CHALLENGES CONTRIBUTING TO THE GENERAL AVIATION WEATHER PROBLEM & DECISION SUPPORT SYSTEMS TECHNOLOGY RECOMMENDATIONS

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General Aviation (GA) weather related accidents have steadily remained the most fatal accidents and incidents in the GA flight community. The majority of these accidents involve low-experienced Visual Flight Rule (VFR) pilots, inadvertently encountering Instrument Meteorological Conditions (IMC). Previous research indicates, poor inflight weather avoidance could stem from insufficient preflight weather planning. Further investigation reveals, pilots' face many challenges during the preflight planning process, including: poor weather product interpretation/ usability, decision making biases and errors, and inadequate aviation weather experience. However, with new technology on the rise, a preflight decision support tool may help guide novice pilots through the preflight process successfully. This paper will discuss the challenges novice pilots encounter during the preflight process and offer recommendations for applying a preflight decision support tool as a solution.

INTRODUCTION

Over the last 30 years, a large percentage of weather-related aviation accidents have occurred under General Aviation (GA) operations (FAA, 2010; Fultz & Ashley, 2016; AOPA, 2008). These accidents often occurred when low-experience pilots operating under Visual Flight Rules (VFR) inadvertently encounter Instrument Meteorological Conditions (IMC) -- an incident commonly referred to as VFR into IMC (Capobianco & Lee, 2001; Fultz & Ashley, 2016). High risk is associated with VFR into IMC, due to its' high probability rate for fatalities. As a result, previous studies have investigated casual factors that may influence the occurrence of VFR into IMC amongst GA pilots (Capobianco & Lee, 2001; Fultz & Ashley, 2016). The purpose of this paper is to: 1) identify challenges for pilots that may contribute to aviation weather-related accidents and 2) provide supported recommendations for applying a preflight decision support tool to the GA aviation weather problem.

Background

In order to avoid hazardous weather, pilots review and interpret a variety of weather products, synthesize the information, and apply it to their flight planning decisions. While this occurs primarily during preflight, it can also occur en-route if weather changes occur. Research claims preflight performance is a key factor in determining inflight performance and weather avoidance (National Transportation Safety Board, 2005). During the preflight phase, pilots access and interpret weather information, along with aeronautical information, to predict weather development (FAA, 2016). In order to use effective preflight planning practices, pilots need to understand weather phenomena fundamentals and have the ability to interpret weather products such as, Winds Aloft, Meteorological Terminal Air Report (METAR), and Radio Detection And Ranging (RADAR) (Lanicci et al., 2012). Pilots must then be able to apply the information to their flight (Parson et al., 2005).

CHALLENGES CONTRIBUTING TO AVIATION WEATHER RELATED ACCIDENTS

Several challenges contribute to the GA aviation weather problem. These include poor interpretation of weather products, decision making biases and errors, and a lack of aviation weather experience.

Challenge 1: Difficult to Interpret Aviation Weather Products

Weather products are crucial for providing pilots with a mental model of current and forecast weather along their flight route. However, if weather products are poorly designed, or if pilots are unable to interpret weather products due to a lack of knowledge, pilots may not have adequate information to make safe decisions about their flight plan (Blickensderfer et al., 2018). Blickensderfer et al. (2018) developed an aviation weather exam to evaluate GA pilots' ability to interpret observation, analysis, and forecast weather products. Results indicated that, pilots' product interpretation scores were quite low. The low scores indicated that pilots are struggling to interpret these products.

Recently, there have been strides towards making weather products more graphical and interactive in order to simplify product interpretation. Unfortunately, evidence suggests that the improved products may be more confusing than helpful (Latorella & Chamberlain, 2002; Yuchnovicz et al., 2001; Beringer and Ball, 2004). New weather technology, such as RADAR and overlaid dynamic maps, have been employed to attempt to improve decision making. However, pilots often have used these devices to tactfully fly closer to degrading weather (Latorella & Chamberlain, 2002; Yuchnovicz et al., 2001; Beringer and Ball, 2004). Among other issues, it is possible that these products overwhelm the user and make the products even more difficult to interpret.

Challenge 2: Pilot's Decision Making Biases and Errors

Human decision making is laden with cognitive biases and illogical reasoning (NTSB, 2005). As a result, decision errors are prevalent in complex, high stress environments such as flight (NTSB, 2005).

For example, “pilot continuation error” is a decision error where pilots continue their flight even when they are presented with cues indicating deteriorating weather and hazardous weather phenomena (NTSB, 2005). Pilots could be prone to pilot continuation error due to risky behavior and/or simply inadequate knowledge of weather principles (NTSB, 2005).

In addition, prospect theory can also affect pilots’ decision making during VFR into IMC incidents (NTSB, 2005). Research suggests that pilots who frame encountering IMC as a “loss” and safe diverting as a “gain” were less likely to fly into hazardous weather conditions (Goh & Wiegmann, 2001). Unfortunately, for pilots under pressure to complete a flight, diverting to an airport other than their planned destination is often viewed as a “loss.” Research indicates that pilots who experience decision biases such as these may often end up inadvertently encountering hazardous weather conditions (Goh & Wiegmann, 2001).

Challenge 3: Inexperienced GA Pilots’ Limited Aviation Weather Experience

Previous research also indicates that novice pilots struggle with interpreting weather products and even intermediate pilots have difficulty in recognizing weather-related cues (Wiggins & O’Hare, 2003; Chansik, 2011). Research suggests that, inexperienced operators have poor feature and cue association due to underdeveloped domain knowledge and lack of experience, which can impact operator situation assessment (Wiggins, 2014). As a result, inadequate experience can have severe consequences on GA private pilots’ decision making and preflight and inflight performance (Wiggins et al., 2002).

It is clear that aviation weather experience and skill acquisition are essential for safe flight operations (FAA, 2010; Fultz & Ashley, 2006). Research in skill acquisition indicates that, novice pilots’ poor performance is a result of undeveloped knowledge and skills needed to effectively complete skilled tasks (Patel & Groen, 1991: Wiggins & O'Hare, 1995). Low experienced pilots may be incurring weather-related accidents due to their inability to access, assess, and apply weather information (Blickensderfer et al., 2018).

Thus, GA pilots face various challenges that can hinder preflight and inflight performance and contribute to the GA aviation weather problem (NTSB, 2005). Although this issue has been heavily researched and new technology and training have been applied to the issue, the problem still continues to negatively affect the GA flight community. Perhaps applying a support tool to help provide inexperienced pilots with a dynamic guide that can assist with decision making and product interpretation in the preflight stage will bridge the gap between inexperienced pilots and new novel environments to improve preflight and inflight performance.

PROPOSED SOLUTION: GA PREFLIGHT DECISION SUPPORT TOOL

Decision support systems (DSS), such as function specific and task specific DSS, are technical aids used to assist operators in problem solving and task completion (Shimon, 2009). Function specific and task specific decision support systems are specifically designed to support task and decision making for a particular field (Shimon, 2009). These systems can benefit the user by providing particular knowledge to facilitate better decision making (Alter, 1980). Theoretically, a decision support tool for aviation could aid inexperienced pilots by offering key aviation weather principles and knowledge at opportune times to improve product interpretation, decision making, and overall preflight and inflight performance (Shimon, 2009). However, without careful design, introducing a new technology, such as a preflight decision support tool, could hinder performance rather than increase it.

Therefore, this section of the paper will discuss recommendations for developing and applying a preflight decision support tool to support GA pilots’ weather decisions.

Decision Support Tool Recommendations

Recommendation 1: Apply specified levels of automation to specific tasks. When designing and implementing decision support tool systems, applying different levels of automation to various preflight tasks could improve preflight and inflight performance. Automation can vary in type and stages; type of automation refers to the task to which the automation is applied. Whereas, *level* of automation describes the amount of automation that is applied (Shimon, 2009). For example, during the preflight process, pilots have difficulty with the task of product interpretation and selection. If automation were applied to this task, a useful support system would suggest which weather products are essential for the pilot’s flight plan. The support system could also prompt the pilots to think about the weather information the way an expert would. That is, by offering tips and guidance, the support system could function like a coach or smart checklist to ensure the novice pilot is performing efficient information acquisition and conceptualizing the retrieved information. As described, this type of automation would be mid-level information acquisition and analysis, where, the automated system is suggesting how novice pilots should access and interpret weather products. This type of automation is more effective than high level type decision automation, where the automation makes decisions for the user (Shimon, 2009).

Recommendation 2: Consider the negative impacts of automation. Whenever automation is being applied to a system or process, it is imperative to consider the potential impact different levels of automation may have on human performance. Previous studies have highlighted complacency and skill degradation as possible negative outcomes of human automation systems (Wiener, 1981; Parasuraman, Molloy, &Singh, 1993). When automation is used to help cue and highlight important information for operators, the operator could become over-reliant on automation. As a result, the operators may fail to identify hazards and automation errors (Yeh, Wickens,& Seagukk, 1999). This could lead to an increase of operators' performance on certain tasks and a decrease in others. For example, a novice pilot could become too dependent on the decision support tool. If the novice pilot is over-reliant on the support tool for assistance with interpreting weather products and attempts to interpret weather products without the support of the preflight decision aid, their performance may decrease instead of increase.

Furthermore, research suggests that complacency and overreliance issues are more common with decision automation rather than information automation (Crocoll & Coury, 1990). As expected, these issues are even more troublesome in high risk environments. Therefore, it is essential to specifically apply appropriate levels of automation to tasks. Research driven automation application could improve performance, whereas, purposeless automation placement could transform an already high risk environment into a hazardous incident. For instance, if the decision support tool uses decision automation to decide whether a flight plan is safe to fly, the pilot could become complacent and accept automation decisions. As a result, a novice pilot could encounter hazardous weather conditions unprepared.

Recommendation 3: Provide training for users on how to use the decision support tool. When implementing a performance support tool, it is imperative to train users on how to use the tool effectively. During the design phase, engineers should determine how transparent the logic of the decision support tool should be for the user. System transparency provides the user with a mental model of the system capabilities and limitations, this can help users gauge dependency and trust (Parasuraman & Riley, 1997). For example, when considering a decision support tool to aid low experienced pilots with the preflight process, the pilot must know how much assistance the system is able to provide. Pilots should not rely on the system to make decisions or provide feedback on their decisions if the systems' only purpose is to provide informative suggestions. A discrepancy between user expectations and system performance can cause confusion and error prone activity (Cohen et al., 1997). However, if users (in this case pilots) are trained on how to use the product, the decision support tool could considerably reduce error and improve operations (Cohen et al., 1997).

Recommendation 4: Consult Subject Matter Experts to Ensure Decision Support Tool Content Validity. Content validity and user-centered design are crucial for supporting human and decision support tool performance (Cohen et al., 1997). Function and task specific decision support tools use "experienced knowledge" to assist operators when performing tasks (Shimon, 2009). Therefore, the content validly of the knowledge based information is crucial for improved performance. For example, a preflight decision support tool would use aviation and metrological knowledge to help the pilots make the best informed decisions concerning their flight. If the system lacks aviation or weather knowledge principles, the novice user may be unprepared to perform their tasks effectively. As a result, a tool that was designed to decrease work load and increase performance could actually hinder safe flight activity and introduce even more confusion to an already complicated environment. Therefore, multi-disciplinary teams are essential for ensuring content validity and system design. Both expert pilots and meteorologists are needed to verify the system is capable of providing proper guidance for novice users.

Recommendation 5: Design a User-centered Decision Support Tool. Usability and human centered design are important principles to consider during decision support tool development (Cohen et al., 1997). Technology is too often applied to complex environments without taking the user into consideration. Previous research suggests, vendors improve technology to assist with pilots' preflight and inflight performance. However, new weather technology such as RADAR and overlaid dynamic maps may encourage hazardous flight activity rather than prevent it (Latorella & Chamberlain, 2002; Yuchnovicz et al., 2001; Beringer and Ball, 2004). Previous research indicates that pilots with dynamic weather in the cockpit actually flew closer to degrading weather, compared to the control group (Latorella & Chamberlain, 2002; Yuchnovicz et al., 2001; Beringer and Ball, 2004).

Instead of repeating previous mistakes, developers of aviation weather decision support tools should consider pilot needs early in the design process. Increased system usability could assist with system transparency and trust (Cohen et al., 1997). Furthermore, the more user friendly the system is the more transparent the systems' functions are for the pilot.

Recommendation 6. Allow Users to Customize the Level of Automation for Decision Support Tools. Research also suggests facilitating decision support tool automation customization could improve system transparency and human machine interaction (Billings & Woods, 1994). For instance, if a novice pilot needs assistance with risk assessment, but was improving on their product interpretation skills, the pilot could adjust the preflight decision support tool automation. The preflight decision support may be even more useful if the pilot is able to change the settings to low automation on product interpretation and medium automation on risk assessment tasks. This way, the pilot can practice using their skills during product interpretation and receive more assistance with risk assessment. When implemented correctly, system customization could help specialize the decision support tool to effectively meet the users' knowledge and skill deficiencies (Cohen et al., 1997).

DISCUSSION

In summary, there are challenges that inexperienced GA pilots may encounter that could lead to weather related accidents; specifically, VFR into IMC (NTSB, 2005). Poor product usability, pilots' lack of aviation weather experience, and decision-making biases have all been identified as possible causal factors for weather-related incidents (NTSB, 2005). Fortunately, experience and knowledge based decision support tool technology can be used to aid novice operators with performing tasks and processes (Shimon, 2009). These systems could offer knowledge and support to help novice pilots' complete weather preflight tasks effectively.

Although decisions support systems have the potential to improve novice pilot performance in preflight and inflight operations, certain precautions should be considered in order to implement this technology effectively. First, developers should apply automation levels to specific tasks appropriately to meet user's needs (Parasuraman, Sheridan, & Wickens, 2000). Second, producers should train users on system capabilities and limitations to avoid under and overreliance of system automation (Cohen et al., 1997). Third, subject matter experts should be involved in system development to offer feedback and support on the decisions support tools' knowledge bank and logic. Lastly, the decision support tool should be user friendly, customizable, and transparent to improve human machine interactions (Cohen et al., 1997).

Future research should investigate which levels of automation are most effective for each preflight task. Furthermore, research should be invested into determining which methods are most effective for developing an effective preflight decision support tool for GA novice pilots.

DISCLAIMER

The views expressed in this paper are those of the authors and do not necessarily represent the organization with which they are affiliated.

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