Computer Based Interactive Training: Tools for Maintaining Proficiency

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Automation complacency and loss of flight skills are at the forefront of aviation safety concerns. While automation was designed to reduce workload and improve safety, modern day aircraft accidents and incidents indicate that technology has yet to eliminate pilot error. The question must be asked if pilots are being provided the right tools to maintain competency in these modern aircraft, and whether flight skill loss is the actual problem. Pilots are legal to operate their aircraft with as little as an annual two-day recurrent simulator session supplemented by an at-home, text on computer, training program. Throughout the remainder of the year, if the pilot has not received three takeoffs and landings within 90 days, this can be accomplished in a simulator to maintain currency. However, this traditional process of maintaining currency may not meet the needs of pilots in modern day complex aircraft. This paper will take a critical look into the concept of an at-home interactive computer-based training program with a game mode philosophy, to supplement recency takeoffs and landings, in order to improve pilot competency. The science of learning combined with the design of computer based training programs, with interaction game-type event scenarios, and how understanding transfers to automated aircraft will be addressed. Beyond text on a computer screen, research presented will identify why computer-based training programs must be interactive, provide a game mode, and allow for unlimited access to achieve the best results.

INTRODUCTION

Federal Aviation Regulation (FAR) 121.439 requires pilots to have three takeoffs and landings in 90 days to maintain proficiency (GPO, 2015). Under these current regulations, takeoffs and landings may be in a simulator with automation engaged. There are no requirements for flight deck setup, in-flight operational procedures (normal, abnormal, or emergency), navigation, or descent profile planning. In addition, there is no requirement for operational competency beyond takeoff and landing to be demonstrated.

The nature of international flying also creates unique challenges for maintaining competency. Long-haul pilots in automated aircraft have limited opportunities to hand fly due to operational constraints, and these challenges will be further exacerbated with NextGen requirements (Darr, Ricks, & Lemos, 2010). Pilots are monitoring more than flying, and those on reserve may not see the inside of a flight deck for many months, or perhaps years. While perception of flight skill loss has become a heightened concern due to this reliance on automation (Franks, Hay, & Mavin, 2014; Geiselman, Johnson, & Buck, 2013; Haslbeck et al., 2012; Moll, 2012), a closer look into the actual problem must be addressed.

With an assumption pilots are losing their flight skills, the Federal Aviation Administration (FAA) released a safety alert, encouraging pilots to disconnect automation and manually fly their aircraft (FAA, 2013a). However, an FAA sponsored working group (2013b), identified lack of understanding and training to be contributing factors to pilot error. Thus the question must be asked if lack of hand flying is the attributive factor to airline crashes, or is there more? Better yet, the question remains whether or not pilots should be practicing hand-flying skills with passengers on board with fatigue induced operational challenges associated with long-haul flights resulting in reduced situation awareness (SA).

When pilots flew less automated aircraft, stick and rudder retention within 90 days may have been effective with simulator takeoffs and landings (Casner, Geven, Recker, & Schooler, 2014). However, today pilots manage their automated aircraft with cognition, and competency may require more than a three-month practice session consisting of five-minutes of stick manipulation with 55-minutes of button pushing in a simulator.

Even on the flightline, the typical pilot spends less than two-minutes per flight hand flying (Lowy, 2011).

Complexity of automated aircraft, cognitive challenges, and the operational structure of long-haul flights have made competency a challenge. Four pilots to divide one takeoff and one landing event, per flight, and the reserve system, have created the automation challenge due to lack of operational exposure. The inability to practice aircraft management, due to minimal use, may be the root of lack of understanding, lack of confidence, and substandard performance—not the lack of hand flying skills.

The question must be asked if the process for maintaining currency with the recency requirement is meeting the needs of pilots regarding competency in automated aircraft. Addressing how airline pilots maintain proficiency versus competency in these automated aircraft may be the solution to lack of understanding. Providing the right tools for pilots to increase understanding though the science of learning, and to improve automaticity and retention that will transfer to the aircraft, could be a viable solution to increase safety in automated aircraft.

Myth of Flight Hours in Automated Aircraft

Colgan Air 3407 (NTSB, 2010), Air France 447 (BEA, 2012), Asiana 214 (NTSB, 2014a), and UPS 1354 (NTSB, 2014b) were attributed to pilot error and skill degradation. While 70-90% of aviation accidents are attributed to human error (Airbus, 2007); none of the pilots in these accidents were new to flying. Combined experience in control of the aircraft in these four crashes was over 50,000 flight hours (BEA, 2012; NTSB, 2010; NTSB, 2014a; NTSB, 2014b).

Despite thousands of flight hours, proficient pilots managed to create errors that manifested in hull losses. In a critical analysis of these crashes, one commonality, beyond pilot error, was that prior to each crash an unexpected event occurred—instrument loss, computer programming issue, stall, or degradation to a level of automation (BEA, 2012; NTSB, 2010; NTSB, 2014a; NTSB, 2014b). Operational experience in the form of flight hours in automated aircraft does not increase aircraft knowledge nor does it improve performance when the unexpected occurs (Casner, Geven, & Williams, 2013). While each of the pilots in the crashes listed were legally current and technically proficient, the question must be asked if currency is the answer to safety, or should the industry focus on pilot competency. An FAA sponsored working group (2013b) conducted an extensive study on performance issues with automation. Analysis of 46 accidents and major incidents, 734 U.S. Aviation Safety Reporting System (ASRS) reports, 9155 global Line Operations Safety Audits (LOSA) and numerous interviews, resulted in a report that identified a lack of aircraft understanding, and training to be among contributing factors. Utilizing the right equipment for pilot training in automated aircraft could be the solution to competency and improving overall safety (Petitt, 2015).

Recency Training

No time limit exists that a pilot may be out of the aircraft and remain legally current. While the FAA requires three takeoffs and landings in 90 days, which may be conducted in the simulator with automation engaged, the question must be asked if this is adequate training to maintain competency. A paradigm shift must take place from legality to technically competent pilots.

Providing pilots the tools for an ongoing learning process of systems management and supplementing the recency takeoff and landing requirement, may be the answer to improving understanding and competency. Pilots who are most likely to fall victim to cognitive loss are pilots who are required to perform three takeoffs and landings in a simulator. If these pilots were offered an at-home opportunity to effectively maintain and increase skills, this may improve understanding resulting in safer operation.

Automated aircraft have higher cognitive demands than traditional aircraft, and without continued interaction, exposure, and practice, pilots will not remember the intricacies of how the plane operates, or which buttons to push and why, when systems malfunction. Pilots who understand their equipment have greater overall situation awareness, which will increase the level of safety (Naidoo & Vermeulen, 2014). The solution to automation complacency is through improved understanding with practice. The answer to improved understanding is through available tools that pilots may access to maintain competency throughout the year.

Tools should be made available to perform all phases of flight, from flight deck set up to engine shutdown, while incorporating systems knowledge. Pilots should be allowed to perform navigation functions, as well as emergency procedures by reading the EICAS on their computer screens and actioning the steps by touching the item with a click of a mouse, or a touch of a finger. Not only would this training be beneficial for recency training to assure pilots retain a knowledge base of their aircraft, but could be cross utilized for initial and recurrent training. An interactive at-home program could be made available to all pilots to improve understanding and performance industry wide.

COMPUTER BASED INTERACTIVE TRAINING

Surprise Events

Surprise events, identified as a startle factor, continue to elude training professionals as how to train pilots for the unexpected (Jackman, 2012). Casner et al. (2013) tested pilots' performance with anticipated maneuvers versus surprise abnormal events. Results identified that pilots have more difficulty with unexpected events than anticipated events. Yet, current training practices utilize an *anticipated event* approach in their annual scenario-based training, and may not be preparing pilots for unanticipated events. Startle events could be built into the operating system of an at-home interactive computer-based training program. During a normal flight on the desktop computer, the pilot could program levels of difficulty in game mode, with surprise startle events.

Lack of understanding and inappropriate reactions to startle events has contributed to numerous modern day airline accidents (BEA, 2012; NTSB, 2010; NTSB, 2014a; NTSB, 2014b). Air Transat Flight 236, an Airbus A330, became a glider after an internal engine fuel leak (Degani, Barshi, & Shafto, 2013); however, the fuel leak did not turn the aircraft into a glider, but pilot reaction due to a lack of system understanding prompted the crew to dump remaining fuel out a hole in the engine. Had this crew possessed an interactive computer based training program to practice these events, this flight may have ended differently. Had the pilots of Air France 447 (BEA, 2012) the opportunity to experience a loss of flight instruments in a simulated environment, or Air Asia 214 (NTSB, 2014a) experience an autothrust disconnect on approach during computer play, results may have ended differently for both these aircraft. Surprise events such as a fuel leak and loss of flight instruments could have been identified and practiced on an interactive at home computer.

The reality is that pilots worldwide may be deficient in knowledge of the aircraft they fly (Dahlstrom, Dekker, van Winsen, & Nycy, 2008), and when the unusual occurs the startle event instigates an inappropriate reaction. The solution may be as simple as providing pilots tools for experience where normal flight operations cannot simulate.

The Science of Learning

Pilot recency training is conducted to fill a legality square (GPO, 2015). However, competency requires [1] practice through repetition, [2] receipt of feedback as to the success and/or failure of performance, and [3] confidence that performance will result in a safe outcome (English & Visser, 2014; Hattie & Timperley, 2007; Johnson, & Fowler, 2011). A shift from legality and training, to competency and learning, could take place with an ongoing at-home computer based interactive training (CBIT) program.

The CBIT program design should include building blocks to success. Level one—normal operations; level two—automation failures such as authothrust disconnect; level three—major system failures such as an engine failure; the highest level with complete loss of all flight instruments. Building blocks of understanding stack upon the next, and reduce overload from an array of startle events. AF447 (BEA, 2012) pilots were clearly overloaded with incorrect instrument data, aural warnings, lack of understanding, and turbulence. (Palmer, 2013). Reducing causal factors of overload by structuring information in a manner that pilots will be able to formulate thoughts to assimilate previous knowledge will improve learning and performance (Kalyuga, 2009; Paas, Renkl, & Sweller, 2004).

Providing an at home CBIT program will enable pilots to have unlimited opportunities to practice. *Overlearning* enhances speed and accuracy, and leads to automaticity (Wickens, Gordon-Becker, Liu, & Lee, 2004), essential for normal operations, leaving working memory available for the unexpected; improving situation awareness (SA) (Endsley, 2010).

Cognitive approach to learning. Automated aircraft are managed with cognition, versus flown with skill. Therefore, a cognitive approach to pilot training should take place where learning is the path to understanding. Information processing and knowledge acquisition are key aspects of learning, where competency defines knowledge application (Franks et al., 2014).

Taking a cognitive approach to training involves understanding how the brain works, and utilizing the process for learning and memory retention. The basal ganglia, the portion of the brain that controls multiple cognitive functions associated with learning, memory, and motor control is related to reinforcement conditioning through *reward-related* loops, where dopamine transfers through neurons, connecting memory with reward (Redgrave, Vautrelle, & Reynolds, 2011). This memory reward system is closely related to *reinforcement learning theory* and results from repetition (Graybiel, 2005). Automaticity occurs through repetition, and enables pilots to perform steps required to execute a missed approach and reconfigure the aircraft within parameters without overloading working memory. Repetition is fundamental to improving performance and can be successfully achieved through CBIT.

Cognitive ability to recall procedures, remember completed steps in a procedure, visualize aircraft position, perform mental math computations, or recognize abnormal events, diminishes without consistent practice; whereas manual flight skills may remain relatively intact without practice (Casner et al., 2014). Retention and knowledge transfer from the training environment to the aircraft is the primary goal of training (Kole, Healy, Fierman, & Bourne, 2010). However, without continued practice, cognitive requirements fade in all phases of flight. CBIT would create an ongoing learning environment increasing a pilot's window of attention. "Runway excursions, in which an aircraft departs a runway during landing or takeoff, are the most common type of accident, accounting for 23% of all accidents over the past five years (2009-2013)" (IATA, 2014). Without the ability of a pilot to maintain familiarization with the aircraft they fly through standard operating procedures and performance required during taxi and takeoff operations (not addressed during recency training) attention will narrow losing big picture aspects of the environment and reduce SA (Endsley, 2010).

Working memory. Learning occurs when systems knowledge and operating procedures move from working memory into long-term memory, and become available for recall (Wickens, Gordon-Becker, Liu, & Lee, 2004). If data transfer does not occur, the result is an overloaded working memory which prohibits both learning and memory formation (Endsley, 1995; Maurino, 2000; Wickens et al., 2004). An overloaded working memory also reduces SA (Endsley, 1995) and limits pilots' decision-making ability. CBIT will move standard operating procedures to long-term memory and free up the working memory for current demand issues when unexpected startle events occur.

International flying creates additional demands with sleep deprivation and mental fatigue, which also decrease pilot performance (Gonzalez, Best, Healy, Kole, & Bourne, 2011), and create all the more reason to provide pilots flying complex aircraft the tools necessary to maintain competency. Advancements have been made in neuroscience identifying brain plasticity, cognitive fluidity, and how the brain's anatomic composition, and neural labyrinth and neural nexus adapt to the situation (Walcott & Phillips, 2013). Allowing the pilot's mind to experience a variety of situations in a continuous manner will assist in changing neural connections, for improved memory.

Six key factors have been attributed to memory formation to include [1] multisensory, [2] attention and memory relating, [3] time limits, [4] virtual reality games, [5] stress, and [6] activating both sides of the brain (Anopas & Wongsawat, 2014). All six factors will be brought to life in an at-home

CBIT program, via the power of games, learning, and memory formation.

CBIT and Games

Traditional computer based training programs leave pilots reading text on a computer screen; however, learning requires *active engagement* (Brown & Ford, 2002; Jonassen, 2002). The focus of CBIT with a game feature is to increase learning and understanding through interaction. Games will be none other than normal operating procedures with startle events that jump out to allow the pilot to identify, manage and learn from experience. "Self-efficacy, declarative knowledge, procedural knowledge, and retention results all suggest that training outcomes are superior for trainees taught with simulation games…" (Sitzmann, 2011, p. 513).

Simulation games are at-home computer based instructional programs designed with *decision-making exercises* for individuals to realize the impact of their decisions (Malone, 1981). Adding a simulation game feature to at-home CBIT will enhance learning, make learning fun, and provide unlimited access. A meta-analysis identified the effectiveness of computer-based training to be attributed to three core principles: [1] active versus passive learning by engaging the pilot's cognitive processes, [2] supplemental to other training (such as the three takeoffs and landings), and [3] made available with unlimited access (Sitzmann, 2011).

Computer games are more engaging due to interaction, improved self-efficacy, and promote mastery of the subject matter (Bandura, 1997; Vogel et. al, 2006; Tennyson & Jorczak, 2008). Programing a score for the success of each level of training could promote pilots to work to improve their previous score, and perhaps beat the scores of de-identified fellow pilots.

Learning occurs with repetition, and since games are *intrinsically motivating,* an at home program will provide unlimited access, and entice pilots to play the games—learning results from motivation, attitudes, and previous knowledge (Tennyson & Jorezak, 2008). Thus interacting with the CBIT game should increase knowledge, as the pilot may be more motivated to play versus read. The game feature may also identify inadequacies that the pilot may not have been aware of due to lack of opportunity to experience such situations on the aircraft, further motivating the pilot to play more often to improve performance.

If any of the pilots in the previous accidents had access to a CBIT program, with the ability to experience their associated failures prior to the actual event, these crashes may not have materialized. Experience, be it real or simulated, through scenario preparation is a valuable teacher (Hadfield, 2013).

Motivation. Confidence. Stress.

Providing a pilot the ability to practice and rehearse normal operations and experience startle events, may improve confidence and increase performance. Research indicates a direct correlation with confidence and competence, which may be a contributing factor to success in both training and flight line operational safety (Johnson, & Fowler, 2011). After a series of routine line checks, a senior check airman determined that pilots did not hand fly their aircraft because they lacked understanding and confidence, thus were fearful to disengage the automation (A330 Check Airman, personal communication, February 12, 2015). Skill, experience, and how individuals deal with stress impact performance (Cuevas, 2003). While a limited amount of controllable stress can improve performance, experiencing unmanageable stress tends to degrade performance (Henderson, Snyder, Gupta, & Banich, 2012; Blouin, Deaton, Richard, & Buza, 2014).

Providing tools that enable pilots to practice via performance-based training, and receive feedback of success, could improve both competence and confidence. The power of confidence, as self-efficacy, when an individual can master the training program and perform the tasks described may improve competence (Bandura, 1997), which could transfer to the aircraft. An at-home CBIT program will enable a pilot to identify deficiencies, and improve to reach success necessary to feel confident they have competence, because they understand their aircraft and have experienced failures.

Program Design

A systems approach to a positive application of the right tools for the job of learning could prove beneficial, to increase competency in pilot performance. If properly designed, a CBIT program could be effective and useful for learning; however the program must be designed with a clear purpose, create a solid design and take under consideration organizational needs with available technology (Bedwell & Salas, 2010).

The system should be developed as a program for an at-home desktop computer to provide unlimited access. A control stick would be optional, as the goal of this trainer is not to practice flight skills, but improve operational performance and understanding to increase competency. An ongoing score will identify pilots' performance for continued improvement. Options to connect to a corporate database to see the top five de-identified scores, instilling a competition among fellow pilots, open for potential corporate rewards, will add incentive.

Plane flight mode. The conceptual design of the program should include a basic flight feature—flight deck setup, engine start, pushback, taxi, departure, flight to altitude, arrival, approach, landing, taxi in, shutdown—normal procedures to airports the airline utilizes, enabling practice prior to the actual line flight to that location. Each phase of flight could be designed for the pilot to configure the plane for the particular phase, call for the checklist, and respond accordingly. Programing departures and arrivals, and inputting clearances would be completed via the computer, and graded per accuracy.

Systems game mode. Design of the systems game mode would include optional questions and answers during set up, or incorrect systems that pilots must identify. The pilot may test the fire system and a question will pop up and ask a question of what the pilot expects to see. If correct the actual response will be displayed in the flight deck. If during preflight, the pilot checks the oil and the level is too low, but the pilot continues, at the end of the segment the system would tell the pilot how many errors were made in the set up. This will encourage the pilot to go back and redo the preflight. If the pilot is unable to discover the errors, the answer may be selected which will re-enforce correct configuration.

Navigation game mode. During the flight phase numerous clearances should be presented to the pilot that utilize all navigation features of the flight management computer. Queries such as when could you climb to flight level 390, or could you make position ABC by a given time would be displayed. If the pilot had no idea how to perform the procedure, the computer would provide the answer. Thus, learning with demonstration and practice would take place.

Abnormal and emergency modes. Multiple levels of abnormal events from autothrust disconnect to emergencies could be introduced, increasing difficulty with each level per complexity. From an engine failure on departure, to a rapid depressurization at altitude, the pilot could configure the aircraft, perform the engine indicating and crew alerting systems (EICAS) procedures, and manage the aircraft. The startle effect of each surprise event will build resilience to surprise events in the aircraft through experience. Each level will progressively get more challenging with compounded maneuvers, prepare pilots for the *what if* by experiencing abnormals, build confidence and competence, and instill a standard of excellence through experiencing all possible negative possibilities (Hadfield, 2013). If the pilot performs poorly they will think about how to respond differently next time in this non-threatening environment.

Decision making game mode. Decisions may end in survival, but alternative solutions may be better options. This process will help the pilot rethink decisions after they have been made. This decision making feature could include a scenario with the ability to choose one of three alternatives, and to sequentially experience each option in order to identify what works best. Through this naturalistic decision making process the pilot will achieve quicker and more accurate decisions having experienced similar situations prior to an actual event (Vidulich, Wickens, Tsang, & Flach, 2010).

CONCLUSION

NextGen is designed to reduce workload, and improve operational systems worldwide; however, at the same time will create more complexity (Darr, Ricks, & Lemos, 2010). If core aircraft operating procedures are not solidified in a pilot's long-term memory, startle events, abnormal events, and non-salient faults such as automation disconnecting, combined with the added complexity associated with NextGen could create yet another opportunity to overload the pilot's working memory leading to future catastrophes.

Expertise does not come from sitting reserve, or monitoring automated aircraft across the ocean with the autopilot engaged. Expertise comes from continued practice, repetition, and motivation for continued improvement. The question has been asked as how to increase pilot motivation so pilots will excel and become the experts passengers deserve and expect (Personal communications, Director of Training, Emirates, June, 2015). The answer may be none other than creating the opportunity for pilots to achieve higher standards by providing them the right tools for mastery.

Technology exists for desktop simulation. Aircraft manufacturers currently offer a variety of on-line training programs to include differing levels of automation, as do some airlines provide a variety of desktop simulation options for training. However, the level of CBIT training, with levels of systems operation, games, and airport data, under discussion should be as functionality operative as a simulator. This design would be complex, with high processing speed, thus a cost benefit analysis of development should be conducted to place this training in each pilot's home. However, the efficacy of this product could prove highly valuable in learning, and be cross utilized for initial ground school and recurrent training as well as recencys, with a potential to reduce level D simulator requirements.

Future research should include identifying the effectiveness of this type of training with understanding, confidence, and competency; followed by a critical analysis with regulatory agencies and potential mandates of higher standards for recency experience in automated aircraft in addition to the 90 day takeoff and landing requirement; with additional research to determine whether or not pilots identify the need for more training, and would they use this system voluntarily if made available.

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