref. 15) --- (Eq. 3.6)

Δx **(ft)** = Δx(**km**) *1000meter/km*3.2808339 ft/meter-------------------(Eq. 3.7)

The flight data were processed to determine the error in airspeed, rate of descent and runway alignment. A linear combination of the non-dimensionalized standard deviations of errors in the three parameters was then calculated and used as a composite error metric for a flight as well.

Results and Discussion

The performance metric was plotted against flight number for the purpose of determining whether student pilot's performance improved over time. In this performance metric, performance improvement means a decrease in the value of the metric. Figure 14 presents the performance metric, normalized with the first training performance, for every participant in the No Hoop (NH) group and for every flight in the training and testing sessions. Likewise, Figure 16 presents the performance metric, normalized with the first training performance, for every participant in the HH group. Figure 17 presents the performance metric of every flight in the training and testing sessions for the NH and HH groups separately averaged over the 12 participants per group. A simultaneous study of Figures 14, 16, 17 leads to the following observations.

In both NH and HH groups, most of the pilots have improved performance in the second training flight (T2) when compared with the first training flight (T1). In any typical training program it is expected that the performance of trainees would show a visible improvement with the amount of training; surprisingly, such a trend is not seen here for the six training flights in sequence from T3 to T8. For the HH group, the average performance for the last five flights is visibly better than that of the first three flights. But the average is unduly influenced by the performance of participant #25. One of the participants in the NH group, #31, offers a strange pattern of alternating increase and decrease of performance from T1 to T8. Few other participants in both groups show a visible decrease in their performance at different stages of their training sessions. Also, there seems to be no improvement in performance for both HH and NH participants from T6 – T8. This could mean that perhaps our training task is too easy, and the number of flights is too many so that the participants have reached a plateau in their training and can't be further trained in that scenario.

The transition from training to evaluation going from T8 to E1 shows that most of the participants in both groups have performed worse in the first evaluation flight than in the last training flight. That is understandable due to a relatively more challenging task in the evaluation flights when compared with the training flights. For the trainees in the NH group the added challenge in the evaluation flight is the presence of mild turbulence. For the trainees in the HH group, the absence of hoops in the evaluation flight is another challenge together with the presence of turbulence. Surprisingly, in the transition from training to evaluation, the additional challenge for the HH group did not result in a larger decrease in performance than that in the NH group. This could be taken as a positive aspect of training with hoops as compared with training without hoops.

Figure 17 shows that the performance of the NH Group, on average, was worse than the HH group when transitioning from the last training flight to the first evaluation flight. The hypothesis was that a training intervention, such as tunnel in the sky, would be a better way to train pilots than would standard methods without a training intervention. Some evidence of this may be seen in the first evaluation flight (E1) in which performance of the HH Group was slightly better than the NH Group (Figure 17).

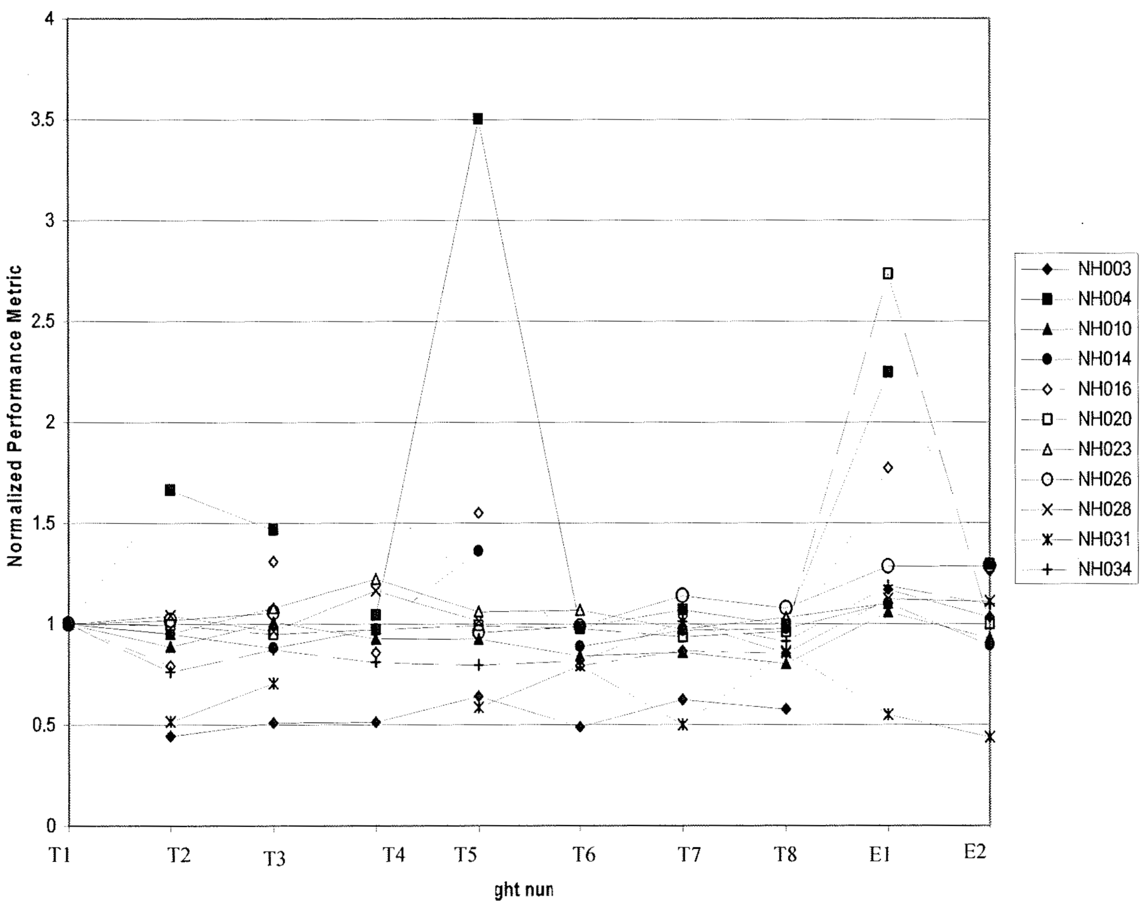

Figure 13. Normalized performance of the participants in NH group.

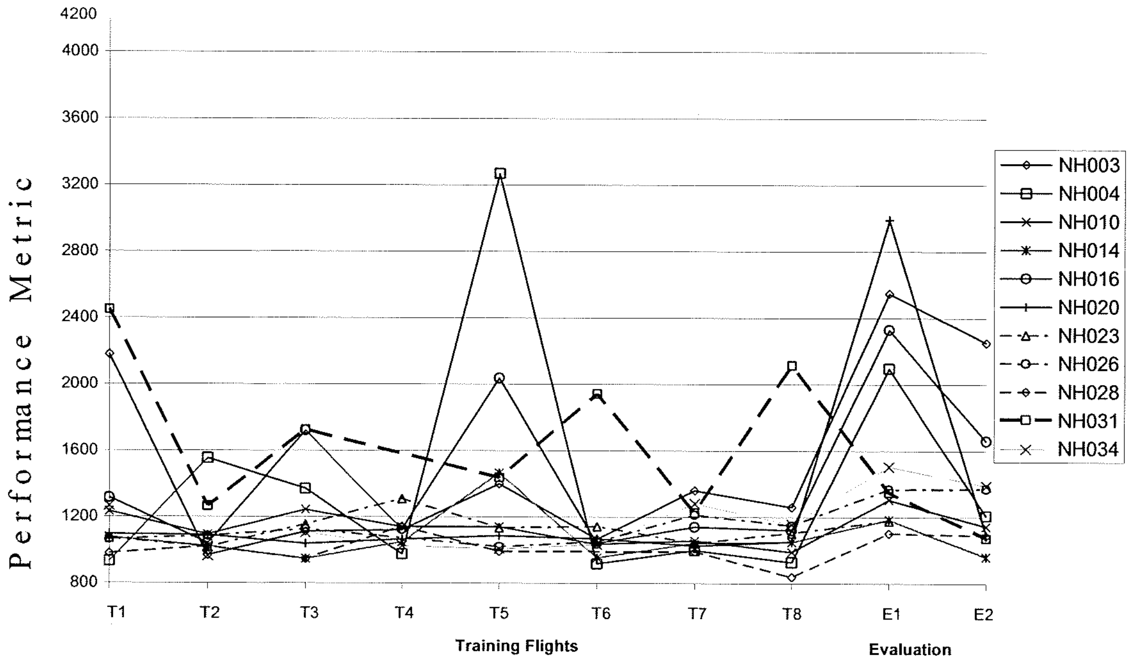

Figure 14. Performances of the participants in the NH group.

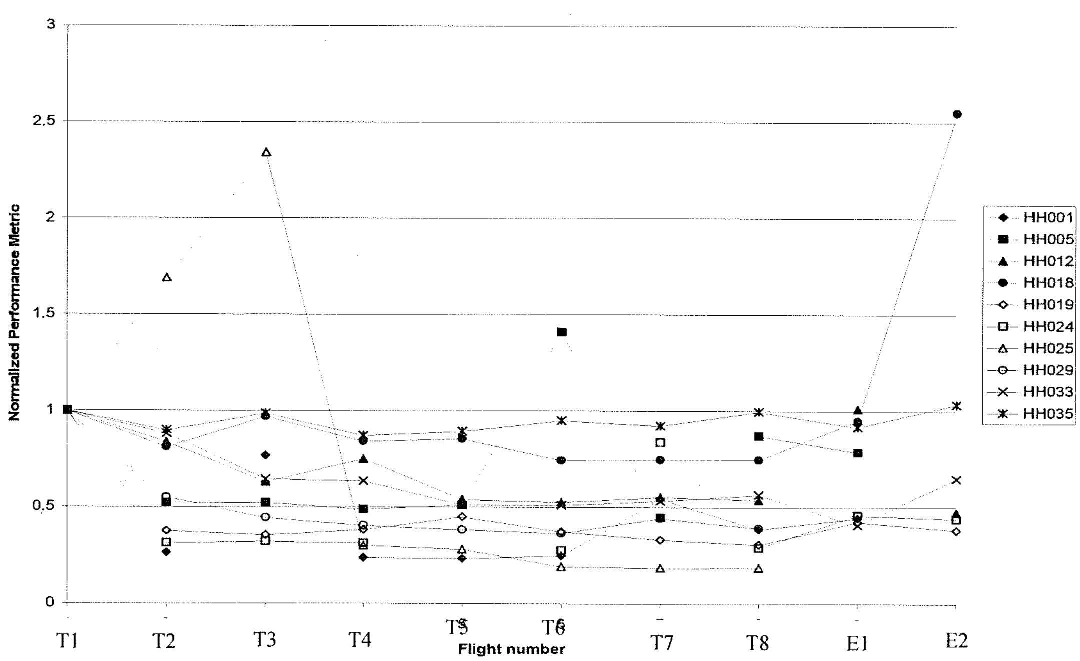

Figure 15. Normalized performance of the participants in the HH group.

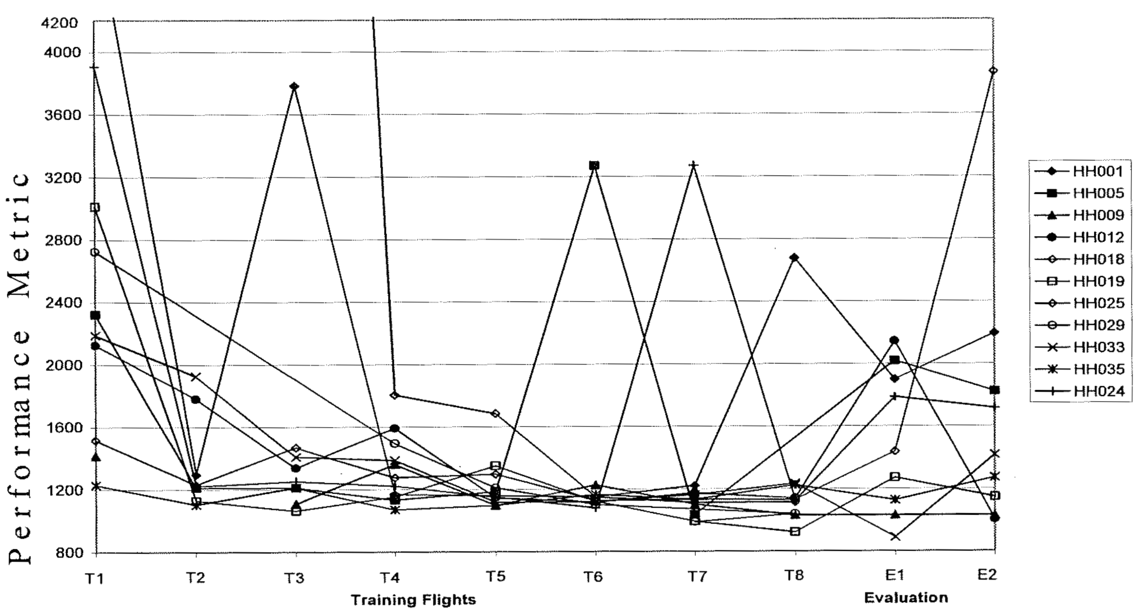

Figure 16. Performance of the twelve participants in the hoop (HH) group.
(Missing data: T5 for HH001, T8 for HH005, T5 HH024, (E1, E2) from HH025, (T2, T3) for HH029, HH009 data for T8, E1, E2 is suspect; Not shown here T1 for HH001; T1-T3 for HH025)

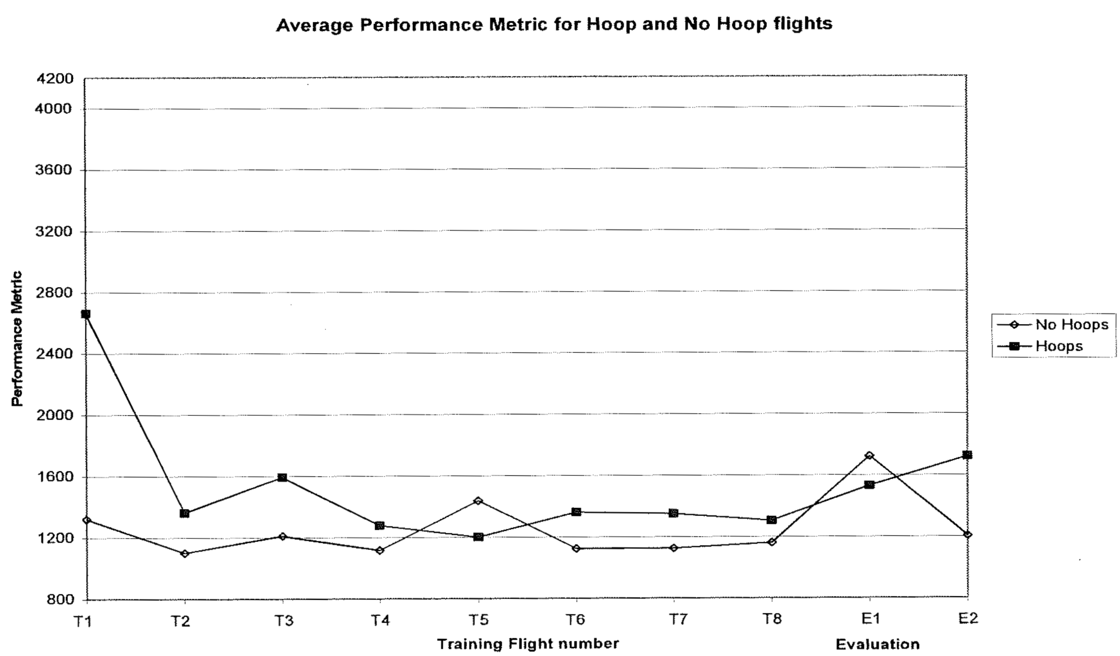

Figure 17. Average performance of the NH and HH groups.

CHAPTER IV

COMPARSION OF COMPUTED METRIC WITH CFI EVALUATION

Introduction

For the student pilot in a FAR Part 61 or FAR Part 141 flight school, ten flight hours of required training can be flown in a PCATD. However, the regulations state that a CFI must also be present to supervise the training (FAA 1997). Vruels and Obermayer[13] emphasize the need of automated performance measures on modern simulators as a substitute for direct evaluation of performance by an instructor. To address this goal for training of a landing maneuver, the present effort included a study of how closely a computer can emulate a CFI's evaluation of a student pilot.

Method

As mentioned above, the study of landing performance of novice pilot on MSFS 2002 required all trainees to fly two evaluation flights under identical conditions irrespective of the strategy used in their training flights. These landing approaches were video recorded using the MSFS2002 capability so that the flights could be independently evaluated by three CFI's with a minimum of 5000 hours of experience (for details see Appendix E).

The CFI's were required only to grade the approach, and not the flare and touchdown. CFI's were not informed regarding the training intervention experienced by the pilots. They were asked to assign each flight a grade based on a 100-point scale. They were also requested to monitor three flight parameters namely, airspeed, rate of descent and runway alignment. Of those parameters they were to indicate the best and the worst controlled flight parameters and the flight parameter most affecting the grading. The details of the instructions to the CFIs are given in Appendix D.

Results and Discussion

For the thirty-three evaluation flights graded individually by the three CFI's, correlations between the pairs of instructors' grades were found to be rather low ($r^2 = 0.43$, 0.51, and .67; see Figure 18.) Therefore, the CFI scores were further analyzed for flights in which the CFIs agreed on both the best and the worst controlled parameters for a flight.

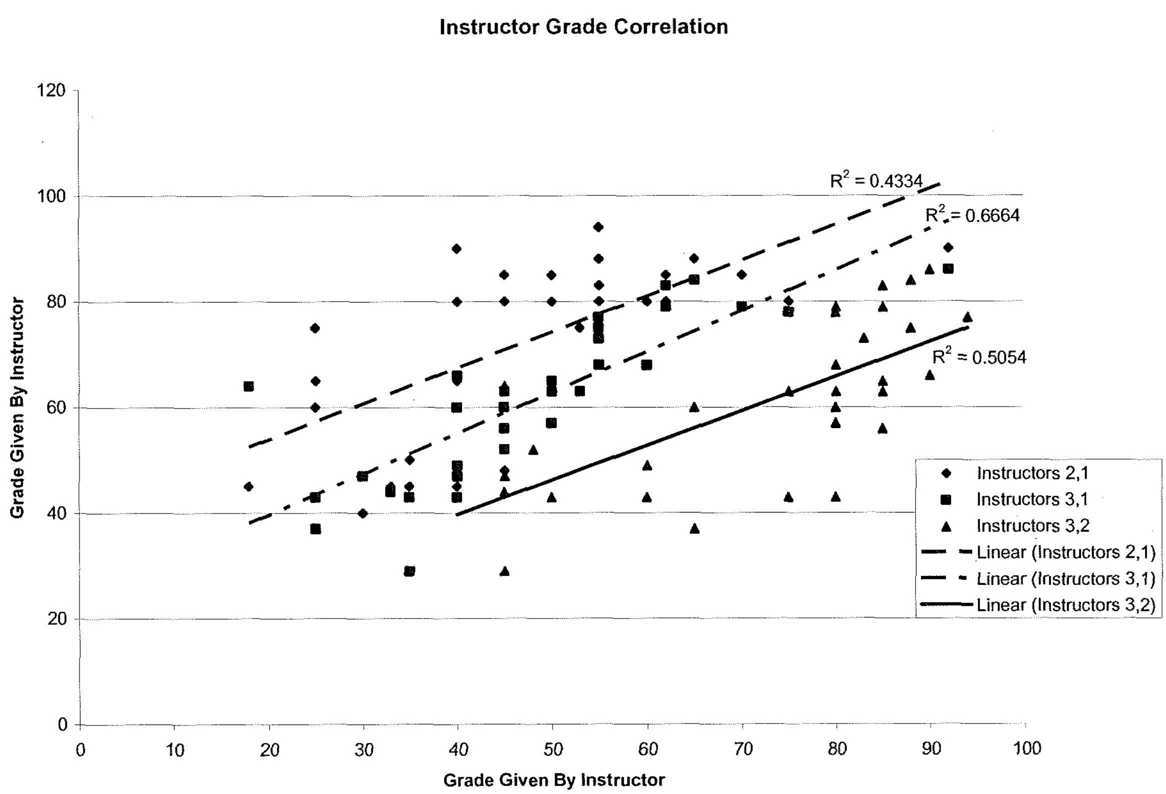

Figure 18. Correlation of instructor grades.

All three CFIs cited runway alignment as the best controlled parameter more often than the other two parameters (Figure 19). Also, rate of descent was identified as the worst controlled parameter more often by all three CFIs (Figure 20). All three instructors agreed on both the best and worst parameters for seven flights. For grading of the seven identified flights, despite their agreements, a high correlation was seen only between the grades of two CFIs (r^2=0.89, Figure 21). The grades of the third CFI had low correlations with the grades awarded by either one of the other two CFIs (r^2= 0.44 and 0.25, Figure 21).

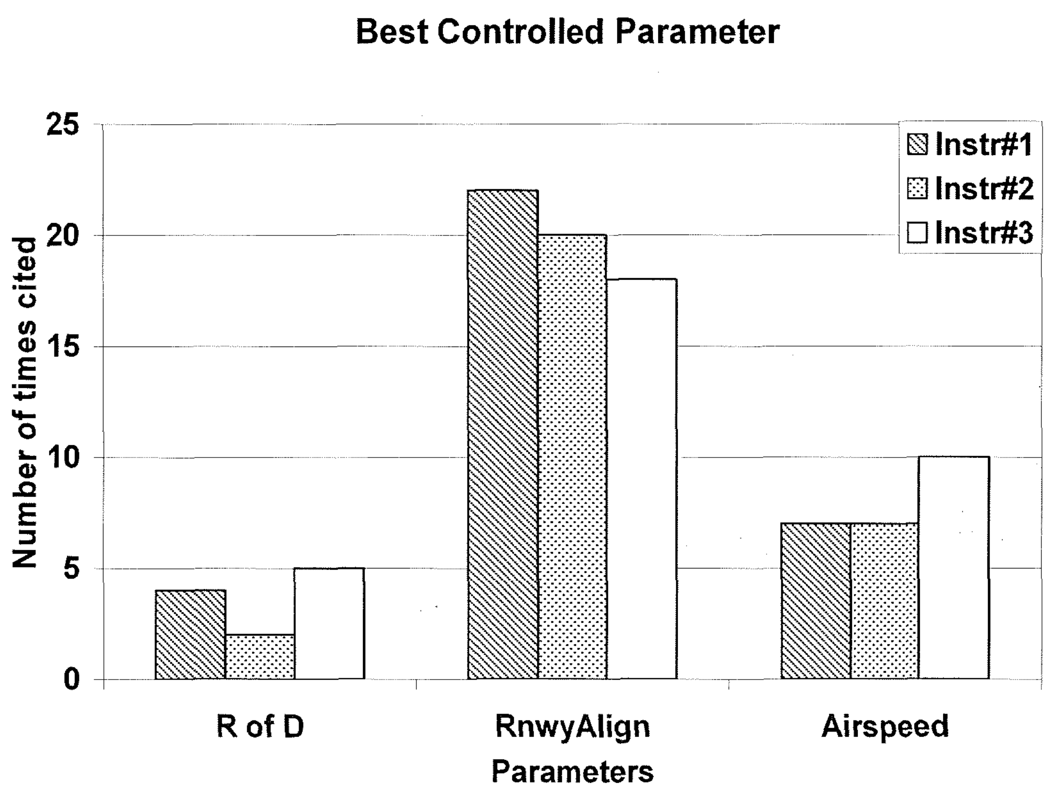

Figure 19. Best controlled parameters as cited by the CFIs.

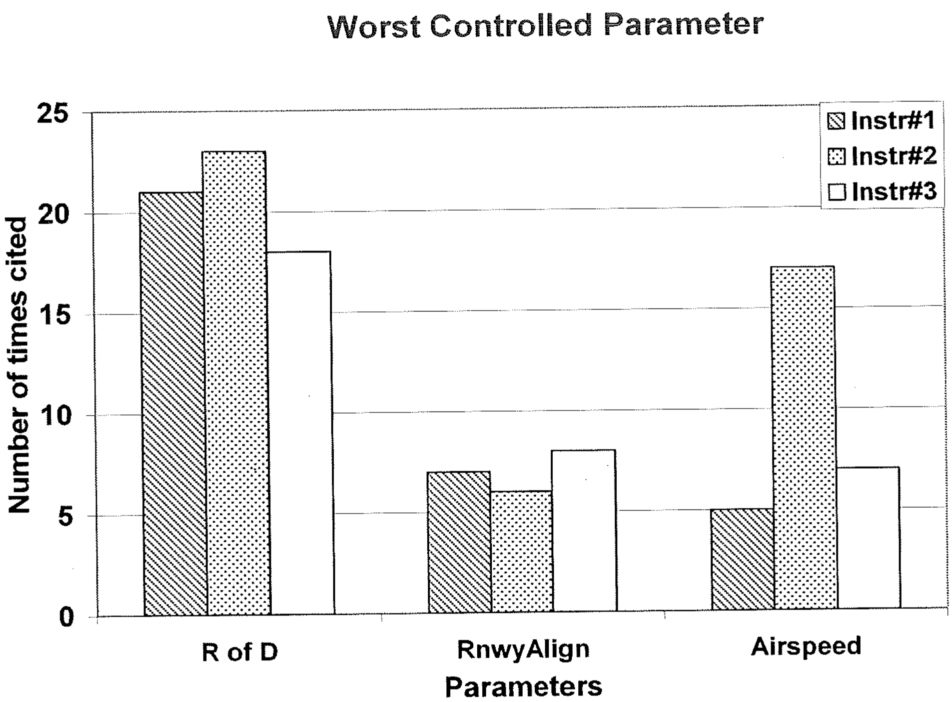

Figure 20. Worst controlled parameters as cited by the CFIs.

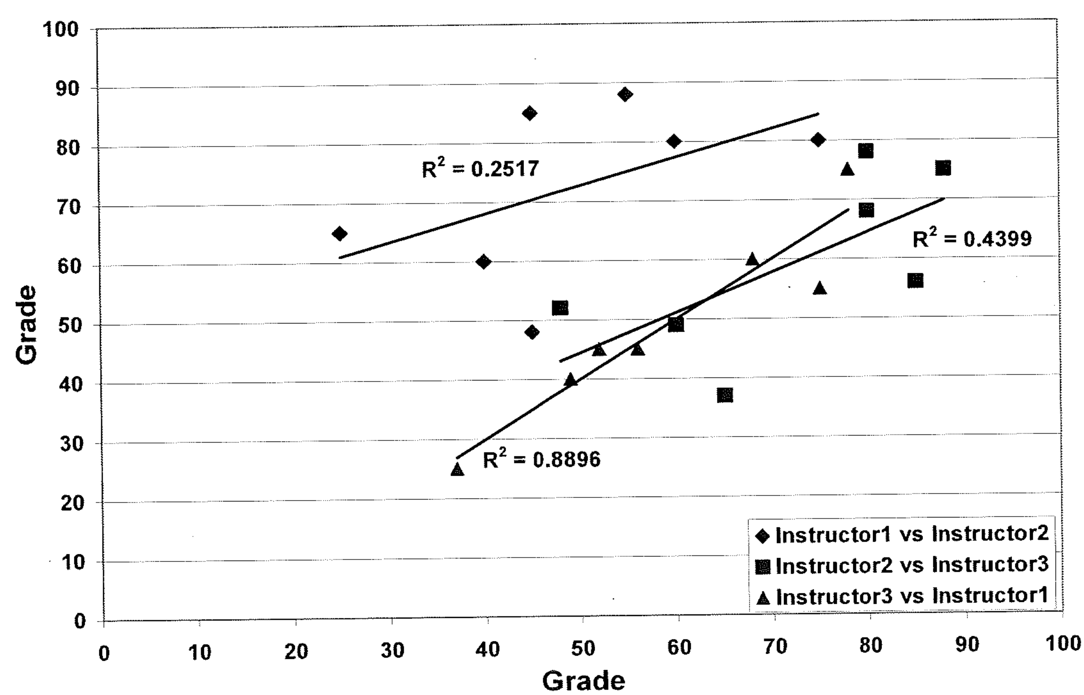

Figure 21. Correlations between flight instructor scores of selected flights.

For the seven landing flights identified, the calculated composite error metric values were plotted on a graph separately against the grades awarded by every one of the three instructors as shown in Figure 22. For the composite error metric, strong and significant correlations were found with the grades awarded by every one of the three instructors ($r^2 = 0.82$, $t = 4.69$, $p < 0.01$; $r^2 = 0.77$, $t=4.15$, $p < 0.01$; and $r^2 = 0.63$, $t = 2.91$, $p < 0.05$).

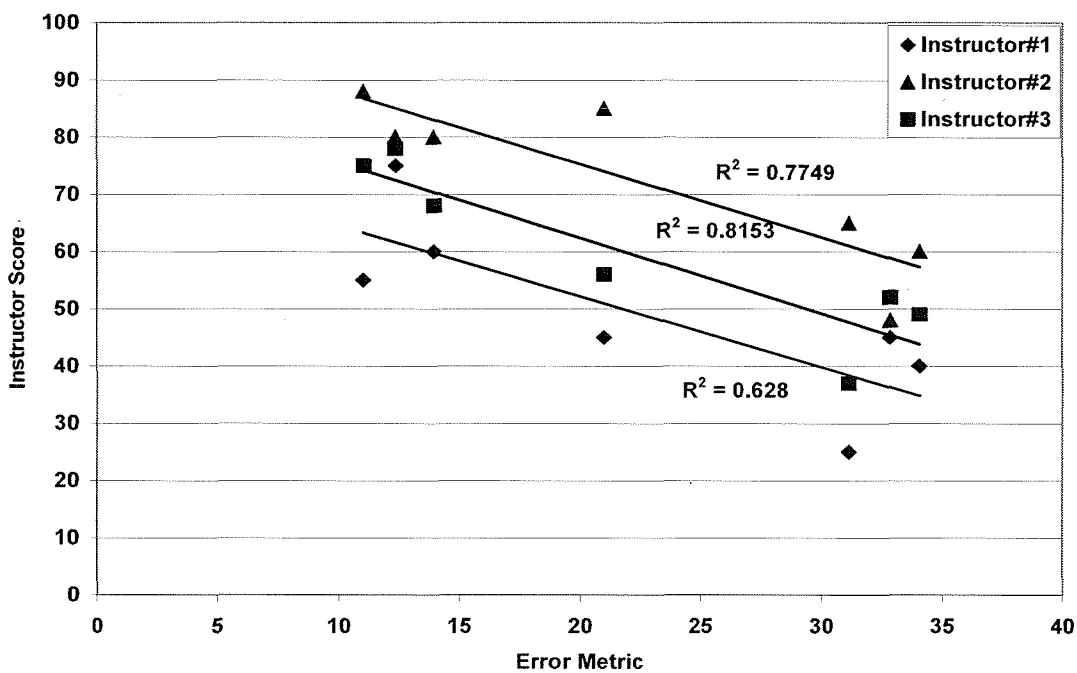

Figure 22. Correlation between composite error metric and instructor scores.

These correlations indicate the suitability of the composite error metric to be considered for use as a measure of performance on a straight-in landing approach. The fact that correlations between instructors on grading a landing approach were low, and that such grades correlated poorly with the performance metric based on RMSE in the flight parameters of rate of descent and runway alignment indicate the difficulties inherent in this research area. The strategy of determining first the flights in which instructors agree on best and worst controlled parameters is a promising one. Such a strategy may be effective in narrowing the focus to fewer variables than what would normally be involved in grading a flight maneuver, and should lead to a better understanding of the variables involved in CFI evaluation of a maneuver. This strategy could then be applied to different maneuvers and perhaps weights could be applied differentially to different parameters depending upon the parameters most important in evaluation of that maneuver.

CHAPTER V

CONCLUSIONS AND SUMMARY

This thesis examined different training interventions for novice pilots in an attempt to develop techniques and performance measures that could be incorporated into an 'intelligent' training system. Effectiveness of training interventions were investigated by comparing performance on a level turn and straight-in approach maneuver flown by novices on a flight simulator with control groups flying the same maneuvers on the flight simulator. Metrics were defined to compute performance using flight parameter data of the maneuvers. Performance computed from flight parameter data of the treatment-group and control group flying the straight-in approach was also compared with certified flight instructor evaluation of the video data of the same flights to validate the metric used for computing the performance.

The following conclusions are drawn from these studies:

- Real Time Training (RT) with post flight feedback resulted in the best performance on the evaluation flight for a level turn as compared to no feedback or training with ARTT.
- Above Real Time Training (ARTT) using a sequence of 1.5/2.0 with post flight feedback was observed to be the next best strategy for a level turn. Thus, if time is of the essence then this training strategy is a promising approach. Further studies with more participants could validate this finding and determine whether 2.0 for all flights, or 1.5 for all flights might be a more effective strategy.

- The particular post flight feedback provided to the participants flying the level turn, consisting primarily of graphical feedback which showed the actual ground track superimposed over the target ground track may be an effective form of feedback to implement in an "intelligent" flight simulator providing automated feedback.
- For the landing task, no statistically significant difference was found between the group provided with visual out-of-the-window cues of hoops and the control group. This indicates that the additional visual cues did not add to the training value, perhaps because visual cues in the form of the runway and visual approach slope indicator lights were already available for this maneuver.
- Poor correlations were observed between inter-CFI evaluations. Where the CFIs agreed on the best and worst controlled parameters, correlations were obtained between the computed performances using the performance metric developed in this study and the evaluations of the CFIs for the straight-in landing approach task.

Future Studies

- The two studies in this volume were meant to be steps on the way to creating an intelligent flight simulator for training novices. To that end, it would be interesting to look at the following:
- To validate any of these training strategies, however, a) more participants need to be studied to determine if the effects observed are generalizable and robust, and b) studies assessing whether these methods produce better performance in the actual aircraft need to be undertaken.

- Conduct more studies to determine the reliability and robustness of the effect of ARTT as a strategy for training. Specifically, compare RTT with ARTT 1.5 on the turn maneuver, both using feedback.
- Use additional feedback mechanisms to enhance the already provided graphical feedback, such as automated audio to correct for error.
- A study of a combination of tunnel in the sky and ARTT as a training intervention might yield interesting information.
- Each training intervention needs to be evaluated for more than one maneuver to determine its robustness.

APPENDICES

APPENDIX A

Visual Basic Scoring Module:
Function to strip repeating data caused by pressing pause button. Also calculates the overall score for the familiarization flight.

```
Function CalcScore()
Dim TotalScore As Double
Dim Count As Integer
Dim Stuff
' Module created by Bruce Heath
' December 31, 2003
'
' Module finds the beginning of relevent data and
' then adds the scores for 180 rows (seconds)
' The totaled scores are then averaged by 180 for
' the average score
'
' Version 2 February 6, 2004
' Complete February 12, 2004
' Corrects the problem caused by pausing the simulator for more
' than 300 seconds while the flight recorder is running

row = 2  'First row of data
col = 4  'Seconds column for Clock time
'MsgBox Sheets("Data").Cells(3, 4).Value

'This loop finds the starting point for the data

Do Until (Sheets("Data").Cells(row, col).Value <> Sheets("Data").Cells(row + 1, col).Value)
   row = row + 1
Loop

' Modification : If the row on the DATA sheet still has not reached the beginning of the
' data after end of the fomulated cells on the rows on the SCORE sheet,
' then find the beginning of the data on DATA and place the processed data on the SCORE sheet.
' Continue to place processed data on the SCORE sheet until the DATA sheet meets an empty
' row.
'
If ((Sheets("Score").Cells(row + 1, col).Value = "") And (Sheets("Data").Cells(row + 1, col).Value <> ""))
Then
  row2 = row
Do While (Sheets("Data").Cells(row2 + 1, col).Value <> "")
'Fill in Data

  'Altitude
  Sheets("Score").Cells(row2, 1).Value = Sheets("Data").Cells(row2, 9).Value - 3000

  'Bank
  If (Sheets("Data").Cells(row2, 10).Value >= 180 And Sheets("Data").Cells(row2, 10).Value <= 360)
Then
     Sheets("Score").Cells(row2, 2).Value = 360 - Sheets("Data").Cells(row2, 10).Value
```

```
Else
   Sheets("Score").Cells(row2, 2).Value = Sheets("Data").Cells(row2, 10).Value
End If

'Airspeed
 Sheets("Score").Cells(row2, 3).Value = Sheets("Data").Cells(row2, 10).Value - 75

 'Altitude Raw Score
 With Sheets("Score")
  If (.Cells(row2, 1).Value < 0) Then
     .Cells(row2, 4).Value = (.Cells(row2, 1).Value / 50) * -1
  Else
     .Cells(row2, 4).Value = .Cells(row2, 1).Value / 50
  End If

  'Bank Raw Score
  .Cells(row2, 5).Value = .Cells(row2, 2).Value / 3

  'Airspeed Raw Score
  If (.Cells(row2, 3) < 0) Then
     .Cells(row2, 6).Value = (.Cells(row2, 3) * -1) / 5
  Else
     .Cells(row2, 6).Value = .Cells(row2, 3) / 5
  End If

  Count = 1
  Do While (Count <= 3)

  'Assign Altitude Score
  'Assign Bank Angle Score
  'Assign Airspeed Score

  Select Case .Cells(row2, Count + 3).Value
     Case Is <= 1
        .Cells(row2, Count + 6).Value = 4
     Case Is <= 2
        .Cells(row2, Count + 6).Value = 3
     Case Is <= 3
        .Cells(row2, Count + 6).Value = 2
     Case Is <= 4
        .Cells(row2, Count + 6).Value = 1
     Case Else
        .Cells(row2, Count + 6).Value = 0
  End Select
    Count = Count + 1
  Loop

  'Three Score total for the row
  .Cells(row2, 10).Value = .Cells(row2, 7).Value + .Cells(row2, 8).Value + .Cells(row2, 9).Value
  'Average Score for the row
  .Cells(row2, 11).Value = .Cells(row2, 10).Value / 3
 End With
  row2 = row2 + 1
```

```
 Loop

End If

' Now find the numeric score
  loopEnd = row + 181  'Loop for the three minute time period

  scorecol = 11 'Column K average for each second on every row
  'Count off 180 seconds totaling the average scores
  displayrow = row

  Stuff = MsgBox(displayrow, , "Data Begins in Row")

  With Sheets("Score")
    Do Until row = loopEnd
       TotalScore = TotalScore + .Cells(row, scorecol).Value
       row = row + 1
    Loop

    'The numeric score is this
    .Cells(7, 14).Value = TotalScore / 180
    'MsgBox TotalScore
   End With
End Function
```

APPENDIX B
Informed Consent Form

INFORMED CONSENT FORM

DEVELOPMENT AND ASSESSMENT OF A NOVEL TRAINING PACKAGE USING SELF INSTRUCTION METHODS AND ABOVE REAT TIME TRAINING (ARTT) FOR BASIC MANEUVERING TASKS ON A FLIGHT SIMULATOR

As an undergraduate student of Tuskegee University, you are invited to participate as a trainee in an experimental research study. The study will develop and evaluate a new program of training on a flight simulator.

Your participation will require approximately two hours of flying on a simulator one day. You will take a seat as a pilot in a mockup cockpit located in the Flight Vehicle Design Laboratory on Tuskegee's Campus. You will control the flight movements of the joystick, throttle and rudder pedals while watching the flight parameter changes on the simulated instrument panel Heads Up Display (HUD) and the moving icon of the airplane on the computer screens. The available instructor will give you a set of instructions, allow you some time for familiarization and for asking questions, and provide feedback on your performance whenever necessary.

No physical or medical testing risks are involved in the experiment. The experiment, however, is not an official pilot training. As a possible risk, some of the simulator flight techniques that you will learn may not be applicable in real flying. Moreover, as it happens in any learning exercise, you may need to overcome temporary disappointments on possible lack of progress in performance, especially when your flight would face a simulated crash.

In general, the training will be an enjoyment and a learning experience. The data provided by you on a survey form and the data on your performance in the training will be coded to protect your confidentiality. Your participation is voluntary and you may withdraw from the experiment at any time. Your participation is voluntary and you may withdraw from the experiment at any time. Your participation according to your agreed upon schedule, however will be greatly appreciated by the investigators.

The successful completion of this research program will be a valuable contribution by Tuskegee University in improving the methods of training pilots on a simulator.

For any questions or concerns, please feel free to contact the investigators on campus: Dr. Syed Ali at 727 – 8853, Dr. Marcia Rossi at 727 – 8830 or Dr. Muhammad Khan at 727 – 8637. In the event of an unresolved grievance, you may also contact Dr. Stephen Sodeke, the Chairperson of the Human Subjects Review Committee (HRSC) at 727 – 8363.

The available investigator will give you a copy of this form to keep. By signing below, you are agreeing to participate in this study.

Signature of Participant/ Date	Signature of Investigator/ Date

Participant Demographic and Data Form Turn Study

Background Survey- Turn Study

Code: ____________________

Major: ____________________

Sex: _____Male
_____Female

Age: _____

Are you: _____Left Handed
_____Right Handed

Do you have any flight experience?
_____Yes
_____No

If so how many hours (estimate)? ________

How long ago was your most recent flight training, if any? ________

How many hours a week do you engage in video/ computer games?
_____ light: 0 – 5 hours
_____ medium: 6 – 13 hours
_____ heavy: 13 or more hours

What type of video / computer games do you play?
_____ sports
_____ fighting
_____ war
_____ cards
_____ flight
_____ mystery
_____ other: If so what type? ________________

What type of controllers do you use?
_____ joystick
_____ control pad
_____ keyboard
_____ arcade

Debriefing Form for Turn Study

Subject Code: ________________

Ask them if they have any questions about what they were doing?

1) Questions asked by participant and answers

____
____
____
____
____

2) Would you describe what you did as (circle one)

very fun
somewhat fun
neutral
somewhat boring
very boring

3) Would you agree that the pre training instructions (before any flight) prepared you for the flight training sessions?

strongly disagree
disagree
can't decide
agree
strongly agree

4) Would you describe the training sessions as (circle one)

very difficult
difficult
neutral
easy
very easy

5) Would you agree that the flight tasks (the first flying sets) prepared you for the flight test?

strongly disagree
disagree
can't decide/ don't know
agree
strongly agree

Tell them the purpose of the study, i.e., to determine if training at different ART levels for turning is more effective than RT training. Answer any questions. Ask them not to reveal the nature of the experiment to any others, as it may disrupt their performance. Include any comments they made that seem relevant, that might help in explaining their performance.

APPENDIX C
Participant Demographic, Data Form, Debriefing Form, Landing Study
Background Survey- Landing Study

Code: ________________

Major: ______________

Sex: _________Male
_________Female

Age: _________

Are you: ______Left Handed
______ Right Handed

Do you have any flight experience?
________Yes
________No

If so how may hours (estimated)? ______

How long ago was your most recent flight training, if any? ________

Do you have any flight simulator experience? Yes____ No______

Overall, how much exposure have you had to Microsoft Flight or Combat Simulator? _______________

How many hours a week do you engage in video/ computer games?
_______*Light:* 0-5 hours
_______Medium: 6-13 hours
_______Heavy: 13 or more

What type of video / computer games do you play?
______ Sports
______ Fighting
______ War
______ Cards
______ Flights
______ Other:

What type of controllers do you use?
______Joystick
______Control Pad
______Keyboard
______Arcade

Have you ever belonged to an organization similar to the C.A.P. or Redtails?
_____Yes If so what organization_________________?
_____No

Are you familiar with any of the following concepts, if so please check?
_______Throttle ________Aileron _________Rudder

Blank Page

Debriefing For Landing Study

Participant Code: ___________

1. **Would you describe what you did as (circle one)**
   Very fun
   Somewhat fun
   Neutral
   Somewhat boring
   Very Boring

2. **Would you agree that the verbal instructions and the orientation instructions (before any flight) prepared you for the training flights?**
   Strongly disagree
   Disagree
   Can't decide
   Agree
   Strongly Agree

3. **Would you describe the training sessions as (circle one)**
   Very difficult
   Difficult
   Neutral
   Easy
   Very easy

4. **Would you agree that the training sessions prepared you for the flight tests (the last two flights without sound)?**
   Strongly disagree
   Disagree
   Can't decide
   Agree
   Strongly Agree

5. **Are there any questions about what you were doing?**

The purpose of the study: To determine if the use of cues (hoops and automated pilot) was effective for landing tasks. Please do not to reveal the nature of the experiment to any others, as it may disrupt their future performance. Thank you for your participation.

APPENDIX D
Instructions and Data form for Flight Instructors

Thank you for your participation in the evaluation. Each of these flights was made by an inexperienced student. Most of the students had no experience flying an airplane and, with few exceptions, no experience with simulators. What we would like for you to do is to view each flight (instructions below) and give the flight a grade. I realize that flight instructors usually do not give a grade on a point scale. However, for these flights please give the overall flight a grade based on a 100 point scale. After each flight, we would like for you to record the parameter which most influenced your grade choice. Also, we would like for you to identify the parameter the student best controlled, and the parameter the student controlled the worst (Runway alignment, Glideslope, or airspeed). The experimenters are looking at three instruments: heading, vertical speed indicator and airspeed.

Instructions for Evaluating Flights

We would like for you to evaluate these flights for a straight-in approach to landing. Each approach was made with turbulence turned on. They should **not** be graded for the flare and touchdown.

For the following flights, the student participants were asked to perform a straight-in approach to landing and to maintain: alignment with the runway, a descent rate of 500 fpm, and 75 knots. Please note that the approach was being made with mild turbulence.

For these flights, **please make sure to turn off the sound** as the students could not hear the instructor when they made the approach. Also, although messages occasionally appear on the top left corner of the screen from the automated instructor, the students were not given any instructions regarding responding to them. Therefore, **please disregard those messages when conducting your evaluation. Please begin your evaluation after the AP light goes off** (the AP light is on the top left side of the instrument panel.)

Thank you,
Bruce Heath

To load the video files of the flights please use the following directions:

We would like for you to evaluate flights for our participants. Microsoft Flight simulator's video recorder was used to make a visual record of each of the flights. In order to replay the video which displays the instruments and a forward outside view, please use the following directions:

Copy all of the files from the CD to :

C:\Program Files\Microsoft Games\FS2002\flights\myflts

Start Microsoft Flight Simulator 2002
At the opening screen select "Learn to Fly" from the menu on the left.

Under "2. Choose a Lesson" select **Lesson 6b: Landings Part II**

Click the **Fly Now** button in the lower right corner.
On the next screen **click OK.**

As soon as the scenario starts, hit the **ALT** key on your keyboard.
Select **OPTIONS** from the menu that **should appear at the** top of the screen.

Click **Flight Videos** from the OPTIONS **menu.**
Select one of the flights under **SAVED VIDEOS** and click **PLAY CLIP.**

The simulation will start paused. Hit the P key on the keyboard when you **are ready** to un-pause the simulation

Flight Number	Score	Best Controlled Parameter	Worst Controlled Parameter	Parameter Most Influencing Grade	Additional Comments
1					
2					
3					
4					
5					

52

Additional Comments:

APPENDIX E
Instructor Experience

Instructor 1	Extensive experience in Flight simulation and flight testing procedures	
Instructor 2	5500 plus flight hours including 4000 plus instructional hours	ATP Certification
Instructor 3	7000 plus flight hours including 500 plus instructional hours	ATP Certification

REFERENCES

[1] FAA Advisory Circular No. 61-126 "QUALIFICATION AND APPROVAL OF PERSONAL COMPUTER-BASED AVIATION TRAINING DEVICES" Par. 5a

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II

"An Experimental Study of the Effect of Out-of-the-Window Cues on Training of Novice Pilots on a Flight Simulator" by M. Javed Khan, Marcia Rossi, Bruce Heath, S. Firasat Ali, Marcus Ward, Proceedings, Human Factors and Ergonomics Society Conference, San Francisco, California, October 2006, 8 pages.

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An Experimental Study of the Effect of Out-of-the-Window Cues on Training Novice Pilots on a Flight Simulator

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Abstract
The effects of out-of-the-window cues on learning a straight-in landing approach and a level 360° turn by novice pilots on a flight simulator have been investigated. The treatments consisted of training with and without visual cues as well as density of visual cues. The performance of the participants was then evaluated through similar but more challenging tasks. It was observed that the participants in the landing study who trained with visual cues performed poorly than those who trained without the cues. However the performance of those who trained with a faded-cues sequence performed slightly better than those who trained without visual cues. In the level turn study it was observed that those who trained with the visual cues performed better than those who trained without visual cues. The study also showed that those participants who trained with a lower density of cues performed better than those who trained with a higher density of visual cues.

Introduction

With the increasing availability of low-cost powerful personal computers the development of 'intelligent' flight simulators for use by general aviation flight schools is becoming viable (Ludwig et. al. 2002, Remolina et. al. 2004)). Such simulators will be able to use the available computational power to incorporate not only traditional but also novel training techniques based on learning theories. Also, these simulators will have robust and realistic assessment of task performance to provide feedback thus making self-instruction effective as well as controlling the training to progress in the right direction. The motivation for developing 'intelligent' flight simulators of course is to reduce the cost of flight training. The FAA already has allowed a certain number of simulator hours on Personal-Computer based Aviation Training Devices (PCATD) to substitute for flight hours thereby reducing the cost of training. However, these simulator hours have to be supervised by a certified flight instructor (CFI). The main advantages of 'intelligent' flight simulators then would be to increase the number of simulator hours substituting for flight hours, effective utilization of simulator hours, increased transfer of training thereby further reducing flight hours to gain proficiency, and reducing/eliminating the need for a CFI during flight simulator training.

To reach these and other such goals there are a number of areas which need to mature before the full potential of such a flight simulator can be realized and used routinely. These include cognitive scaffolds such as aural, visual and environmental cues for learning various flight skills, performance evaluation metrics faithfully capturing certified flight instructors' assessment techniques and seamless incorporation of simulator-based training in the flight training curricula.

The current research has focused on special out-of –the window (OTW) visual cues in a flight simulator to develop a pedagogical model for training novice pilots. The use of OTW visual cues in flight training is not a novel idea. Two such cues are (a) using a certain perspective of the runway to judge height/glide slope and (b) maintaining a far-off object on a certain location on the windscreen/canopy for learning to maintain glide slope or keeping a tree/fixed point on ground for 360° level turns. However, if cues are used without understanding their limitations, incorrect habits developed may result in potentially hazardous situations. Foyle et. al. [1992] have pointed to a number of such cues which have high saliency but low reliability as is pertinently pointed out in AIM Chapter 8-1-5 as well.

A number of studies have evaluated various aspects of 'perspective displays or the more commonly referred to as tunnel-in-the-sky concepts. These include the effects of egocentric and exocentric depictions, terrain texture, projected path cues, trajectory shape (Mulder 2003(1), Mulder 2003(2), Doherty & Wickens 2001, Sachs 2003). Such perspective displays are now commercially available. However it must be noted that this concept is being implemented primarily in a heads-down display (HDD) mode. It has been reported that flying in the tunnel resulted in definite improvements in flight path control. Limited research has been conducted in evaluating its utility as a navigation/flight path aid in a heads-up display (HUD) mode. Fadden et. al.[2001] have reported their observations of the implementation of the 'tunnel-in-the-sky' or 'perspective' displays as a HUD. They determined that it did result in improvements albeit with cognitive tunneling. This was exhibited in the form of inattention towards unexpected traffic outside the tunnel. They also conducted experiments to compare the HUD 'tunnel' with a HDD 'tunnel'. They determined that a HUD implementation had slightly degraded performance in vertical path control while resulting in better performance in lateral flight path control in comparison to a HDD implementation. However their overall assessment was that a HUD implementation would combine the advantage of a HUD and a perspective display.

The advantages of the tunnel-in-the-sky motivated us to investigate a HUD implementation of such a visual cue as a cognitive scaffold to help learn flight path control by novice pilots. In fact such an implementation exists in the form of the 'magic hoops' of the landing lesson in the various versions of the Microsoft Flight Simulator (MSFS).

Experimental Method

The two maneuvers chosen to evaluate the concept were a straight-in landing approach and a 360° level turn. These two maneuvers were expected to capture the effects if any of path curvature for such a training concept. Each maneuver was flown by a different batch of novice pilots. Each batch consisted of a control group and a number of treatment groups. The treatments philosophy was based on the concept of gradually reducing the dependence on the scaffold. Two methods of fading were evaluated. The first method was to reduce the number of hoops (tunnel cross section outlines) as the training progressed. The other approach was to mix flights with hoops and without hoops in a certain sequence as the training progressed. Preliminary studies with the hoop-reduction technique for a level turn exhibited the need for a certain minimum number of hoops on the flight path for it to be effective as a training aid. For the level-turn maneuver two hoop-densities were used to investigate the effectiveness of hoop density. The study then concentrated on evaluating the effectiveness of mixing flights with hoops and without hoops.

The study was divided into two parts. The first part evaluated the effect of visual cues on a learning a straight-in landing approach, while the other part investigated a level turn. The participants were undergraduate students of an introductory psychology course who took part in the study for extra credit. They had no prior flight simulator or flight experience. The participants were screened for their aptitude to fly the simulator based on their performance in three straight and level flights. The selected 'novice' pilots were then randomly assigned to various treatment and control groups.

Straight-in Landing Approach

The study consisted of three groups flying a straight-in landing approach in a Cessna 172. Each group flew 8 training flights followed by an evaluation flight more challenging than the training flight. The training flights were flown according to the sequence given in Table I. The participants then flew a straight-in approach with mild turbulence increasing their workload to maintain the glide slope.

360° Level Turn

In this experiment the participants flew 8 training flights which consisted on a 360° level turn with a 10° bank angle. The control group was not provided any cues while the two treatment groups flew some flights with visual cues and others without. The visual cue densities differed for the two treatment groups. The training flights sequence is given in Table II. After the training the participants then flew a more challenging flight by executing a 30° bank level turn.

Performance Measures

Various performance measures have been suggested to evaluate a pilot's performance based on flight recorder data (Rantanen et al. 2001, Rantanen & Johnson 2005). These include standard deviation, root mean square error, number of deviations, total time outside tolerance and mean time to exceed tolerance. In this study the root mean square error (RMSE) was used as a performance measure. In case of the straight-in landing approach, the sum of the RMSE in air speed, rate of descent and runway alignment was used for evaluating performance. For the level turn, RMSE from the required path as evidenced by bank angle and altitude loss determined the performance of the participants. The performance of all participants in each group was averaged to compare between group performances.

Experimental Setup

The experimental setup was a Microsoft Flight Simulator (MSFS) 2002 environment running on four PCs networked using the IPX/SPX gaming protocol. Three out-of-the-window views were driven by the three PCs while the fourth computer was used to display the synthetic instrument panel. Cougar a joystick and throttle and CH4 rudder pedals were used for controls. Flight parameters of interest were written to file every second for later analysis. The landing approach study used the canned landing lesson in MSFS2002 suitably modified to remove instructor audio and control inputs. The level turn study used gmax to render the visual cue hoops along the turn path. These hoops were included as add-on scenery in MSFS 2002. The flights were designed to start at the same location in a trimmed condition.

Results & Discussion

The study revealed the following aspects of the influence of out-the-window visual cues.

Straight-in Landing Approach Task

A summary of the task performance is shown in Table III. As can be noted, providing visual cues throughout the training regimen (H-group) did not help the participant in learning to fly the simulator. This is primarily because the participants probably were more concerned about flying through the hoops and hence looking OTW rather than also scanning the instrument panel to ensure that the flight parameters for the task were being maintained. In case of the participants who trained without the visual cues (NH-group) performed much better as they had probably learned to divide attention between the OTW view so as to maintain runway alignment as well as scan the instrument panel to maintain the flight parameters for the task. The participants who trained using a mix of the flights with and without visual cues (FH-group) though in the beginning exhibited similar performance as the H-group were most probably able to learn to divide attention effectively and maintain the flight parameters and took the hoops as a challenge to fly through.

Level 360º Turn

The performance in the level turning task is summarized in Table IV. It can be observed that visual cues had a major influence on the performance in the evaluation flight. The performance improved for both the cue-density methods as compared to the group who trained without visual cues. This observation is consistent with the observation of the landing study. The performance was observed to be better for the lower density method as compared to the higher density method. This is attributed to the increased time between hoops thereby forcing the participant to look inside the cockpit at the flight parameters required for the task. With the increased hoops density the tendency to 'chase' the hoops and not paying enough attention to the flight parameters most probably was the cause for the relatively lower performance.

Table I: *Treatment Sequences: Straight-in Landing Approach*

H: Flight with Hoops; NH: Flight with No Hoops; Evaluation Flight: E

Group#1 (Control) (NH)	Group#2 (H)	Group#3 (FH)
NH	H	H
NH	H	H

NH	H	H
NH	H	NH
NH	H	NH
NH	H	H
NH	H	H
NH	H	NH
E	E	E

Table II: ***Treatment Sequences for a 360º Level Turn***

H: Flight with Hoops; NH: Flight with No Hoops; Evaluation Flight: E

Group#1 (Control)	Group#2 (36 Hoops)	Group#3 (18 Hoops)
NH	H	H
NH	N	N
NH	H	H
NH	N	N
NH	N	N
NH	H	H
NH	N	N
NH	N	N
NH	N	N
E	E	E

Table III: ***Composite Error for Straight-in Landing Approach***

Group	Error
Control (No hoops)	25.5
All training flights with hoops (H-group)	32.1
Faded-cues training flights (FH-group)	22.2

Table IV: ***Error for Level 360º Turn***

Group	Error in Bank Angle	Error in Altitude
Control (No Hoops)	17.99	233.1
Low Density Hoops	10.12	109.5
High Density Hoops	11.22	170.3

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FAA AC 61-126 Appendix 1, C & FAR 61.4(c)

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III

"Correlating Automated and Flight Instructor Assessments of Straight-In Landing Approaches by Novice Pilots on a Flight Simulator" by Bruce E. Heath, M. Javed Khan, Marcia Rossi, Syed Firasat Ali, Proceedings, Huntsville Simulation Conference, Huntsville, Alabama, October 2005, 8 pages.

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Correlating Computed and Flight Instructor Assessments of Straight-In Landing Approaches by Novice Pilots on a Flight Simulator

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The rising cost of flight training and the low cost of powerful computers have resulted in increasing use of PC-based flight simulators. This has prompted FAA standards regulating such use and allowing aspects of training on simulators meeting these standards to be substituted for flight time. However, the FAA regulations require an authorized flight instructor as part of the training environment. Thus, while costs associated with flight time have been reduced, the cost associated with the need for a flight instructor still remains. The obvious area of research, therefore, has been to develop intelligent simulators. However, the two main challenges of such attempts have been training strategies and assessment. The research reported in this paper was conducted to evaluate various performance metrics of a straight-in landing approach by 33 novice pilots flying a light single engine aircraft simulation. These metrics were compared to assessments of these flights by two flight instructors to establish a correlation between the two techniques in an attempt to determine a composite performance metric for this flight maneuver.

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INTRODUCTION

With the advent of faster computers, it has become possible and cost effective to use personal computer-based aviation training devices (PCATD) to provide supplemental training for pilots. Such devices are regulated by the Federal Aviation Administration (FAA). The airplane or flight training device (FTD) flight-hour training time required for an instrument rating may be reduced by using PCATDs that have been determined to meet acceptable FAA standards. For the student pilot in a Part 61 or Part 141 flight school, 10 of the total allowable flight-hours in a FTD can be flown in a PCATD. However, the regulations state that a certified flight instructor (CFI) must also be present (FAA 1997). Vruels and Obermayer (1985) emphasize the need of automated performance measures on modern simulators as a substitute for direct evaluation of performance by an instructor. One strategy to address this goal is to determine how closely a computer can emulate a CFI's evaluation of a student pilot. Therefore, an investigation of different computed evaluation techniques is needed to compare against instructor evaluations.

Rantanen and Talleur (2001) have suggested the following five primary measures for pilot performance from the flight data recorder for nine flight parameters: (1) Standard deviation. A small standard deviation is indicative of good performance. (2) Root mean square error (RMSE) which summarizes the overall error. (3) Number of deviations, which is a measure of occurrences of the aircraft staying outside the prescribed tolerances. (4) Time outside tolerance is the cumulative time the aircraft spends outside prescribed tolerances. (5) Mean time to exceed tolerance is computed from the rate of change between successive data points and the aircraft's position relative to a given tolerance. Heath and Crier (2003) used computerized scoring and certified flight instructors (CFI) to attempt to devise a computed performance measure for a level turn. A performance index based on deviations from the required heading, altitude and airspeed was compared with the instructors' letter grades. One of the challenges of such comparisons is inter-rater reliability of the flight instructors.

The objective of the current study was to explore the possibility of determining computed measures for a landing task by novice pilots on a flight simulator which would realistically depict their performance. The approach there has been that if these performance measures correlate with assessments of the task by CFIs that these measures then can be used routinely to inform student pilots of their performance. This study chose to use the standard deviations of the errors in flight parameters to represent pilot performance. A straight-in landing approach was chosen as the maneuver to be studied.

METHOD

Equipment

The experiment was performed at the Aerospace Science Engineering Department, Tuskegee University. The flight simulation environment consisted of four computers that were all running Microsoft Flight Simulator 2002 (MSFS 2002). The computers were connected by LAN using a Netgear Fast Ethernet Switch. Three of the computers were used for out of the window (OTW) views. One computer was used as the main computer. Communication between the computers was made using FSUIPC; a third party software that runs over IPX/SPX. The OTW view was created using Wideview software; also third party. Data was collected into Excel spreadsheets using a third party flight data recorder. All of the computers run Windows XP Professional. The OTW view computers are all Gateway E series computers with the following specifications: Pentium 4 2.60GHz processor Hyper-Threading Technology with 512KB cache, 512 MB ram, bus speed 800 MHz and memory speed of 333 MHz. An NVIDIA GeForce FX5200 is the video card used for the OTW view computers. The master computer has the following specifications: Pentium 4 2.4GHz processor with 512 KB cache, 512 MB ram, bus speed 133 MHz. The video card for the master computer is a NVIDIA GeForce Ti 4600 with 128MB memory. A Thrustmaster HOTAS joystick, a Cougar throttle and CH Products rudder pedals were used.

Procedure

Three CFIs were asked to individually view and evaluate 33 video recordings of straight-in landing approaches made by novice pilots on the flight simulator. The pilots were students at Tuskegee University who had had little or no experience flying an airplane or simulator. Two of the flight instructors also had airline transport pilot (ATP) certification with one CFI having 7100+ flying hours with 580+ instructional hours while the other CFI had 5800+ flying hours with 4000+ instructional hours. The third CFI had extensive experience in certification requirements and flight testing and flight simulation.

The task given to the pilots was to maintain 75 knots airspeed, descend at 500 feet per minute, and head towards and line up with the centerline in a straight-in approach to the Bremerton International Airport in the Seattle, WA area. The aircraft being flown was a Cessna 172. The flight scenario was a modified version of a landing lesson from the "flight school" portion of Microsoft Flight Simulator, MSFS 2002. The approaches made by the pilots were recorded and sent to CFIs for evaluation. The instructors were asked only to grade the approach, and not the flare and touchdown. Further, they were told to turn the sound off of the recording, and to disregard any text messages that may have appeared on the screen. They were asked to evaluate the flights after the 'autopilot' light was turned off. The CFIs were asked to assign each flight a grade based on a 100 point scale. They were also asked to monitor three flight parameters namely, airspeed, rate of descent and runway alignment and record the best and worst controlled flight parameters and the flight parameter most affecting their grading.

The various flight parameters including airspeed, heading and altitude were written to an Excel file with a 1HZ frequency for each flight. Also certain other events such as 'autopilot status', 'aircraft on ground' were also written to the file. The data for each flight was then processed to determine the error in airspeed, rate of descent and runway alignment. The standard deviations for these errors were then calculated.

RESULTS & DISCUSSION

The performance measures investigated were the standard deviation of the errors in runway alignment, rate of descent, airspeed and linear combinations of these deviations. Pearson Product Moment Correlations were calculated between these measures and the individual instructor scores. Weak correlations ($r^2 = 0.263, 0.09, 0.12$ for rate of descent error, $r^2 = 0.08, 0.1, 0.05$ for runway alignment error, $r^2 = 0.14, 0.19, 0.1$ for airspeed error) prompted a detailed analysis of the instructors' grading.

Correlations between the pairs of instructors grades were calculated and found to be only moderate ($r^2 = 0.4334, 0.5054, 0.4334$). Therefore, the instructor responses were analyzed to determine whether there was consistency in scoring procedures not captured in the grades. The frequencies of citing the best and worst controlled parameters are shown in Figs. 1(a) and 1(b). As can be seen, all three instructors most frequently cited runway alignment as the best controlled parameter while citing rate of descent as the worst controlled parameter. In addition, one instructor also cited airspeed almost as frequently as the other two parameters as the worst controlled parameter. This suggested that a composite of the standard deviations of runway alignment error, rate of descent error and airspeed error to be a candidate error metric.

Seven flights were identified for which all three instructors agreed on both best and worst controlled parameters. Correlations between the instructor grades and the composite error metric (a linear combination of the standard deviations of errors in runway alignment, rate of descent and airspeed) were calculated for these flights (Fig. 2). A strong and significant correlation was found for all three instructors ($r^2 = 0.8153$, $t = 4.6878$, $p < 0.01$, $r^2 = 0.7749$, $t = 4.14877$, $p < 0.01$, $r^2 = 0.628$, $t = 2.91$, $p < 0.05$). Correlations between pairs of instructor grades were also calculated for these seven flights (Fig. 3). It can be seen that despite their agreement on the best and worst controlled parameters, one of the flight instructor's grades was weak to moderately correlated with the other two (r^2 = 0.8896, 0.44, 0.2517).

In conclusion the following observations are noted:

(a) Inconsistency in grading between instructors is a probable cause for weak correlations between instructor grading and the error metric.

(b) Despite agreement on best and worst controlled parameters, the weak to moderate correlation of one instructor's grades with the others suggests that the instructors' grades may be influenced by other factors.

FUTURE RESEARCH

- Study the effect of student pilot experience on inter-CFI correlation.
- Evaluate the influence of student pilot experience on correlation of computed performance measures with CFI-grades.
- Investigate other performance measures to determine most robust measure.

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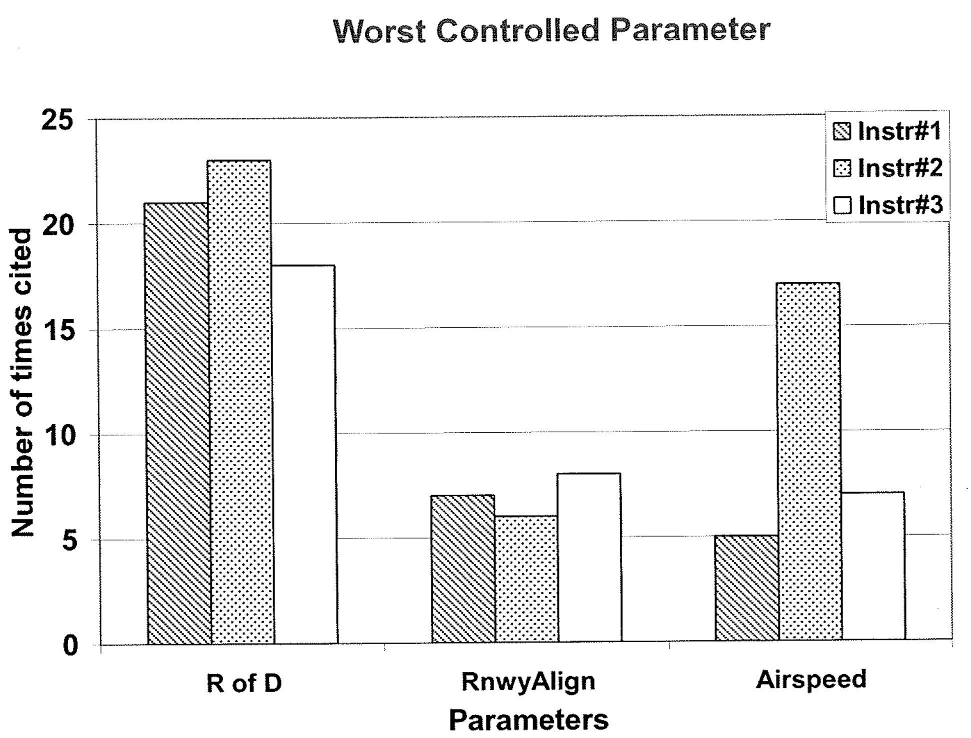

Figure 1(a): Number of Citations of Worst Controlled Parameter

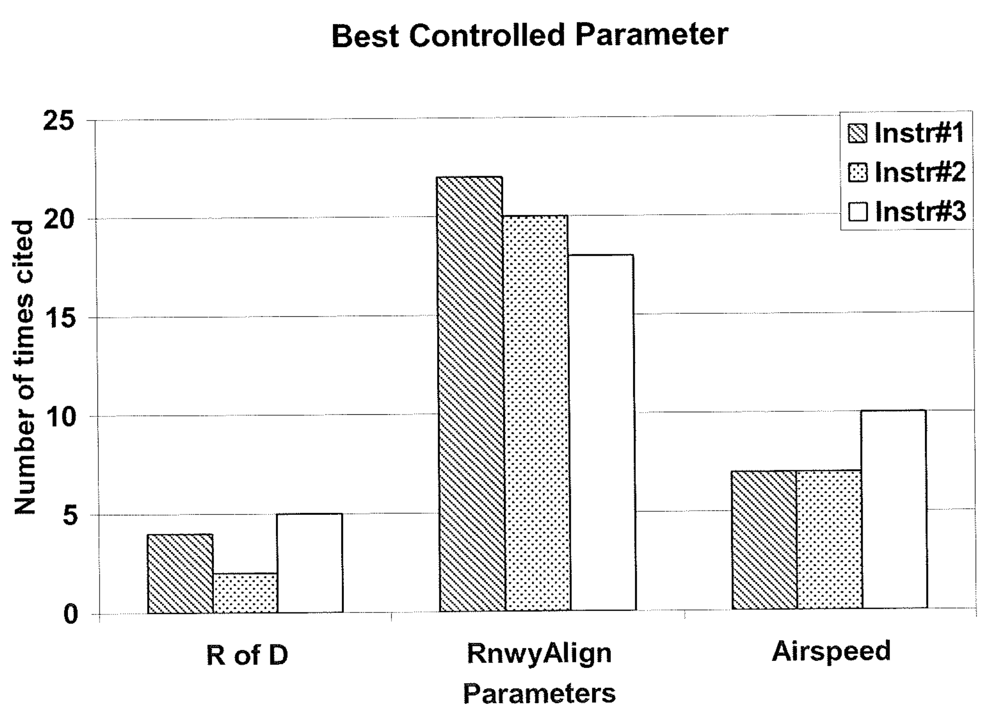

Figure 1(b): Number of Citations of Best Controlled Parameter

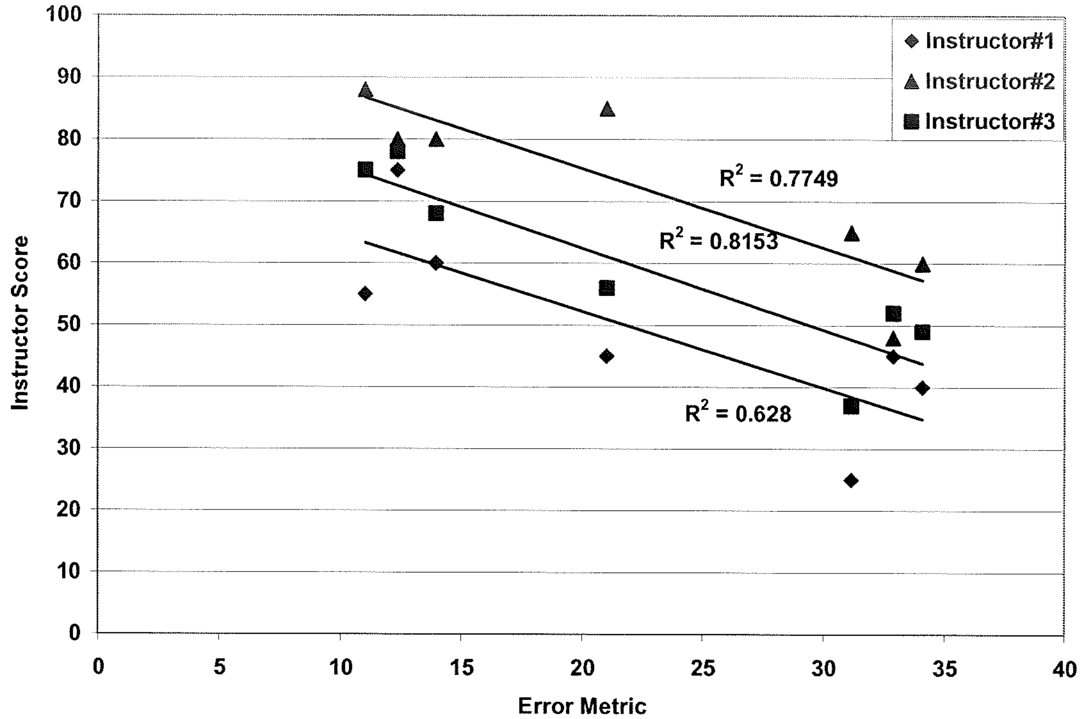

Figure 2: Correlation between the Composite Error Metric and Instructors' Scores

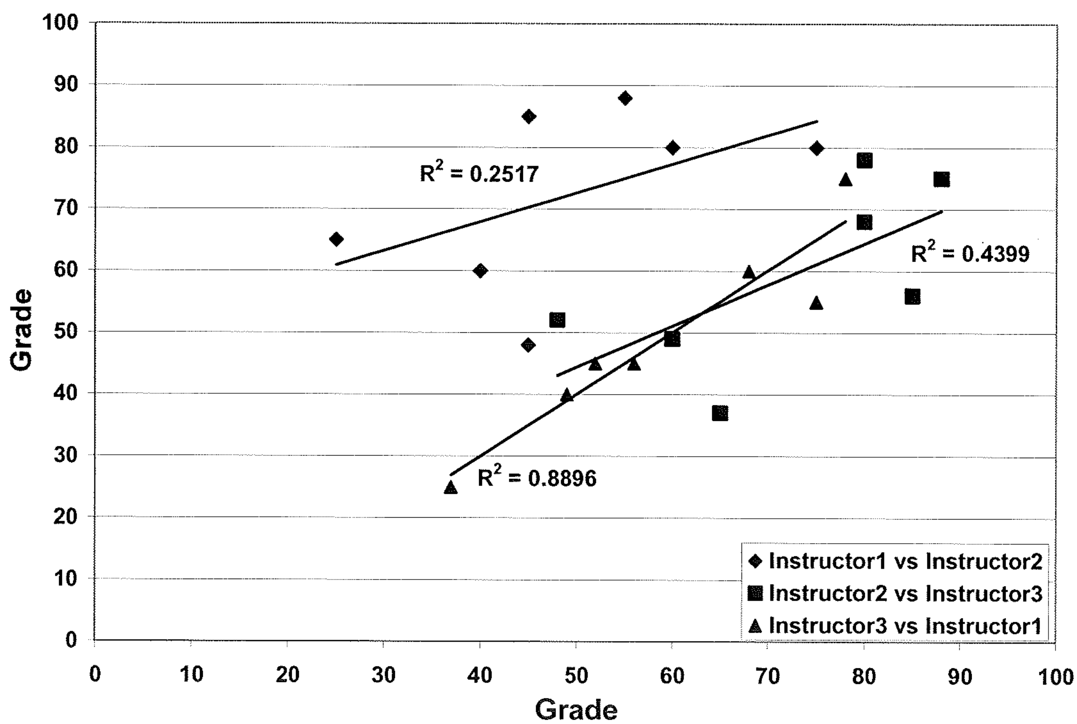

Figure 3: Correlation between Flight Instructors' Scores

IV

Using a Low Cost Flight Simulation Environment for Interdisciplinary Education by M. Javed Khan, Marcia Rossi, Syed F. Ali, Proceedings, ASEE Annual Conference and Exposition, Salt Lake City, Utah, June 2004, 6 pages.

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Using a Low Cost Flight Simulation Environment for Interdisciplinary Education

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Abstract
A multi-disciplinary and inter-disciplinary education is increasingly being emphasized for engineering undergraduates. However, often the focus is on interaction between engineering disciplines. This paper discusses the experience at Tuskegee University in providing inter-disciplinary research experiences for undergraduate students in both Aerospace Engineering and Psychology through the utilization of a low cost flight simulation environment. The environment, which is pc-based, runs a low-cost of-the-shelf software and is configured for multiple out-of-the-window views and a synthetic heads down display with joystick, rudder and throttle controls. While the environment is being utilized to investigate and evaluate various strategies for training novice pilots, students were involved to provide them with experience in conducting such interdisciplinary research. On the global inter-disciplinary level these experiences included developing experimental designs and research protocols, consideration of human participant ethical issues, and planning and executing the research studies. During the planning phase students were apprised of the limitations of the software in its basic form and the enhancements desired to investigate human factors issues. A number of enhancements to the flight environment were then undertaken, from creating Excel macros for determining the performance of the 'pilots', to interacting with the software to provide various audio/video cues based on the experimental protocol. These enhancements involved understanding the flight model and performance, stability & control issues. Throughout this process, discussions of data analysis included a focus from a human factors perspective as well as an engineering point of view.

Introduction
The 'Programs Outcomes and Assessment' detailed in Criterion 3 of the ABET2000 document [1] for accreditation of engineering programs is a template for educating well-rounded engineers. This criterion is a consequence of an awareness of the fact that today's graduates need to have skills for success and competitiveness in a global and highly interactive work environment. In order to fulfill the requirements of this criterion, educators are now consciously designing and delivering their educational materials [2].

Interdisciplinary research is considered to be an effective method for exposing students to the skills outlined in Criterion 3(a) – (k) of Reference [1]. Such a research environment when properly structured provides the students with opportunities to develop collaborative, technical and communication skills. The added advantage is that students actually are able to see a practical application of the skills they are acquiring and have a sense of accomplishment. The 'Calpoly Interdisciplinary Monarch Butterfly Nuptial Flight Research' [3] is an interesting example of interdisciplinary research in which students of behavioral ecology, molecular and cellular biology statistics and aeronautical engineering are attempting to determine characteristics for a successful mating. The Mind Project [4] of Illinois State University is designing 'simulated persons' using artificial intelligence, robotic devices and is although aimed at cognitive research has involved students from a variety of departments.

The authors have been conducting research at Tuskegee University in the area of flight simulator based training methodologies. These investigations have been directed towards novice pilots as the volunteers for the research are students with no flying experience. Some of the factors that have been studied are the impact of above-real time (a scenario in what events are presented at a higher speed than normal) training strategies, self-instruction and team interactions etc. [e.g. 5,6]. Currently an interdisciplinary research effort towards determining training strategies utilizing a low-cost flight simulation environment for ab-initio or novice pilot training and minimizing flight instructor interventions is being undertaken.

This research has provided excellent interdisciplinary exposure opportunities for students from aerospace engineering and psychology majors [7, 8]. Interdisciplinary research, however have many unknowns and need to be carefully structured for students involvement. Some of these pertain to working attitudes, project concepts and plans, specialist jargon, execution methodologies etc. For example Reference 9 notes that 'established means of facilitating working relationships among social and computer scientists are currently lacking'.

This paper details the approach taken to successfully involve students.

The Team & Tasks

The objective of the investigation was to determine an effective training strategy on a flight simulator for learning to land a light aircraft using a straight-in approach. The faculty research team consisting of the authors identified a group of psychology and aerospace engineering majors students interested in the research who were invited to the preliminary planning meetings. The research meetings served an important purpose. Students were exposed to interdisciplinary terminologies, concepts and interactions between the disciplines. For example the engineering students were exposed to the subtleties of human responses, while the psychology students gained a better understanding of time needed to setup physical hardware and develop software patches etc. They also realized the constraints due to limitation of resources, and time.

These initial meetings established the tasks and timelines to achieve the research objective. The students were then given various responsibilities based on the following tasks:

(a) Establishing the flight simulation environment
(b) Determining orientation, training and evaluation maneuvers

(c) Coding automatic performance grading
(d) Designing the experiment
(e) Recruiting volunteers
(f) Establishing experiment protocols
(g) Conducting the experiment
(h) Analyzing & evaluating the data

The first objective for the aerospace engineering students was to establish the low cost flight simulation environment. During the planning meetings the various required characteristics of the environment were discussed. The students brought some useful observations to the table regarding maintaining interest of volunteers in the research. These included the importance of a realistic and interesting flight simulation environment. This was based on their earlier experiences with a simulator which had a bland desert scenery.

The establishment of the flight simulation environment then was an exercise in systems engineering as the objective was to use off-the-shelf software and hardware. The public domain FlightGear Flight Simulator and the commercial MicroSoft FS2002 Professional software were evaluated by the students to determine its ease of use, sensitivity, realism etc. For the current investigation the MSFS2002 was determined to be a suitable engine. However, to use it effectively a number of enhancements were needed. One of the requirements for the environment was to have a multiple monitor out of the window display. An extensive internet search was conducted by the students to determine availability of software extending the capability of the MSFS2002. The WideView [9] software was found to provide exactly this capability. The multi-monitor capabilities of WindowsXP software were used for configuring the various parts of the synthetic instrument display. Since one of the objectives of the research was to minimize the involvement of a 'flight instructor' in the learning process, an automated performance grading had to be established. This required the comparison of the actual with the desired flight parameters; hence a data extraction software was needed to interact with the simulation engine. Again an internet search was conducted and the 'FltRec82' [10] was determined to be an appropriate software. However the data extracted by this utility had to be manipulated to determine the performance of the 'pilot'. An excel macro was therefore written by the students to calculate and provide a quick answer to the student researcher as to whether the 'pilot' had passed or failed the flight maneuver. The students were exposed to the various performance metrics used in previous investigations in which the students were involved. During these previous investigations the students had conducted a comparative study of various grading strategies with flight instructors grading [8] exposing them to statistical analyses. While the aerospace engineering students were at ease with the discussion of the rationale for including certain flight parameters while excluding others, the psychology students were exposed to practical applications of concepts like that of kinetic and potential energy interchanges which they had studied in physics courses.

The research team meanwhile considered various candidate training methodologies for investigation. The impact of the use of visual cue of flying through a 'tunnel in the sky' on the landing approach versus instrument scanning technique was chosen for investigation. The impact of 'fading' of the visual cues was also included. The reasoning behind the planned sequencing of flights, and fading was explained to the team along with the design of the experiment. The aerospace engineering students were thus exposed to the theory of design of experiments and became familiar with concepts like 'between-subjects' and 'within subject' designs.

Since the research was to be conducted with volunteers who had no flying or flight simulator experience, effective protocols for conduct of the experiment had to be designed. These included standardized briefings on simulator operation, using the post-flight feedback on performance, orientation flights, training and evaluation maneuvers. This process required intensive teamwork between the engineering and psychology students and involved role-playing (of the volunteer and pre-experiment briefer etc.) to ensure standardized, repeatable and smooth conduct of the experiments. During this process the student researchers were exposed to the important aspect of sensitivity to the volunteers' response to the evaluation of their performance/skill. The students then presented their protocols and demonstrated the experimental procedure to the faculty team members.

The requirement of standardized orientation, training and evaluation flights scenarios was met by understanding the Adventure Basic Language on the MSFS2002 so as to appropriately modify the landing lessons already programmed in the software. Also, the orientation flights which were primarily straight & level flights to screen the volunteers required an understanding of the interactions between altitude, throttle setting and speed to establish the desired flight parameters. This provided an opportunity for the psychology students to understand the basic aspects of flight mechanics.

As the investigation would utilize volunteers, the University's requirements for research involving human subjects had to be fulfilled. The students were thus exposed to the ethical aspects of research. Details of the research had to provided to the University for approval and the students realized that a well thought out research plan was essential as after the approval of the plan by the University, any changes would again have to be referred to the Human Subjects Committee causing delays in the investigation.

Forms were designed by the students to collect demographics and data organizing coding was established. The students then conducted final 'dry runs' to ensure the experimental procedures correctness and determined the durations for the various phases of the experiments. Flyers for soliciting volunteers for the research were designed and distributed. An elaborate schedule was then worked out by the student team allocating time slots to the volunteers and the student researchers. Data was then collected on a number of volunteers.

Summary & Conclusions

An interdisciplinary team of aerospace engineering and psychology majors was involved in an interdisciplinary research project. The research provided the students an opportunity to function as a closely knit team. They were exposed to:

(a) Participation and interaction as a research group
(b) Establishing tasks for achieving research objectives
(c) Time and effort management

(d) Interdisciplinary academic areas
(e) Literature searches
(f) Formal presentations of results

The team successfully met the objectives set forth by the faculty mentors. The main elements of success were primarily a high level of motivation of the students due to the opportunity of learning of concepts not covered in their major areas, being given responsibility of tasks with practical impact on the investigation and planning and actual conduct of the experiments under minimal supervision. However, it is essential that for interdisciplinary student research teams, the faculty mentors have a well-structured research plan so as to minimize overwhelming of the students. Regular meetings to provide well defined tasks are an important element of the structure.

Acknowledgement

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Effect of Above Real Time Training and Post Flight Feedback in Training of Novice Pilots in a PC-Based Flight Simulator by M. Javed Khan, Marcia Rossi, Bruce E. Heath, Syed Firasat Ali, Peter Crane, Tremaine Knighten, Christi Culpepper, Proceedings, Huntsville Simulation Conference, Huntsville, Alabama, October 2003, 8 pages.

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EFFECT OF ABOVE REAL TIME TRAINING AND POST FLIGHT FEEDBACK ON TRAINING OF NOVICE PILOTS IN A PC-BASED FLIGHT SIMULATOR

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Trainers, Real-time simulation, Personal computers, Man-in-the-loop simulation

ABSTRACT

The use of Post-Flight Feedback (PFFB) and Above Real-Time Training (ARTT) while training novice pilots to perform a coordinated level turn on a PC-based flight simulator was investigated. One group trained at 1.5 ARTT followed by an equal number of flights at 2.0 ARTT; the second group experienced Real Time Training (RTT). The total number of flights for both groups was equal. Each group was further subdivided into two groups one of which was provided PFFB while the other was not. Then, all participants experienced two challenging evaluation missions in real time. Performance was assessed by comparing root-mean-square error in bank-angle and altitude. Participants in the 1.5/2.0 ARTT No-PFFB sequence did not show improvement in performance across training sessions. An ANOVA on performance in evaluation flights found that the PFFB groups performed significantly better than those with No-PFFB. Also, the RTT groups performed significantly better than the ARTT groups. Data from two additional groups trained under a 2.0/1.5 ARTT PFFB and No-PFFB regimes were collected and combined with data from the previously studied groups and reanalyzed to study the influence of sequence. An ANOVA on test trials found no significant effects between groups. Under training situations involving ARTT we recommend that appropriate PFFB be provided.

INTRODUCTION

Advancements in computer technology have made the use of computer-based simulators and trainers more feasible for research investigating factors related to pilot training effectiveness. One of the training strategies utilized for skills acquisition is that of ARTT in which training skills are acquired on a real-time simulator when it is modified to present events faster than normal. The motivating factors for ARTT can be traced back to Kolf (1973) who noted that, "regardless of type or amount of pre-flight simulator training accomplished by the pilot, the actual flight appears to take place at a much faster time frame than real time" and Hoey (1976) who reported that the mental state of test pilots operating remotely piloted vehicles can be approximately simulated without stressful conditions by increasing the simulated rate of time passage. More recently, Crane and Guckenberger (1997) reported that pilots trained using ARTT performed emergency procedures and defeated bandit aircraft significantly faster than pilots trained in real time. Rossi et al. (1999) trained university students on a gunnery task to compare RTT and ARTT at 1.5 times real time. The students trained in ARTT performed on test trials as well as students trained in RTT, although the ones trained in ARTT spent less clock time. During training, the performance of students in ARTT was depressed compared to those trained in RT. The authors suggested that using ARTT as top-off training after RTT might result in more effective training. Williams (1999) also observed that ARTT as top-off training after RTT offers better training in comparison to ARTT alone or RTT alone in a similar gunnery task. Ali, Guckenberger, Rossi, and Williams (2000) addressed the use of ARTT for training of pilots to perform basic flight maneuvers. They classified the flying maneuvers with reference to Fitts and Posner's (1967) model that recognizes different stages of skill acquisition as cognitive, associative, and autonomous. Ali et al. (2000) observed that using ARTT at the cognitive stage was beneficial for acquiring skills in straight-and-level flight. However, as climb and descent and level turns are relatively more complex than straight-and-level flying, they propose that ARTT is beneficial at the autonomous stage or as top-off training after RTT.

Self-instruction through the use of feedback is increasingly being incorporated in computer-based learning. Proctor and Dutta (1995) provide a comprehensive discussion of the influence of feedback on motor skill acquisition. Ali et al. (2000) used two forms of feedback; first, automated in-flight aural cues that signaled to the pilot trending out of prescribed tolerances in altitude and heading and second, post-flight feedback in the form of strip-charts consisting of a graphical comparison of altitude, heading, airspeed, and other parameters during flight with the target values/tolerances. They observed that these two feedback strategies in general improved the performance.

In summary, previous studies have determined that the efficacy of training depended on types of feedback, the type of piloting tasks, and the use of ARTT. The interaction of these parameters has not been systematically studied for training of novice pilots.

Objectives

The current investigation consisted of two related studies that attempted to:

(a) understand the influence of different sequences of ARTT values, and

(b) determine the adequacy of PFFB.

EXPERIMENTAL SETUP

Mock setup of a partial cockpit housed in the Flight Vehicle Lab at Tuskegee University was used as the pilot training station. This setup provides an out-the-window (OTW) panoramic view on three monitors with a heads-up display (HUD) on the center monitor. The heads-down display (HDD) of a conventional instrument panel was on a fourth monitor located below the OTW monitors. The four monitors are controlled by a Quantum 3D Heavy Metal Computer having two Pentium II 400 MHz processors, 400 MB RAM, three extra display cards for Open GVS, based graphics, and a Sound Blaster audio card. The computer was configured by SDS International, Orlando, Florida and runs the Lite Flite version 3.3 (199) flight simulation software by SDS International. Lite Flite offers flight simulation of several aircraft including a Predator unmanned air vehicle (UAV) which was used in these studies. The controls include a Saitek X36F joystick, a Saitek X35T throttle, and CH rudder pedals.

EXPERIMENT 1

The purpose of this experiment was to investigate the effects of increasing values of ARTT in comparison to RTT, and the effects of PFFB vs. no PFFB during the training of a standard two-minute turn with novice pilots. As previous studies have suggested ARTT to be useful for top-off training, the use of increasing values of ARTT may also prove beneficial.

Participants

Twenty undergraduate college students enrolled at Tuskegee University who had little or no prior flying experience served as novice pilots in exchange for course credit.

Experimental Design

This experiment consisted of a 2 X 2 X 2 mixed factorial design. The between subjects variables were the type of training (RTT vs. ARTT) and feedback condition (PFFB vs. No-PFFB). The within subjects variable was the two evaluation flights. There were five participants in each group, with the exception of four in a RTT, no feedback (No-PFFB) group.

Procedure

All participants experienced the following segments: Orientation to Simulator Controls and Functions, Demonstration Flight, Familiarization Flights, Training Flights, and Evaluation Flights.

Orientation to Simulator Controls and Functions, Demonstration and Familiarization. During the orientation process, participants were informed of the basic control surfaces of the aircraft, their functions, and the movements associated with each control surface. The participants then were given an overview of the locations and functions of the joystick, rudder pedals, and the throttle located in the mock cockpit. Then, participants were instructed in the location and functions of the following displays on the HUD: altimeter, radio altimeter, airspeed indicator, heading tape, artificial horizon, pitch ladder, and clock. They were also instructed on the location and functions of the following instruments on the HDD: artificial horizon and the vertical velocity indicator. Because the turn-and-slip indicator on the HDD was not functioning properly, the use of the HUD to determine if the aircraft was making a coordinated turn was explained.

Participants observed the experimenter fly one 3-minute flight, while explaining the controls and operation of the aircraft. Participants flew four flights of 3-minute duration each in which they were told to maintain airspeed of 129 knots, a heading of 360 degrees, and an altitude of 5,000 feet. Participants who achieved a score of 2.0 (grade based on comparing parameter values in the flight with the parameter values and tolerances in an input file) on at least one familiarization flight continued into training. Twenty participants, who achieved the passing grade continued on to the training phase.

Training and Evaluation. The experiment consisted of a training phase and an evaluation phase. The training mission consisted of a coordinated 180° turn with a 10° bank angle while the evaluation task was an S-turn with a bank angle of 30°. However, a loss of situational awareness was observed in most of the participants after the first leg of the S-turn. Thus, only the first leg of the S-turn was evaluated for analysis purposes. Each group conducted their training in the following sequence immediately followed by two evaluation flights in real time.

Group I: Five missions in 1.5 ARTT then five missions in 2.0 ARTT with No-PFFB

Group II: Five missions in 1.5 ARTT then five missions in 2.0 ARTT with PFFB

Group III: Five missions in RTT then five missions in RTT with No-PFFB

Group IV: Five missions in RTT then five missions in RTT with PFFB

Feedback. Participants in the No-PFFB groups received no feedback during or after flights. If they asked questions about the task, they were reread the relevant instructions. Participants in the PFFB groups received verbal feedback after each flight consisting of information about errors in manipulating the controls and in focusing on the wrong instruments. After the second, fourth, sixth, eighth, and tenth flights, participants in the PFFB groups were also shown a printout of the desired ground track and the pilot's actual ground track for comparison. Then, the instructor explained possible reasons for the deviations in performance

Performance Measure. Performance of the pilots was assessed by comparing a 'root-mean-square' error in the bank-angle, and altitude (normalized by the radius of turn) calculated every three seconds of flight and averaged over the duration of the flight. In general the error in velocity should also have been included but it was observed that once the pilot initiated a turn, there was no attempt to manipulate the throttle, as a consequence of which the changes in altitude and speed were correlated (Figure 1).

More details of the selection, training, and evaluation process are given in Ali et al. (2003).

Results and Discussion

A three-way , split plot ANOVA was conducted with one within-subjects factor, evaluation flight #1 vs. evaluation flight #2, and two between-subjects factors, training time and feedback condition. There was no significant difference in performance scores between the two evaluation flights, $F(1, 15) < 1$, and interactions between evaluation trials and training time, feedback condition, and evaluation time by feedback condition interaction were all not significant (all F values < 1). For the between-subjects factors there was no significant interaction between training time and feedback condition, $F(1, 15) = 2.99$. However, there was a significant difference in performance scores between feedback and No-PFFB groups, $F(1, 15) = 6.418$, $p < .05$. Specifically, participants in the PFFB groups performed better than those in the No-PFFB groups in the evaluation flights. In addition, there was a significant difference in

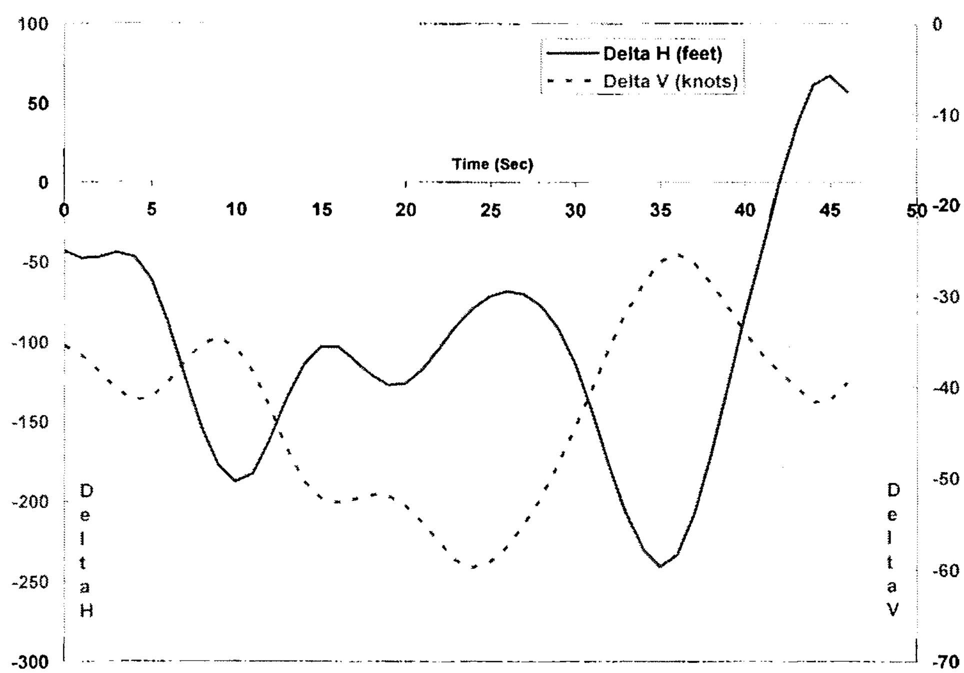

Figure 1: Varaition of Altitude & Speed

performance scores for training time, i.e., participants in the RTT/RTT groups performed better than those in the ARTT groups on evaluation trials, $F(1,15) = 7.009$, $p < .05$.

The various training interventions were observed to influence performance across training flights and the evaluation flights (Figure 2). The participants who experienced RTT without feedback may be viewed as a control group and it may be seen that their performance improved with practice in the absence of extrinsic feedback; however, this improvement did not appear substantially until the eighth training session. In general, participants in the feedback groups improved performance early in training, and performed better than their counterparts across training sessions. However, as can be observed from Figure 2, the error in the evaluation flights for both the RTT groups was higher than the errors during training. This is attributed to the increased complexity of the task. The group which received ARTT without feedback (1.5/2.0 No-PFFB) did not exhibit improvement with time, and worsened in performance after switch over from 1.5 to 2.0 ARTT. This perhaps was due to the increased difficulty of the task due to the switchover to a higher value of ARTT conditions.

It was also observed that the 1.5/2.0 No-PFFB group performed the worst in the evaluation flights (Figure 2), exhibiting a poorer transfer of training from training conditions to evaluation conditions. Perhaps responses acquired during the ARTT carried over into the evaluation flights in RT.

EXPERIMENT 2

In the previous study participants who experienced ARTT values of 1.5 followed by 2.0 were compared to those who experienced real-time training. The purpose of this second study was to expand the previous study by comparing the previous

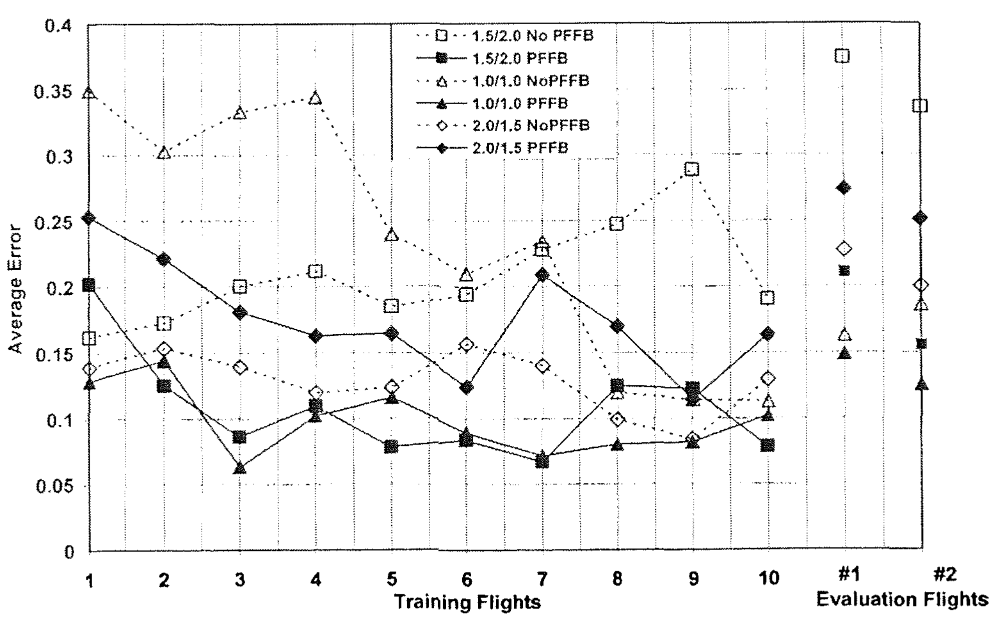

Figure 2: Average Errors During Training & Evaluation Flights

four groups with two additional groups of participants who received ARTT at a value of 2.0 followed by 1.5. One group received feedback and the other did not.

Participants, Experimental Design and Procedure

Two groups of five novice pilots in each participated, and their data was combined with the previous four groups, making a total of 30 participants. Thus, with the addition of the two new groups, the design was a 3 X 2 X 2 mixed factorial design, with the ARTT condition (1.5/2.0, 2.0/1.5, 1.0/1.0) and feedback (PFFB/No-PFFB) as the between subjects factors and evaluation trial as the within subjects factor. The procedure was exactly the same as in the previous study.

Results and Discussion

Participants in the 2.0/1.5 ARTT sequence exhibited some interesting characteristics. The No-PFFB 2.0/1.5 ARTT group demonstrated a continuous improvement in performance over the training flights even after the switch from 2.0 to 1.5 ARTT. However, in comparison to the switch over error during training, there was a relatively larger error exhibited during the evaluation flights which occurred in RT. This again suggests that performance in the evaluation flights was being affected by both transfer of training effects as well as a change in task complexity. It is however noted that this impact is lesser as compared to the larger change of slowing down from 2.0 ART to RT as was in the case of the 1.5/2.0 group. The performance by the 2.0/1.5 ARTT with PFFB group showed the impact of PFFB through continued improvement as training progressed which is consistent with the other PFFB groups. However, its performance during the evaluation flights was observed to be not as good as the 2.0/1.5 No-PFFB group. This is attributed to the fact that the PFFB group was not as strong (the PFFB group had an initial average error of 0.25 as compared to 0.14 for the No-PFFB group). Thus, performance on the evaluation task (which was more challenging) was more depressed.

A split-plot ANOVA was carried out with evaluation trial as the within subjects factor and ARTT condition and feedback condition as the between subjects factors. There was no significant difference between evaluation trials and the interactions between evaluation trials and the other factors were not significant. The between subjects effects were also not significant. An analysis of the means of the evaluation trials, however, shows that the 1.5/2.0 No-PFFB group performed considerably worse than all other groups.

SUMMARY AND CONCLUSIONS

In summary, the analysis suggests that for a coordinated level turn:

1. 1.5/2.0 ARTT with No-PFFB is not an effective training strategy;
2. ARTT does not seem to offer any advantage over RTT for this maneuver;
3. ARTT should be used in conjunction with appropriate PFFB;
4. PFFB in RTT is the most efficient combination.

Future work should address a) whether the depressed performance of ARTT groups continues with further evaluation trials, b) if pilots trained with one value of ARTT throughout training perform better than those with RT, and c) whether ARTT is beneficial for other flying maneuvers.

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Comparison of Different Methods of Grading a Level Turn Task on a Flight Simulator by Bruce E. Heath, Tomyka Crier, Proceedings, Huntsville Simulation Conference, Huntsville, Alabama, October 2003, 7 pages.

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COMPARISON OF DIFFERENT METHODS OF GRADING A LEVEL TURN TASK ON A FLIGHT SIMULATOR

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ABSTRACT

With the advancements in the computing power of personal computers, pc-based flight simulators and trainers have opened new avenues in the training of airplane pilots. It may be desirable to have the flight simulator make a quantitative evaluation of the progress of a pilot's training thereby reducing the physical requirement of the flight instructor who must, in turn, watch every flight.

In an experiment, University students conducted six different flights, each consisting of two level turns. The flights were three minutes in duration. By evaluating videotapes, two certified flight instructors provided separate letter grades for each turn. These level turns were also evaluated using two other computer based grading methods. One method determined automated grades based on prescribed tolerances in bank angle, airspeed and altitude. The other method used was deviations in altitude and bank angle for performance index and performance grades.

INTRODUCTION

With the invention of faster personal computers it has become possible to use flight simulation on cost effective computers. Because the advantages of training on flight simulators includes savings in time and money, computer based training provides researchers with increased opportunity to investigate such factors that may affect flying and pilot training. Investigation of scoring practices is needed to evaluate different strategies in training. Computerized scoring is desirable as it could, if properly implemented, give immediate feedback about the pilot's performance.

Straight and level flight, climb, descent and level turn are regarded as the four basic flight maneuvers in a Federal Aviation Administration (1995) publication on private pilot practical test standards. For evaluation of a trainee's flight, it prescribes certain tolerances in the basic flight parameters. Following FAA's guidelines, an expert flight instructor directly evaluates the performance of a trainee's flight.

For modern training simulators, Vreuls and Obermayer (1985) emphasize the need of automated performance measures as a substitute for the evaluation of performance by direct observations. They present several benefits of the automated performance measures. The authors have suggested several methods for validating automated measures. One method includes the need of experts to judge performance quality, and then determine which measures correlate with the experts' judgments.

Williams (2000) used grade points for flying performances on the simulator. To validate the automated scoring, several flights flown on a simulator were simultaneously evaluated by the computer and by a certified flight instructor. He found acceptable correlation for straight and level flights but low correlation for climb, descent and turning maneuvers. Ali, Khan, Rossi, Crane, Guckenburger and Bageon (2001) proposed that a performance measure which represents an increase or decrease of performance at different stages of training is a valid measure to assess progress in training even if the measure is not adopted for certifying a trained pilot.

We used an RMS value of deviation in bank angle and altitude as a performance index. We compared the automated grades, and performance index with the instructors' letter grades. Following Williams (2000) method, we used grade points for our automated grade. Furthermore, two instructors independently evaluated the flights and gave letter grades.

In an attempt to create a numerical grade using the RMS value, performance index and automated grades were graphed and a regression line was drawn. University students performed six different flights. Each flight consisted of two level turns. For a level turn task, two kinds of performance measures were devised, automated grades and performance index. In the automated grades, A, B, C and D grades were based on prescribed tolerances in bank angle, and altitude. A performance index was based on deviations in bank angle and altitude. Video recordings were made of the HUD and relevant instrument panel gauges. Two certified flight instructors independently evaluated the videos of the flights. This study attempts to correlate the performance index, the automated grades and instructors' evaluations.

EQUIPMENT

The experiment was performed in the Flight Vehicle Design Lab at Tuskegee University. Flights were conducted on a training simulator that had LiteFlite version 3.3 installed. The PCs for the simulator were two Heavy Metal computers made by Quantum 3D. Each computer has 2 processors running at 400Mhz, 400MB RAM, and has three extra video cards for the Out of the Window (OTW) view. Three display monitors showed the OTW view. The center monitor displayed not only a forward view, but also a heads up display (HUD). Figure 1 shows the entire setup including the four monitors and a moving map display monitor on the right of the picture. The moving map display was not used in this experiment. Figure 2 shows a close up of the inside the cockpit view screen. The joystick was a Saitek X36F and throttle was Saitek X35T controller. Rudder pedals used were from CH products. Williams

(2000) gave more details on the fidelity of the equipment used.

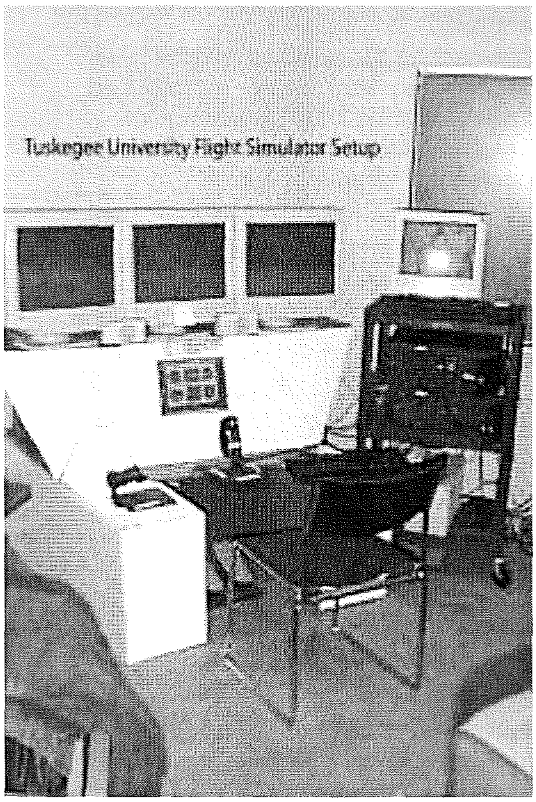

Figure 1: Simulator setup including OTW view.

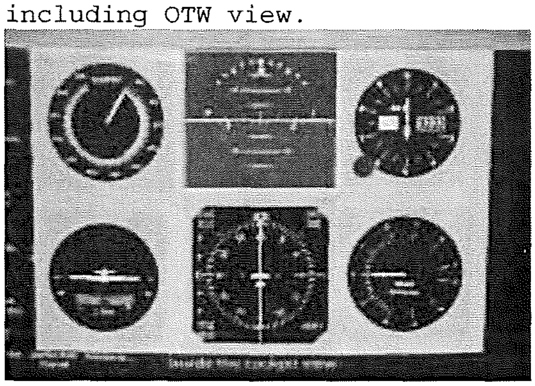

Figure 2. Instrument Panel (Inside the cockpit view)

METHOD

Level turn task

This task was to be a level turn from 0 degrees to 180 degrees heading. The pilot, in this scenario, was to bank the airplane 30 degrees to the right or left while flying at a speed of 90 knots. After the plane reached 180 degrees, the pilot was to bank in the same or opposite direction at a new bank angle of 45 degrees. The pilot was to hold the bank angle and speed until the airplane reached 360 degrees. After that time the pilot was to fly straight and level until the simulator stopped.

Each turn task was recorded by videotaping the HUD on the center monitor and the turn and bank instruments on the inside the cockpit monitor.

Instructors' grades

Two Certified Flight Instructors were then asked to view the videotaped sessions and write down a score (A,B,C,D,E or F) for, in turn, altitude, bank angle and airspeed over the time slots: 21 - 72 seconds, and approximately 120 - 171 seconds. These time intervals represented each of the two turns in a flight. An average of the three-parameter grades was calculated to represent the instructors' grade for a single turn. This was used as a data point. For the six flights there were 12 data points representing all turns.

Automated grades

The automated grade criteria were based on the requirements of 90 knots ±3knots in airspeed, 30 or 45 degrees ± 3degrees in bank angle and 10000 ft ± 50 feet in altitude. Flight parameters within these limits were graded as 'A'. Deviations of ± 6 knots in airspeed, ± 6 degrees in bank angle and ± 100 feet in altitude were graded as 'B'. Deviations of ±9 knots in airspeed, ±9 knots in bank angle and ±150 knots in altitude were graded as 'C'. Deviations of ±12 knots in airspeed, ±12 degrees in bank angle and ±200 feet in altitude were graded as 'D'. And, deviations of < - 12 knots and > +12knots in airspeed, -12 degrees and >+12 degrees in bank angle and < -200 feet and > +200 feet in altitude were graded as 'F'. The flight parameters were grading every three seconds. An average grade was then calculated for each of the turns.

Performance Index and Performance Grades

The performance index of the level turn flights were obtained by taking the root of the squared sum of the average deviations of the heading, altitude, and airspeed.

It should be noted that as a performance index (P.I.) increases, the performance of a pilot actually decreases. For that reason, in order to obtain some reasonable 4 point scale score we used an equation of the form A/(B+P.I.) and the values tried for A and B were such that B= 0.25*A.

RESULTS AND DISCUSSION

Our set of evaluation consisted of 12 data points representing 6 flights with 2 turns in each flight. Five such sets of evaluation were: Automated grades, instructor 1 and instructor 2 grades, performance index and performance grade. A comparison of the different evaluations that were made is as follows.

Automated Grade versus Instructors' grades

The comparison of the overall automated grade vs. the instructors' grades for each of the turns is shown as scatter charts in Figs. 3 and 4. As can be seen from the scatter plots, most of the scores are in the 2.0 or below range. This was expected, as the subjects were novice pilots. However, the two instructors' scores were somewhat inconsistent with one another. In general, instructor#1 graded higher in comparison with the automated grade, while the grading of instructor#2 was lower than the automated grade.

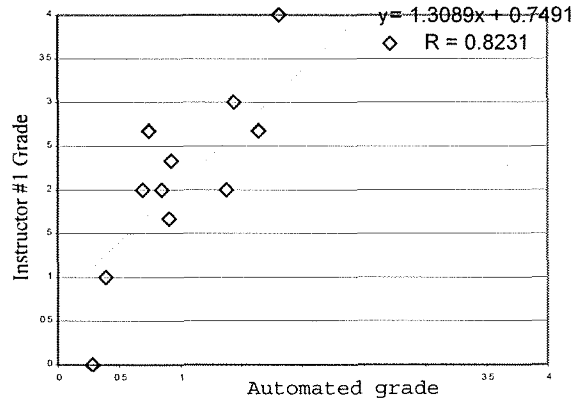

Figure 3. Scatter plot of Instructor One Grade vs. Automated grade (Turn Task)

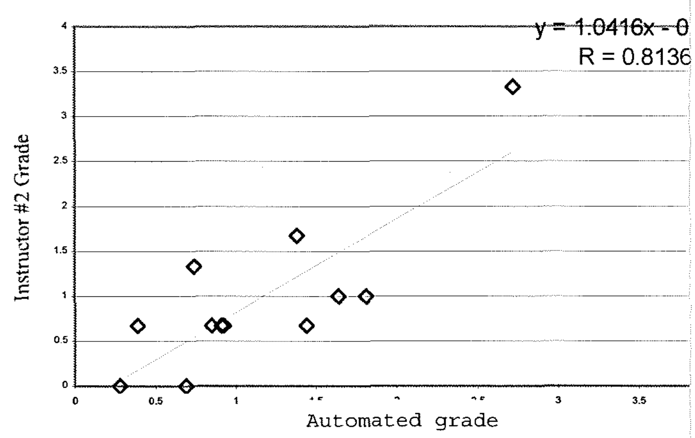

Figure 4. Scatter plot of Instructor Two Grade vs. Computer Automated Grade (Turn Tasks)

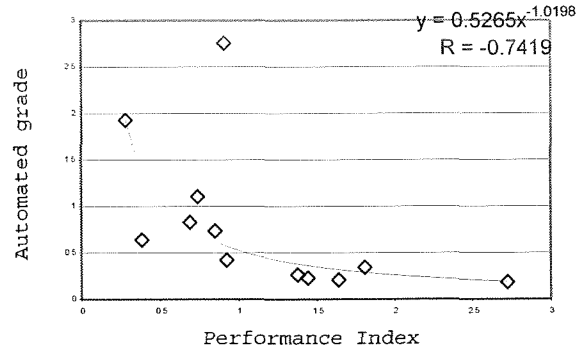

Figure 5. Scatter plot of Automated Grade (AG) vs. Performance Index (PI) (Turn Task)

There exists a negative correlation of the automated score with the performance index. This should be expected as the performance index has an inverse relationship with both the instructor grades and the automated score. However, the best-fit regression more resembles a curve of the form: $AG = 0.5265PI^{\wedge}(-1.0198)$ (Figure 5).

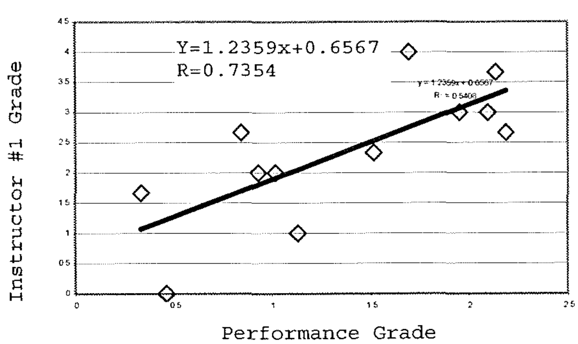

Figure 6. Scatter plot of Instructor #1 Grade vs. Performance Grade (Turn Task)

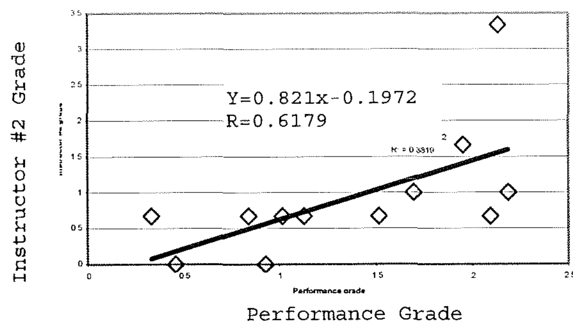

Figure 7. Scatter plot of Instructor #2 Grade vs. Performance Grade (Turn Task)

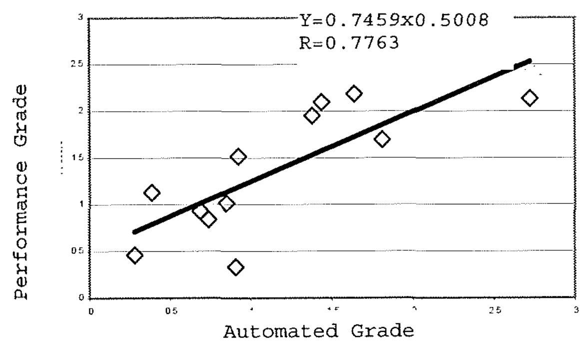

Figure 8. Scatter plot of Performance Grade vs. Automated Grade (Turn Task)

In order to obtain some reasonable 4 point scale score we used an equation of the form A/(B+P.I.) and the values tried for A and B were such that B= 0.25*A.

The formula: 1.0/(0.25 + P.I.) seems to be better suited for the purpose of determining performance grade from performance index. This formula was used after several attempts with other similar formulae. Most of the P.I. values seemed to match with 0.25.

The performance grades appear to correlate well with the automated grades and the automated grades correlate well with the averaged instructor grades. The instructor #1's grades correlate better with the performance grade than does instructor #2 's grades. In general instructor #2's grades don't seem to correlate well with any of our computer grading measures.

This analysis suggests that letter-grades may not be appropriate for tracking training progress as for novices the improvements are incremental. Thus they may exhibit improvements in controlling individual flight parameters but still the overall 'letter' grade may not show an improvement in overall skill. Although the correlations are moderate to high between instructors, the instructors both seem to have a systematic difference between their score and the automated grade. Further, the differences in correlations on different parameters between instructors and the computer grade suggests that perhaps, the instructors are making evaluations based on different factors from each other. Thus the factors influencing the assessments of the instructors need to be understood. Future studies could systematically address these issues.

A failed attempt was made for a power regression between the two instructors grades and the performance index.

An increase in performance grades for a level turn corresponds with an increase in performance for a novice pilot. Therefore, they can be considered for further study for the evaluation of progress in training of level turns in simulators.

CONCLUSION

Four kinds of grading have been obtained and compared for evaluating level turn flights performed by novice pilots in a simulator. They are: instructor's grades, automated grades, performance index and performance grades. Instructor's grades are the grades provided by a certified flight instructor. Automated grades are based on prescribed tolerances in bank angle, altitude and airspeed. The performance index (P.I.) is created using the square root of the sum of the squares of dimensionless deviations in altitude and bank angle. Performance grade, which is defined as 1/(0.25 + P.I.), provides a reasonable 4-point grading scale. The comparison of performance grades with the other three performance measures, leads to the suggestion that they deserve further study for the evaluation of progress in training of level turns in simulators.

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BIOGRAPHIES

Bruce Heath is a graduate student in Mechanical Engineering at Tuskegee University and is currently researching training of novice pilots on simulators. Bruce has work experience with NVR Inc., in the Information Technology field. He has a BS from Tuskegee University in Aerospace Engineering and a BS (cum laude) in Airway Science from University of Maryland Eastern Shore.

Tomyka Crier has a BS in Aerospace Science Engineering from Tuskegee University. Her experiences include conceptual design projects for university customers such as NASA and the Boeing Company. During a co-op at NASA Kennedy Space Center, she worked as an Avionics Trainee in a Guidance, Navigation, and Control group. While currently enrolled in the Master of Mechanical Engineering program, she concentrates on aerospace simulation topics.