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Pilot Situation Awareness Training in General Aviation

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While the majority of research on the topic of situation awareness has been focused on designing better systems, significant interest also exists in finding ways to improve SA through training. This paper describes an ongoing program that is directed at developing programs for training SA in general aviation pilots. Factors that have been found to pose problems for SA in pilots are reviewed and directions are established for creating programs for improving SA through training.

INTRODUCTION

Having a high level of SA is perhaps the most critical factor for achieving successful performance in aviation. Problems with SA were found to be the leading causal factor in a review of military aviation mishaps (Hartel, Smith, and Prince, 1991). In a study of accidents among major airlines, 88% of those involving human error could be attributed to problems with situation awareness as opposed to problems with decision making or flight skills (Endsley, 1995). Although similar studies have not been performed for general aviation (GA) accidents, SA is reported to be considerable challenge in this population as well, particularly as GA pilots are frequently less experienced and less current than operators for major airlines (Hunter, 1995). NASA has identified situation awareness as one of seven major task areas targeted for human error reduction in its Aviation Safety Program which is seeking to meet the government's goal of reducing fatal aircraft crashes by 80% over the next ten years (Huettner and Lewis, 1997). Given the key role of situation awareness problems in pilot error, programs to deal with this issue should be particularly effective at achieving the accident reduction goal.

While training for SA may be effective for pilots at different levels of experience, the present effort is focused on SA in general aviation. This focus was selected for a number of reasons: (1) General aviation accidents and incidents account for 94% of accidents and 92% of fatalities (based on July, 1999 accident data), an accident/flight hour rate over 27 times that of scheduled part 121 carriers (NTSB, 1999). Reduction of accidents in this arena will contribute substantially towards the overall goal of reducing aircraft accidents. (2) Improvement of SA in GA pilots will also contribute towards improving the overall safety of the airspace system as these aircraft share the same congested airport areas, runways and enroute environment with commercial aircraft. (3) Improvement of SA in GA pilots may also have a trickle-up effect. As major airlines and commuters are more frequently seeking to hire pilots from the GA population, partially due to limits in the numbers of pilots available from the military ranks, improved skills in GA pilots may translate into better pilot capabilities in other areas of aviation. (4) Many of the research and training techniques developed for the GA pilot may also be transferable to other areas of aviation. Many of the issues that can be found to underlie problems in SA in the GA pilot appear to also be a problem for pilots at-large (as will be discussed in more detail). (5) By focusing this developmental research on the GA pilot, a more readily available population can be studied at much lower cost than can commercial pilots. This focus also allows us to study individual SA separately from the problems of team SA.

PROBLEMS IN GENERAL AVIATION

A total of 1,907 U.S. registered general aviation aircraft were involved in accidents in 1998. Of these 1,907 accidents, 361 accidents resulted in fatal injuries, with a total of 621 fatalities. U. S. general aviation accounted for 7.12 accidents per 100,00 flight hours as compared to 0.26 accidents per 100,000 flight hours for scheduled U.S. air carriers operating under 14 CFR 121 (commercial operations). In addition, general aviation accounted for 1.35 fatalities per 100,000 flight hours as compared to 0.006 fatalities per 100,00 flight hours for U.S. part 121 air carriers.

A 1989 NTSB review of 361 GA accidents concluded that 97% of the probable causes were attributable to pilot error. The pilot has also been found to be a "broad cause/factor" in 84% of all GA accidents, and 90.6% of all fatal accidents (Trollip and Jensen, 1991). An earlier review, attributed 85% of GA accidents to pilot error, with faulty decision making cited as the primary cause (Jensen, 1982).

The NTSB profiled GA pilots most likely to have accidents (NTSB, 1989). Wells (1992) reported that based on the profile, the greatest number of accidents involved "pilots between 35 to 39 years of age with between 100 to 499 hours total time who were engaged in personal flying, took place in daylight visual meteorological conditions (VMC), were precipitated by a loss of power in the landing and takeoff phases, were complicated by a loss of directional control for which pilots decision making and/or weather conditions were to blame, ended with a collision with terrain or obstacles, and resulted in no fire or injuries".

Based on this profile, Trollip and Jensen (1991) have concluded there is a period between 100–500 hours in which pilots' confidence level exceeds their ability level. They suggest two periods that are particularly dangerous, (1) approximately 100 hours, after the pilot has accumulated about 50 hours beyond the private pilot certificate, and (2) between 50 to 100 hours after earning an instrument rating. Both periods are marked by an increase in confidence, without a substantial experience gain. It appears that an appropriate SA training intervention strategy would be at this stage, after basic flight skills have been acquired but an in-depth level of expertise on which to build SA has not yet been accumulated.

SA TRAINING NEEDS

One way of identifying methods for improving SA is to examine in what ways SA errors occur. A second method is to identify the ways in which pilots successfully develop and maintain SA as compared to pilots who do a poorer job at these tasks. Endsley and Robertson (2000) review a number of studies that have been performed pertinent to these issues.

An analysis of SA errors in aviation was conducted (Jones and Endsley, 1996) using reports from NASA's Aviation Safety Reporting System (ASRS) using an SA error taxonomy based on a model of SA (Endsley, 1995). As shown in Table 1, SA errors can be attributed to a wide range of factors.

Table 1: SA Error Taxonomy

Level 1 SA Errors	**76.3 %**
· Data not available – *System & design failures, failure of communication, failure of crew to perform needed tasks*	11.6 %
· Data hard to detect — *Poor runway markings, poor lighting, noise in the cockpit*	11.6 %
· Failure to monitor/observe data — *Omission from scan, attentional narrowing, task related distractions, other distractions, workload*	37.2 %
· Misperception of data — *Prior expectations*	8.7 %
· Memory loss — *Disruptions in routine, high workload, distractions*	11.1 %
Level 2 SA Errors	**20.3 %**
· Incomplete mental model — *Automated systems, unfamiliar airspace*	3.5 %
· Incorrect mental model — *Mismatching information to expectations of model or model of usual system*	6.4 %
· Over-reliance on default values — *General expectations of system behavior*	4.7 %
Level 3 SA Errors	**3.4 %**
· Incomplete/Poor mental model	.4 %
· Over-projection of current trends	1.1 %
· Other	1.9 %

Gibson, Orasanu, Villeda and Nygren (1997) also performed a study of SA errors based on ASRS reports. They found problems with workload/distraction (86%), communications/coordination (74%), improper procedures (54%), time pressure (45%), equipment problems (43%), weather (32%), unfamiliarity (31%), fatigue (18%), night conditions (12%), emotion (7%) and other factors (37%). Consequences of loss of SA resulted in altitude deviations (26%), violations of FAR (25%), heading deviations (23%), traffic conflicts (21%), and non-adherence to published procedures (19%). Dangerous situations were found to result from 61% of the cases. Clearly loss of SA should be taken seriously in aviation.

While both of these studies included loss of SA by controllers and commercial pilots in addition to GA, they shed some light on the nature of the problems that occur in situations where SA is lost. Several other researchers have investigated the differences in SA between pilots who perform well and pilots who do not.

Prince and Salas (1998) studied the situation assessment behaviors of GA pilots (means experience level = 720 hours), airline plots (mean experience level = 6,036 hours), and commercial airline check airmen (mean experience level = 12,370 hours). They found several key differences:

(1) Increasing levels of preflight preparation - GA pilots talked about personal preparation before the flight, while line pilots also emphasized knowing the equipment and its limits and briefing for the flight. Check airman focused on planning and preparation specific to the flight and gathered as much

information as possible about the conditions and flight elements (e.g. weather, ATC, airport status) in order to prepare in advance.

(2) More focus on understanding and projection – GA pilots described themselves as passive recipients of information with an emphasis on information in the immediate environment (Level 1 SA). Line pilots dealt more at the level of comprehension (Level 2 SA) and emphasized an active role in seeking out information. Check airmen were more likely to deal with Level 3 SA, seeking to be proactive. They dealt with large numbers of details and the complex relationships between factors in this process.

In conducting critical incident reviews with pilots, Prince and Salas (1998) identified four major actions that are important for team SA in commercial pilots: (1) identifying problems or potential problems, (2) demonstrating knowledge of the actions of others, (3) keeping up with flight details, and (4) verbalizing actions and intentions. Prince, Salas and Stout (1995) found that those aircrews who performed better on an objective measure of SA demonstrated more actions in these areas. They seemed to solve problems faster and recognized problem situations developing. While the focus of this research was on team SA rather than individual SA, it does point at certain characteristics that are important for developing SA in aviation settings.

Orasanu and Fischer (1997) studied the characteristics of commercial aircrews in making various types of decisions through an analysis of ASRS data and observations from simulator studies. They found that in making go/no-go decisions about an approach, the better performing crews attended to more to cues signaling deteriorating weather and sought out weather updates allowing them to plan for a missed approach in advance. When studying a choice type task which involved picking an alternate airport, however, the better performing crews took longer. They were much more attuned to the constraints imposed by a hydraulic failure and reviewed other alternates in light of the constraints. They gathered more information allowing them to make a better decision, whereas poorer performing crews went right to evaluating options. Analysis of a hydraulic failure, which represented a scheduling type task, showed the better performing crews taking active steps to manage what would become a high workload task. They planned in advance for actions that would occur in the high workload periods and thus were more effective in these situations.

From this research, Orasanu and Fischer have focused on a two step decision model: situation assessment and action selection. Time availability, risk level and problem definition are indicated as critical components of the situation assessment phase. Situation ambiguity and the availability of responses were hypothesized to be critical factors dictating the difficulty of the decision. When cognitive demands are greater, the higher performing crews managed their effort by performing actions that would buy them extra time (e.g. holding) and by shifting responsibilities among the crew. Good situation assessment, contingency planning and task management were critical behaviors associated with success. Less effective pilots appeared to apply the same strategies in all cases rather than matching their strategy to the situation.

In examining accident reports, Orasanu, Dismukes and Fischer (1993) also report that pilots who had accidents tended to interpret cues inappropriately and often under-estimated the risk associated with a problem and over-estimated their ability to handle dangerous situations. Wiggens, Connan and Morris (1995) found that GA pilots who preformed poorly in deciding to continue into inclement weather were poorly gauged in terms of matching their skill level to the situation. "In the absence of extensive task-related experience, pilots are more inclined to rely on their self-perceived risk-taking behavior than their self-perceived ability to resolve various decisions." The more experienced pilots demonstrated behaviors that were much more related to perceptions of their own ability. It would appear that inexperienced pilots may be deficient in their ability to properly assess risk and capabilities (Level 2 SA) from the situational cues at hand.

In studies of individual differences in SA abilities, Endsley and Bolstad (1994) found that military pilots with better SA were better at attention sharing, pattern matching, spatial abilities and perceptual speed. O'Hare (1997) also found evidence that elite pilots (defined as consistently superior in gliding competitions) performed better on a divided attention task purported to measure SA. Gugerty and Tirre (1997) found evidence that people with better SA performed better on measures of working memory, visual processing, temporal processing and time-sharing ability.

SA Problems in General Aviation

Since most research on factors associated with SA problems have been conducted with regard to commercial and military pilots, a recent study was undertaken to specifically identify SA problems for GA pilots (Endsley, Garland, Shook, Coello, and Bandiero, 2000). This research (1) conducted an analysis of accidents and incidents involving general aviation pilots (at different levels of experience) based on reports collected at a general aviation flight school; (2) carried out a survey of flight instructors to determine observed problems with SA in GA pilots, including key flight tasks, environmental features and other factors associated with SA problems; and (3) observed GA pilots at different experience levels in simulated critical flight scenarios to ascertain SA problems and behaviors associated with good and poor SA.

This study found that key problem areas to be addressed for low experience GA pilots include:

(1) Task Management — managing high workload, dealing with distractions, task criticality and prioritization, task management, divided attention, avoiding attentional narrowing;

(2) Basic procedures— completing checklists, carrying out procedures, performing instrument cross-checks, cross wind take-off and landing, understanding ATC radio communications;

(3) Vigilance — maintaining awareness of traffic, maintaining awareness of airspeed;

(4) Awareness and effects of weather — surface winds, winds aloft, turbulence(cruise and approach), thunderstorms, icing (en route), considering changes in weather (future predictions) in the pre-flight;

(5) Dealing with malfunctions — diagnosis, understanding problems and emergencies, impact of failures;

(6) Building mental models — understanding of own capabilities and limitations, impact of time constraints & fatigue, building familiarity with destination airports, airspace, and ATC procedures, recognizing current trends, implications of information;

(7) Critical Skills— contingency planning, in-flight planning and decision making, seeking out relevant information.

TRAINING RECOMMENDATIONS

In summary, from these various studies several key factors that indicate where SA can be improved through training can be identified.

Task management

Interruptions, task related distractions, other distractions and overall workload pose a high threat to SA. Good task management strategies appear critical for dealing with these problems. Schutte and Trujillo (1996) found that the best performing crews in non-normal situations were those whose task management strategies were based on the perceived severity of the tasks and situations. Those who used an event/interrupt driven strategy (dealing with each interruption as it came up) and those who used a procedural based strategy performed more poorly. The ability to accurately assess the importance and severity of events and tasks is an important component of Level 2 SA. This understanding also allows pilots to actively manage their task and information flow so as not to end up in situations in which they are overloaded and miss critical information.

Development of comprehension

In addition to problems with properly assessing the importance or severity of tasks and events, pilots will also perform poorly if they are unable to properly gauge the temporal aspects of the situation, the risk levels involved and both personal and system capabilities for dealing with situations. Simmel and Shelton (1987), in analyzing accident reports, note that accurately determining the consequences of non-routine events appeared to be the problem for these pilots. Each of these factors (timing, risk, capabilities, consequences and severity) are major components of Level 2 SA (Endsley, Farley, Jones, Midkiff, and Hansman, 1998). Inexperienced pilots appear to be less able to make these important assessments, remaining more focused at Level 1.

Projection (Level 3 SA) and planning

Amalberti and Deblon (1992) found that a significant portion of experienced pilots' time was spent in anticipating possible future occurrences. This gives them the knowledge (and time) necessary to decide on the most favorable course of action to meet their objectives. Experienced pilots also appear to spend significant time in pre-flight planning and data gathering and engage in active contingency planning in flight. Each of these actions serves to reduce workload in critical events. Using projection skills (Level 3 SA) these pilots are able to actively seek important information in advance of a known immediate need for it and plan for various contingencies. Not all planning is equally effective, however. Taylor, Endsley and Henderson (1996) found that teams who viewed only one plan were particularly susceptible to Level 2 SA errors, failing to recognize cues that things were not going according to plan. Actively planning for various contingencies and not just the expected in flight is critical.

Information seeking and self-checking activities

Pilots with high levels of SA actively seek out critical information, making them quicker to notice trends and react to events. These pilots are also good at checking the validity of their own situation assessments, either with more information or others (Taylor, et al., 1996). This is effective in dealing with false expectations and incorrect mental models. Other researchers have also suggested a "Devil's Advocate" strategy where people are encouraged to challenge their interpretations of situations (Klein, 1995; Orasanu, 1995).

In conclusion, many factors including meta-cognitive skills and knowledge base deficiencies can be linked to problems with poor SA. Training programs that address these issues should be effective at improving SA in GA pilots.

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