Enhancing Pilot Training with Advanced Measurement Techniques

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Abstract. Certified Flight Instructors (CFIs) in general aviation are tasked with training student pilots the knowledge and skills related to piloting an aircraft. This requires CFIs to have indepth knowledge about common student errors including early indicators of non-optimal performance in flight, an understanding of probable root cause(s) of non-optimal performance, and instructional techniques to address root cause(s). There is an opportunity to improve CFIs' awareness of common student errors that lead to accidents/incidents and training effectiveness by integrating low fidelity scenario-based training. Such scenarios provided using low cost simulation environments coupled with detailed performance measures outlined in the ADAPT framework can aid CFIs in understanding common errors so that effective recognition and appropriate training intervention is provided to student pilots with the goal of optimizing training while minimizing student accidents/incidents.

1 Introduction

Training focuses on changing cognition, behaviors, and attitudes, where this change is focused on correcting "deficiencies by targeting the right competencies" (Salas et al., 2006). In civilian aviation, certified flight instructors (CFIs) are key personnel in training future pilots, as they are hired to teach students all required knowledge and skills related to piloting an aircraft, and recommending pilots for test flights and certification. While CFIs are provided training handbooks (e.g., FAA-H-8083-9A) and the opportunity to attend training workshops, these resources provide theoretical methods to identify root cause of accidents, instructional theories, and inform CFIs of typical accidents/incidents that occur with student pilots. However, the information available is not organized into a body of instructional techniques based on typical student errors. Information on why accidents/incidents occur must be individually gleaned from National Transportation Safety Board (NTSB) reports or the Aircraft Owners and Pilots Association (AOPA) Nall reports. This information is critical to CFIs, as they must teach recognition/recovery of unsafe flying in order to allow a student to learn from mistakes, but at the same time be ready to take over the controls if an accident/incident is immanent. Oftentimes, the "teaching moment" in flight is not recoverable for safety reasons and precious learning time may lapse between the student error in flight and the opportunity to teach once returning safely to the ground.

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A second challenge faced by CFIs is that student attention is often so focused on flying the airplane that he/she seldom can absorb instruction while in flight. Thus, the typical instructional flying technique is that the instructor demonstrates, then the student emulates; however, "monkey see, monkey do" does not provide convincing evidence of student grasp of the complex relationships of the multitude of factors contributing to safe flight. Diagnostic performance measures are needed to enhance CFI situational awareness of student errors and root cause, as in-flight CFI attention must be shared between attention to student performance while also attending to ensuring the flight environment remains safe. Student observation must come second to maintaining a safe environment.

One obvious solution would seem to be the use of simulation for training. The FAA is a strong proponent of simulator training citing such benefits as “more in-depth training [than] the airplane”, a “very high percentage of transfer of learning”, and “safer flight training” (FAA, 1983). The military and airlines do in fact use simulation extensively, but the general aviation pilot does not have readily available the “free” access to simulators that is afforded to pilots of the airlines. A simulator must fly like the airplane in order for the FAA to approve its use (FAA, 2010), making it expensive to build a simulator (Adams, 2008). One that can be approved for the kinds of flight that represent the typical accident in general aviation has yet to be marketed. Thus, pilots may be turning to unconventional “simulators” from the gaming industry (Parsons, 2010; Beckman, 2009). The question is whether affordable simulation can achieve sufficient benefit to impact positively the accident rate of general aviation pilots. In particular, could the CFI learn to recognize the cues of a student’s eminent accident by using a simulator to re-create typical accident scenarios from Nall Reports (AOPA)? Then, could that learning transfer to the actual aircraft to enhance the student’s training and safety? We believe it is quite feasible.

2 Learning Theories

Two prominent learning theories include (1) Behaviorism, where learning can be observed via measurable responses to stimuli, and (2) Cognitive Theory, which focuses on what happens within the brain – the process of thinking and learning (FAA, 2009). One of the main premises to enhancing performance according to the Behaviorism theory of learning is to provide reinforcement, which is provided by CFIs in aviation training. This theory provides the instructor with ways to manipulate students with stimuli, induce the desired behavior or response, and reinforce the behavior with appropriate rewards. In general, the behaviorist theory emphasizes positive reinforcement rather than no reinforcement or punishment. As an instructor, it is important to keep in mind that behaviorism is still widely used today, because controlling learning experiences helps direct students toward specific learning outcomes.

Cognitive theory focuses more on internal processes related to learning that are not necessarily observable using traditional methods. However, with advances in neurophysiological measurement, cognitive processes are becoming more ‘observable’ utilizing technologies such as eye tracking that can provide quantification of visual attention in real-time and brain-based measurement techniques that can provide indications of cognitive constructs such as workload, distraction, and fatigue. Integrating such measures into scenario-based training opportunities that simulate conditions that occur during flight can provide further insights into a student's performance by not only identifying where performance breakdowns occur, but also provide indications of *why* performance errors occurred. This is particularly relevant for the aviation domain, where multitasking is a key skill required for safe flight. Effectively being able to switch attention and perform multiple tasks simultaneously are two key components student pilots must learn, and thus CFIs must effectively train.

3 Scenario-Based Training for CFI Training

Scenario-based training is one tool that may be implemented to enhance CFI situation awareness and training effectiveness, and this training can be provided via simulation systems that engage students and instructors into the scenario. Parsons (2010, p.36) noted that simulations may be used to "practice and reinforce the lessons learned" from a student perspective. In a similar fashion, scenario-based training could be implemented for CFIs to provide effective learning by developing scenarios that have a clear objective tailored to meet the needs of an instructor, and which capitalize on the nuances of the local environment. Such scenarios could be based on pervious accident reports, which would allow CFIs to view incidents from a number of viewpoints that are not available when they are situated in the cockpit (e.g., can review cockpit view, tower view, from either side of the aircraft), and can also pause and replay incidents. Using such repeated review sessions, CFIs can begin to identify what happened, and identify cues prior to the incident that indicated a potential problem (e.g., too fast in landing approach, excessive control correction).

To further enhance understanding of root cause of incidents, additional advanced measurement techniques beyond those captured by existing desktop-based simulated flight environments may be implemented into a simulated scenario to provide detailed student pilot information. Design Interactive, Inc. has created the Auto-Diagnostic Adaptive Precision Training (ADAPT) framework (Figure 1) that measures, diagnoses, and adapts training based on individualized trainee outcomes. ADAPT is flexible to capture a number of measures simultaneously that indicate trainee state in real-time throughout a training scenario. For example, behavioral data such as flight control manipulations and eye fixations, and brain-based data from electroencephalography (EEG) to indicate cognitive states of workload, engagement, and distraction were incorporated into a flight instrument landing task (Carroll et al., 2010). The suite of measures captured is then analyzed using a diagnostic engine to determine error patterns in behavior and associated root cause(s) related to observed errors. Root cause(s) could include inappropriate scan strategies, non-optimal cognitive states, lack of procedural understanding, etc. Based on the diagnosis, ADAPT can provide precision in one of two ways: (1) adapt the training scenario in real-time to target inefficiencies/deficiencies, and/or (2) provide after action review (AAR) feedback that summarizes trainee performance, key performance inefficiencies/deficiencies, and recommends future training focus.

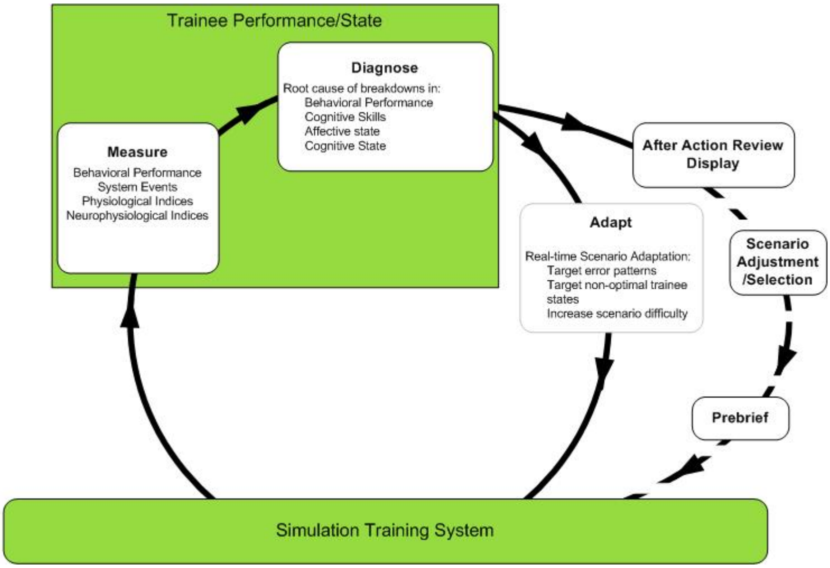

Fig. 1. ADAPT Framework

For example, ADAPT's AAR components may display eye gaze data showing where a student pilot was visually focused throughout a given time segment of a scenario (Figure 2). This information could provide early indicators of potential accidents that are not otherwise available by observing behavioral outcomes or aircraft maneuvers. For example, it may become evident that students are focused in the cockpit at a specific gauge that is not relevant to the current flight segment and/or where the student inappropriately fixated just over the aircraft nose, which is an early indicator of non-optimal landing techniques that can often lead to hard landings. Insights can be gained not only to errors that happened, but why such errors occurred.

Fig. 2. Fixation Overlay on Approach (red circles indicate fixation points)

The diagnostics based on student behavior could be of great utility to CFIs during their instructor training. By viewing student behavior, including in-depth gaze pattern and cognitive state metrics, CFIs could identify potential causes of accidents, and develop a 'virtual experience database' of underlying causes of common errors (e.g., visual focus in the cockpit or too close to the nose is often cause of porpoising). This knowledge and experience will better prepare CFIs to provide targeted feedback to student pilots that addresses the underlying cause of a poor outcome (e.g., improper scan pattern) as opposed to identifying the poor outcome in isolation (e.g., aircraft porpoise during landing). By focusing on the underlying issue, the student should be better able to adapt their behavior to optimize performance outcomes. Using accident re-creation in a dynamic simulated flight environment, the CFI can observe specific student behaviors (both observable as well as eye tracking data that is 'unobservable' during actual flight) leading to an accident. Such exposure could allow CFIs to temper with detailed knowledge surrounding common student errors, and develop a more thorough understanding of early indicators of non-optimal performance, and identify optimal training intervention techniques and timeline, such as knowing how far to allow students to fly into a mistake for training purposes without risk of a mishap.

Having this detailed knowledge regarding underlying causes that is summarized in a focused, applied manner should provide CFIs a more practical method to learn evaluation skills related to recognizing why errors occur, which allows CFIs to provide targeted feedback to address the underlying cause of inefficient piloting as opposed to simply providing more practice.

4 Future Directions

The CFI is the backbone of General Aviation training. In her introduction, Parsons (2009, p.36) notes that CFIs perform "one of the most vital and influential roles in aviation and, just as in medicine, the work can have life and death consequences. But while the medical profession uses internship and residency programs to provide supervised real world training for newly graduated MDs, newly certificated flight instructors – like new instrument pilots – are mostly left to learn on their own." Systematic exposure to progressively more challenging student behaviors is commonly considered how one gains experience. Parsons (2009) proposes 25 flights in such a progression before the new CFI ever flies with a beginning student. Simulation could be used to expose the CFI in a safe environment to student behaviors that have resulted in accidents, and thus better prepare the CFI for successful accomplishment of their vital role.

Further, the ADAPT framework could be extended from a student-focused evaluation to a CFI-focused evaluation. Specifically, performance measures collected and summarized from a simulated flight segment may focus on CFI time to identify student error, CFI method of instruction for addressing error, time for student pilot to recover from error, and CFI workload during flight segment. Providing such detailed feedback regarding their performance in instructing a pilot while maintaining flight safety provides unprecedented training opportunities to CFIs that are currently unavailable. By implementing such training techniques, CFI situation awareness of student pilots and their own instructional abilities can be explicitly measured and targeted feedback can be provided to improve instructor-pilot interaction, student training, and accident/incident rates in civil aviation.

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