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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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KEYWORDS

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

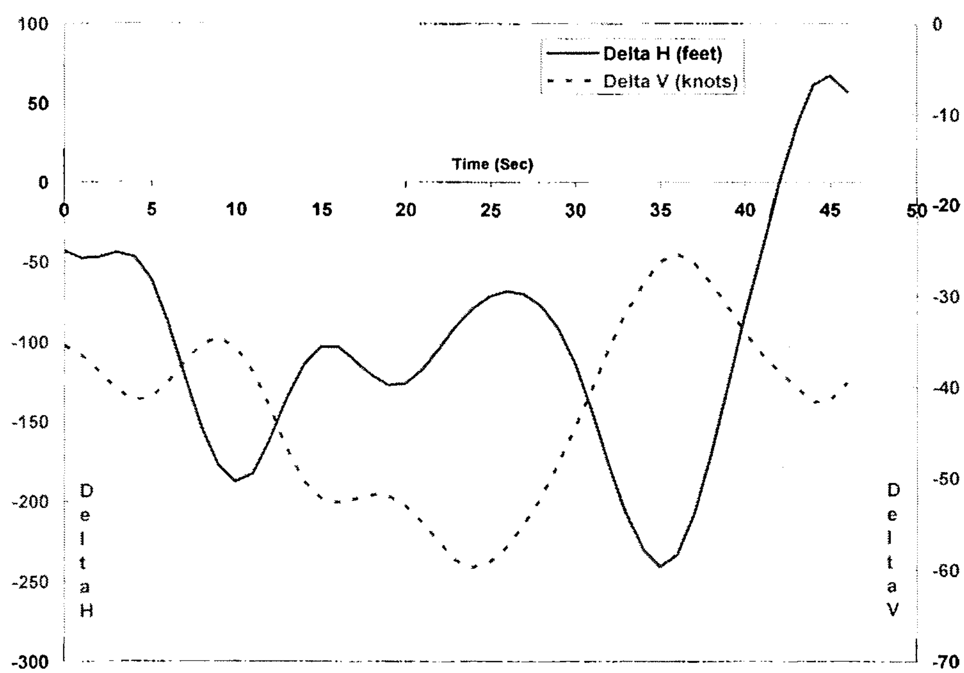

Figure 1: Varaitlon of Altitude & Speed

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

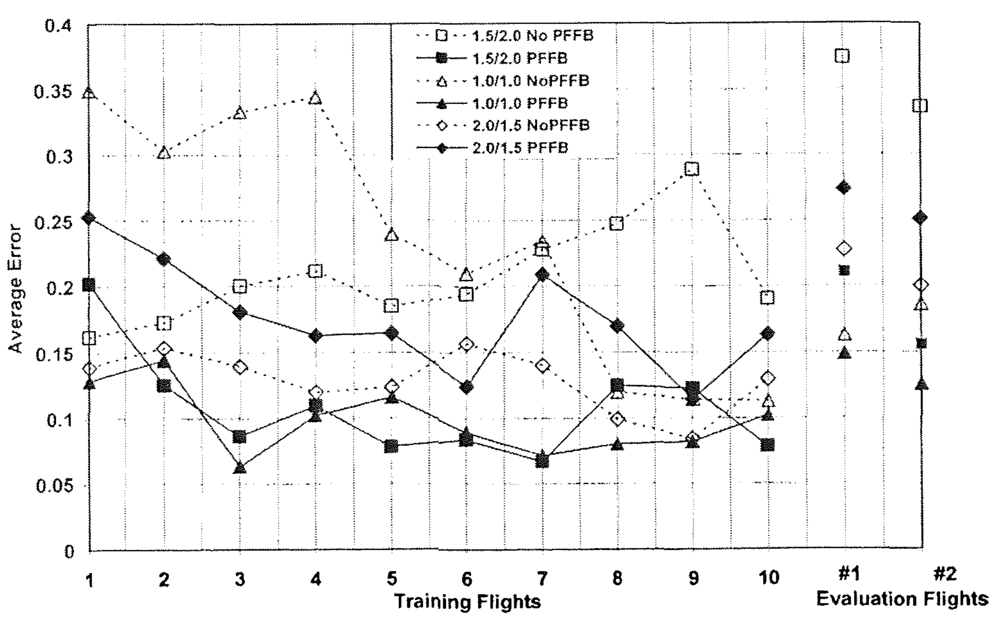

Figure 2: Average Errors During Training & Evaluation Flights

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.

ACKNOWLEDGEMENT

This study was carried out under NASA DFRC grants NAG4 203 and NAG4 226. The authors appreciate the support provided by the Air Force Research Laboratory.

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BIOGRAPHIES

M. Javed Khan is an Associate Professor of Aerospace Engineering at Tuskegee University. He has a PhD in Aerospace Engineering from Texas A&M University. His research is focused on aircraft design and development and use of low cost flight simulation for pilot training and as a learning resource for engineering students.

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