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Currently, General Aviation (GA) pilots working toward their instrument rating (IFR) in aircraft equipped with Global Positioning System (GPS) technology receive little, if any, formal flight instruction on GPS technology. Therefore, the hypothesis examined in this study was that instrument rated pilots already certificated to fly IFR / GPS have insufficient knowledge of the GPS technology to use it effectively. Our goal was to develop a single pilot crew, scenario-based training program to increase the knowledge and safety of pilots using this technology by focusing on GPS mode awareness, situational assessment, risk and time management, and situational awareness.. The study included thirty-four pilots who had completed their instrument rating in a GPS-equipped aircraft within the last 12 months. All participants were given Pre-experiment GPS screening tests to assess overall GPS knowledge and, more specifically, knowledge regarding the Garmin 430. Each participant underwent simulator familiarization sessions in a Frasca 142 flight simulator equipped with a panel mounted IFR approved GPS. After the familiarization sessions, participants were randomly assigned to one of two groups: 1) Experimental or 2) Control. All groups then flew IFR-generated flight scenarios designed to assess their aircraft system monitoring skills (situational assessment), GPS mode awareness, situational awareness, and understanding of the Garmin 430 IFR programming. Each scenario lasted approximately 60 minutes. Following the first session, the experimental group received training sessions concentrating on mode awareness, situational awareness, time management, and situational assessment using computer based training (CBT) with a Garmin 430 simulation software program. The control group received sessions that covered basic IFR flying skills. Following the training sessions both groups flew another scenario in the Frasca 142 simulator. Each subject was video-taped to assess eye fixation in three areas of interest: 1) out the window, 2) aircraft instruments, and 3), GPS display. The results of this study revealed that a GPS scenario-based training program significantly reduced omission errors and incorrect or inappropriate use of the GPS when compared to controls. In addition, a significant effect of training versus eye gaze was observed. Pilots in the experimental group spent significantly less time gazing at the GPS following the training sessions and more time gazing at the instruments compared to controls.

Introduction

Over the last decade, there has been profound development in regard to automated flight deck technology, undoubtedly leading to increased safety in commercial aviation (Parasuraman and Riley, 1997). Until very recently, however, issues with automated flight decks were only relevant to the commercial flying industry involving multiple flight crews (Endsley and Kabor, 1999; Funk and Lyall, 1997; Sarter and Woods, 1995). This is no longer the case with the advent of automated cockpits that have recently proliferated in the General Aviation (GA) community.

One critical component of any automated cockpit is its flight navigation system (Wiener, 1988). One of the most popular in the GA community is the Global Positioning System (GPS). In fact, it is estimated that as many as two thirds of GA pilots use some form of GPS technology to navigate (St. George, 2000). Currently, in the GA community, however, there is no accepted training program for aircraft equipped with GPS technology. Indeed, this has led to a kind of "self-instruction" where GA pilots either teach themselves to use their GPS or obtain informal instruction from other GPS users. While in some cases this has resulted in only minor problems, in other cases, the results have been more tragic (O'Hare and St. George, 1994). Consequently, one key issue with the establishment of GPS technology in the GA aircraft is how to train pilots/students to take advantage of the increased safety opportunities available with the new technology. This is in striking contrast to the commercial airline industry where there is a plethora of scenario-based training programs involving specific events known to be problematic for multiple crew in an automated flight deck (Funk, Lyall, and Niemczyk, 1997).

Based on the above, it should come as no surprise that the general consensus emerging among the GA community, as well as the FAA, is that a thorough training program is needed to educate pilots on the

use of GPS technology. Indeed, in a recent study on GPS usability, Adam at el. 2004, recommend that a specific GPS training program be compared to a control group not receiving any formal GPS training. If successful, the training program could be submitted to the FAA for incorporation in flight schools (Adam et al. 2004). Currently, however, the authors are unaware of any empirical data that exist to support the notion that a specific GPS training program will increase pilot proficiency in the use of GPS technology. Moreover, what constitutes a viable training program is also unknown.

Methods

This study was comprised of pilots who had completed their instrument rating in a GPS-equipped aircraft within the last 12 months at MTSU. All participants were given screening tests to evaluate their overall GPS knowledge as well as their specific knowledge of the Garmin 430. In addition, all participants were given a flight questionnaire regarding demographics, flight experience, comfort flying alone in the IFR environment, flying alone IMC, and personal IFR minimums. Before the beginning of the experiment, each participant was given a familiarization session in a Frasca 142 flight simulator equipped with a panel mounted IFR approved GPS located in the MTSU Department of Aerospace. During these sessions pilots were instructed to fly an instrument approach into Nashville International airport without the GPS. After the familiarization sessions, participants were randomly assigned one of two groups: 1) Experimental or 2) Control. All groups then flew two IFR-generated flight scenarios that were designed to assess their aircraft system monitoring skills (situational assessment), GPS mode awareness, situational awareness, and understanding of the Garmin 430 IFR programming. Each scenario lasted approximately 60 minutes. Following the first session, the experimental group received training sessions concentrating on mode awareness, situational awareness, time management, and situational assessment using a CBT with a Garmin 430 simulation software program currently available in the Aerospace Department. In contrast, the control group training sessions covered basic IFR flying skills. Following the training sessions both groups flew another scenario in the Frasca 142 simulator. During the scenario-based flying sessions, incorrect or correct GPS mode usage was recorded. A score of "0" was assigned to activities that required GPS programming following an ATC instruction, but were omitted by the pilot. A score of "1" was assigned to activities that required GPS programming following an ATC instruction, but where the GPS was used inappropriately. A score of "2" was assigned to activities where appropriate GPS use occurred, but the pilot failed to comply with an ATC instruction. A score of "3" was assigned to activities where accurate use of the GPS along will full ATC compliance was observed. For example, in each scenario, pilots were instructed to descend and cross a particular "fix" at a specific altitude. A score of "3" was recorded if the pilot used the "VNAV/VSR" in the GPS (an appropriate GPS mode). If the pilot only began to descend, a score of "0" was recorded. Participants were video taped in order to monitor the overall scanning patterns in the cockpit. Using a template developed by Diez et al. (2001) data analysis of eye fixation was based on dwell time in three areas of interest (AOI): 1) out the window, 2) aircraft instruments, and 3), GPS display. Following the completion of the study, all parametric data were analyzed using an analysis of variance (ANOVA) mixed design. Any significant main effects were assessed by Post Hoc analysis using the Scheffe's test. Non-parametric data was analyzed using the Kruskal-Wallis test.

Results

As can be seen in Table 1, a multivariate comparison of group means of total instrument time, total time, and total actual time, revealed non-significant differences between the experimental group compared to controls ($p > 0.05$).

GROUP	AGE	Total Time	Total Instrument	Total Actual
CTL (n=17)	20	181	43	4.2
EXPL (n=19)	2	220	42	2.3

Table 1. *Mean age, total flight time accumulated, total instrument time, and total actual flight time in the experimental group compared to controls.*

Table 2 illustrates GPS competency scores in the two groups following a specific GPS CBT program (experimental group), compared to controls (traditional IFR training). A 2X2 factorial design revealed a significant group by treatment interaction $F = 29.6$ (1,35), $p < 0.01$. Following the CBT scenario-based training, the experimental group made significantly fewer errors compared to controls (see Table 2). In addition, as can be seen from Table 3, a 2X2X3 ANOVA revealed a significant 3 way Group by Session by AOI interaction on eye gaze in the experimental group compared to the controls; $F= 32.89$ (2,198) $p < 0.01$. Participants who had the GPS

scenario-based training seminar (experimental group) spent significantly less time gazing at the GPS unit and more time on the Flight/Engine instruments compared to controls.

GROUP	BEFORE TREATMENT	AFTER TREATMENT
EXPERIMENTAL	7.8 +. 76	29.6 + .9 ***
CONTROLS	4.1 + .65	11.4 + 1.3

Table 2. *Means ± standard error of the mean of the mean. GPS errors in the experimental group that received GPS scenario-based training compared to controls that received IFR training on two simulator flight scenarios. *** = $p < 0.01$ A higher score corresponds to more errors .*

GROUP	WINDOW	INSTR	GPS
EXPERIMENTAL	4.23 + .1	22.3 + .3	43 + .2 ***
CONTROL	6.68 + .1	48 + .1***	5 + 1.2

Table 3. *Mean eye gaze ± standard deviation of the mean in the experimental group that received GPS scenario-based training compared to controls that received IFR training. *** = $p < 0.01$*

Table 4 illustrates the results of several questions that were asked regarding IFR experience, as well as personal IFR minimums. As can be seen from Table 1, the mean total actual time is surprisingly low. Another surprising result can be seen in Table 4. When asked about personal IFR minimums, an overwhelming majority (76%), reported that "they had never really thought about it". A Spearman's correlation coefficient between total IFR hours and personal minimums revealed no significant relationship.

TOTAL IFR TIME	MEAN VISIBILITY	MEAN CEILING	PERCENT NEVER THOUGHT ABOUT IT
>151 HRS	1.86 + .2	1200 + 299	68 %
101-150	1.6 + .5	1329 + 273	71 %
35-100 HRS	1.3 +	1000 + 300	75 %

Table 4. *Reported Mean visibility and Cloud minimum reported based on IFR flight experience. In addition to minimums, the percentage of participants that had "never thought about personal minimums" is reported.*

Discussion

The results of this study revealed that prior to a GPS training program, pilots who were perfectly legal to fly an IFR GPS panel mounted aircraft knew very little about the procedures involved. This was reflected in a significant amount of inappropriate programming, omission errors where the GPS was not used following an ATC clearance, poor time management, and lack of mode and situational awareness. This lack of GPS awareness resulted in a significant amount of time spent pre-occupied with the GPS which resulted in a lack of situational awareness (many were completely disoriented and, as a result, often dangerously off course), as well as situational assessment (most spent a significant amount of time focusing on the GPS and considerably less time monitoring engine/flight instrument panel). For example, in many cases the over-focusing on the GPS display resulted in altitude busts or overshooting a heading following an ATC assigned vector.

The results of this study reveal that a maneuver based approach characteristic of traditional IFR training is insufficient given the dramatic changes in technology that now typify GA aircraft. Moreover, the traditional IFR training curriculum with a focus on rote learning, is in our opinion, also antiquated and must be changed. For example, now where in the current Part 141 syllabus is GPS mode awareness, or proper time management skills emphasized. Typically the focus is on learning how to fly a GPS approach using multiple approaches.

In this study, the experimental group which received CBT seminars focusing on scenario-based training had significantly fewer errors compared to controls that utilized the traditional focus on IFR maneuvers. In our opinion, all curricula which utilize aircraft with GPS technology should incorporate at least four major components. First, ground school should focus on GPS technology and specific GPS knowledge regarding the equipment available in the aircraft, followed by specific tests to assess the students' knowledge. Second, the flight training should incorporate realistic GPS scenario-based training utilizing CBT. Indeed, CBT has the advantage of enabling the instructor and student to focus on such critical tasks as time management, proper mode awareness, and situational awareness. Third, a minimum of five hours should be required for simulator training using realistic scenarios immediately following CBT. Here, the focus would be on incorporating system management, mode awareness, and situational assessment while actually

flying the aircraft. Lastly, a specific checklist should be developed that emphasizes the technology that is on board the aircraft. In our study, we developed a specific checklist that emphasized GPS mode awareness. For example, the last item on the before takeoff checklist was: "GPS / OBS……AS REQUIRED". This was designed to prompt the pilot to consider what was the appropriate GPS mode for takeoff.

In conclusion, the results of this study reveal that a GPS scenario CBT based training program significantly reduces omission errors and incorrect or inappropriate use of the GPS when compared to controls. The added benefit of this training program is pilots then spent significantly less time gazing at the GPS panel and more and more time gazing at the instruments.

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