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Predicting General Aviation Pilots' Weather-Related Performance through a Scenario-Based Assessment

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Predicting General Aviation Pilots' Weather-Related Performance through a Scenario-Based Assessment

Weather-related accidents continue to challenge the general aviation (GA) community and with the development of advanced weather technology, GA pilots need additional education and training on how to effectively use these weather products to ensure flight safety. Currently, the literature on aviation weather suggests that there is a gap in both training and assessment strategy for GA pilots. Furthermore, several studies advocate assessing GA pilots at a deeper level of learning by including weather-based, scenario/application questions on the Federal Aviation Administration's (FAA) written exam for private pilots. After first developing a scenario-based, aviation weather assessment, we used a multiple regression analysis to predict aviation weather performance from 90 GA pilots. In addition, we used Baron and Kenny's (1986) test for mediation to predict aviation weather performance from four predictor variables (i.e., a scenario-based aviation weather assessment, a traditional, non-scenario-based weather assessment, weather salience, and aviation weather experience). The results of the study indicated that scores on the scenario-based assessment were the strongest predictor of aviation weather performance followed by aviation weather experience. These results support the need for scenario-based weather questions on the FAA written exam for private pilots. The results of this study could help aviation officials and educators better assess and train general aviation pilots on weather-related topics.

INTRODUCTION

Degraded weather continues to challenge the General Aviation (GA) community and although weather-related accidents account for a smaller portion of the total number of GA accidents, they include roughly 83% of the fatality rate. After examining the fatal effect of degraded weather on GA accidents, it is evident that pilots need to understand the various weather conditions that may pose a risk to their flight. With the advances in weather technology, pilots are required to comprehend a large variety of weather products and sources (Lanicci, 2012; Shappell, 2012). However, aviation weather research indicates that GA pilots lack the understanding and appreciation of weather-related concepts, products, and sources (Cobbett, Blickensderfer, & Lanicci, 2014; NTSB, 2005). The next section discusses the aviation weather knowledge and skills that are required for aeronautical flight.

Aviation Weather Knowledge and Skills

Throughout all phases of GA flight, pilots are required to make a number of weather-related decisions that will ultimately affect the outcome of the flight. For example, during preflight, pilots need to collect weather information from a variety of weather sources and products that inform these pilots about weather forecasts and conditions along their flight. The weather information that pilots collect at this time will influence aeronautical decision-making along the flight. Therefore, pilots' understanding of this type of weather-related knowledge is crucial to the overall success of the flight.

Lanicci et al. (2011) examined GA pilots' education and training of weather technology in the cockpit products (WTIC) and advocated that there were three different domains of aeronautical meteorological knowledge that pilots need to know. These knowledge domains are *weather phenomenology*, *weather hazard products*, and *weather hazard product sources*. Within each of these domains, there is a list of the necessary knowledge and skills that pilots are required to obtain in order to understand the complexity of weather on GA flight.

To gain a deeper understanding of GA pilots' aviation weather knowledge and skills, Cruit and Blickensderfer (2015) used a task analysis approach to determine what tasks are required for each phase of GA flight and then determined what type of knowledge and skills pilots need to have in order to effectively complete those tasks. Furthermore, Cruit and Blickensderfer (2015) categorized each task according to the Lanicci et al. (2011) domains of meteorological aviation knowledge. What was unique about this task analysis was that it included a comprehensive account of all phases of GA flight (e.g., preflight, taxi, take-off, climb, cruise, descent, and landing) in order to determine what weather-related tasks GA pilots were required to understand and then to illustrate both gaps in training and assessing GA pilots' knowledge and skills of these tasks. This aviation weather task analysis can be used to aid educators and test developers to assess GA pilots on required knowledge and skills throughout all phases of GA flight.

While it is clear that GA pilots need various levels of weather-related knowledge, it is unclear how much weather-related knowledge is needed to be an effective GA pilot. More importantly, more clarity is needed on how to accurately assess various levels and degrees of weather-related knowledge and whether the amount and type of weather-related knowledge predicts GA pilot performance. The next section discusses some of the limitations with respect to how GA pilots are currently assessed.

Limitations with the Current Assessment Strategy

Despite the evidence that GA pilots lack the understanding of meteorological knowledge, student pilots are still passing their private pilot certification exam (FAA Written Exam). Wiegmann, Talleur and Johnson (2008) investigated the relationship between students' lack of meteorological knowledge and skills and their pass rate on the FAA Written exam. The results concluded different issues with the exam that suggest that the FAA Written Exam is not predictive of GA pilots' actual weather-related knowledge and skills and may not be predictive of GA flight performance. For example, student pilots could pass the entire exam yet fail all of the weather questions. In addition, the weather questions only assessed a rote level of learning, which meant that students could memorize questions and answers from a study guide and then see those same questions and answers on the actual test. This leads one to speculate if those students who did pass the weather questions actually understood the material or if they only memorized the correct answers.

By including application/scenario level questions on the FAA Written Exam, this would allow for a deeper level of learning where students would conceptualize, apply, and correlate their weather knowledge and skills to future scenarios. The next section describes literature in support of a scenario-based exam for predicting future performance.

Scenario-Based Assessment to Predict GA Weather Performance

Existing literature in healthcare supports the argument that a scenario-based assessment captures a wider range of actual knowledge and is a better predictor of performance over a non-scenario assessment (Brailovsky, Charlin, & Beausoleil; Meterissian, 2006). Drawing from theories of expertise and decision-making (Ericsson & Smith, 1991; de Groot, 1978; Wiggins et al., 2004), a scenario-based assessment can create a contextualized environment where students draw from their actual weather knowledge and skills. Therefore, the researchers of the current study proposed a scenario-based weather exam to predict GA pilot performance.

Purpose of the study. The purpose of the current study was to design a scenario-based assessment that measured GA pilots' weather knowledge and skills and then to determine whether the scenario-based assessment was a better predictor of GA weather performance over a traditional, non-scenario-based assessment. The results of the study could guide government and industry officials in developing stronger assessment measures that capture more aviation weather knowledge and ultimately help to decrease the GA accident rate.

Hypothesized Models

The researcher predicted two models. The first model predicted that any relationship between pilots' scores on a traditional, non-scenario-based weather assessment and their aviation weather performance would be fully mediated by one's aviation weather experience (i.e., flight hours plus meteorological knowledge) and weather salience (i.e., how one is motivated by weather). The second model predicted that the relationship between pilots' scores on a scenario-based weather assessment and their aviation weather performance would be partially mediated by aviation weather experience and weather salience.

METHOD

Participants

Participants included a total of 90 GA pilots from a local flight school. The mean age of pilots was 22.1 years (*SD* = 2.7) and the average total flight hours for the participants were 73 hours (*SD* = 9.5). To be eligible to participate in this study, pilots had completed the necessary ground school education enabling them to take the FAA Written Exam to obtain a private pilot's certificate. This is consistent with the FAA requirements for private pilots-in-training to be eligible to take the FAA Written Exam (FAA, 2015).

Design/Setting

The current study used a predictive correlational, quasi-experimental design with four independent variables (i.e., *aviation weather experience*, *weather salience*, *traditional weather-related assessment* and *scenario-based weather-related assessment*) and one dependent variable (i.e., *aviation weather performance*). The study took place in the simulation building of the institution and the setting was equipped with a PC-based flight simulator station. Participants completed all independent measures through SurveyMonkey.com and completed the *aviation weather performance* in the flight simulator which used Lockheed Martin's software, Prepar3D (www.prepar3D.com).

Procedure

General Aviation pilots were sampled from various flight courses at their flight institution and then were scheduled to participate in the study. Participants completed a written portion (i.e., informed consent, demographic questionnaire, Weather Salience Questionnaire (Stewart, 2005), a traditional weather-related knowledge exam, a scenario-based, weather-related knowledge exam) followed by a 30 minute simulated weather-related performance measure. In order for the researchers to capture a more accurate representation of the participants' true weather-related knowledge, researchers asked participants to perform their best on all measures. Participants were given one hour to complete all written measures and one half hour to complete the simulated performance measure. The simulated performance measure was videotaped so that additional raters could evaluate the participants' performance. Finally, participants were debriefed after the study and were given $25.00 compensation for their time.

Measures

Aviation weather experience. To capture variance in GA pilots' weather expertise, we define *aviation weather experience* by how many hours participants have taken from a meteorology course (i.e., classroom hours over the semester per course) as well as how many flight hours flown. For example, if a pilot completed one semester of only one meteorology course (i.e., 48 hours of classroom training) and they accumulated 25 flight hours, their aviation weather experience score is equal to 73 hours. Although this method does not necessarily categorize different levels of expertise, it does help differentiate among GA pilots with various levels of weather training experience.

Weather salience questionnaire. The Weather Salience Questionnaire (WxSQ) is a 29-item survey that assesses the extent to which weather and climate are important in different aspects of people's lives (Stewart, 2005). Stewart (2005) suggests that individuals differ in how they perceive various weather and climate situations and that the degree of weather salience one holds could affect emotional responses and decision-making around weather-related events. One's degree of weather salience can also affect the way people use and seek out weather information (2005). Stewart et al. (2012) sampled 1465 individuals from around the United States and looked at the relationship between their scores on the Weather Salience Questionnaire and their climate zone of residence along with their weather-related attitudes and behaviors. Stewart et al. (2012) found that one's level of weather salience was positively related to the frequency these individuals sought out weather information from news reports, or online weather services.

The purpose of using the WxSQ for the current study was to examine the relationship between GA pilots' weather salience and their aviation weather expertise and GA pilots' weather salience and their scores on a weather-related *scenario-based assessment*. As previously mentioned, GA pilots have challenges using and interpreting some of the modern aviation weather technology along with seeking out additional weather information throughout their flight. We expected to see a positive relationship between GA pilots' *weather salience* and *aviation weather experience* as well as a positive relationship between GA pilots' *weather salience* and their scores on the *scenario-based weather-related assessment*.

Traditional weather-related assessment. The *traditional weather-related assessment* used for this study contains 21 multiple-choice questions that were selected from the Gleim® testing software for private pilots. The 21 questions were selected based on the Cruit and Blickensderfer (2015) aviation weather task analysis, which includes weather topics from preflight to landing, including a selection of the Lanicci et al. (2011) three domains of meteorological knowledge (i.e., weather phenomenology, weather products, and weather product sources). The question content in the *traditional weather-related assessment* was selected to match the question content in the *scenario-based weather-related assessment*. To obtain questions for the *traditional weather-related assessment*, the researchers logged into the Gleim® software test bank and selected, "private pilot." Then the researchers chose to only view "aviation weather" questions, producing a total of 167 randomly generated questions. Then, the researchers selected questions that contained an equal amount of weather phenomenology, weather products, and weather product sources. Subject matter experts then approved these questions.

Scenario-based weather assessment. The *scenario-based weather assessment* is a 21-question exam that was developed using the Cruit and Blickensderfer (2015) GA weather task analysis. This scenario-based exam assesses the GA pilot's ability to think through a scenario and apply their knowledge of aviation weather to solve for the best answer to the question. The 21-question assessment is designed to replicate chronologically, the steps a pilot would take to solve a variety of weather-related tasks during any given flight (preflight-landing phases of flight). The goal of the scenario-based test is to draw from a larger pool of pilots' weather-based knowledge, through utilizing scenario-based questions, in order to determine whether a scenario-based exam could better predict GA pilot performance over a traditional, multiple-choice test. It is important to note that all questions on the scenario-based exam were validated with subject matter experts, which included flight instructors and meteorologists.

Aviation weather performance. During a typical GA Checkride, a flight instructor assesses GA pilots on various task requirements. Some of these tasks include the pilots' ability to perform during weather scenarios. However, since weather is variable, student pilots often lack a comprehensive assessment of weather-related tasks from preflight through landing phases of the flight. Therefore, for this study, researchers developed a simulated aviation weather performance measure that assessed how well GA pilots performed weather-related tasks during all phases of flight. The *aviation weather performance* measure was developed to assess private pilots' aviation weather knowledge on multiple weather-related tasks from preflight through landing. This measure was divided into two phases: 1) An oral assessment, which simulates aviation weather tasks of the preflight phase of flight and 2) A flight simulation exercise simulating aviation weather tasks from the taxi phase of flight through the landing phase.

Human Raters

Three human factors professionals independently rated items on the *aviation weather performance* measure. Each rater was first trained on the measure by the primary researcher. Before independently coding GA pilots' performance, the raters jointly analyzed a sample of 5 participants to establish a thorough understanding of the evaluation tool. After the joint rating session, the data from the 5 participants were replaced in the original 90-sample dataset and then each rater watched 30 videotaped performances of the GA pilots in the simulator and independently rated the measure. Cohen's Kappa revealed a high level of consistency between raters A and B; $k = .78$, $p \leq .05$ and a high level of consistency between raters A and C; $k = .83$, $p \leq .05$.

RESULTS

The results of this study are explained in two sections. The first section explains the results of the hypothesized models with Baron and Kenny's (1986) test for mediation and the second section explains the relationships among the variables using Pearson's Correlation.

Hypothesized Models

A multiple regression analysis using Baron and Kenny's (1986) test for mediation was used to test both hypothesized models. Results for Model One were non-significant; b = .08, t(89) = .45, p > .05, meaning that the *traditional weather-related assessment* was not a strong predictor of *aviation weather performance* and neither *aviation weather experience* nor *weather salience* mediated the relationship.

The results for Model Two suggested that the *scenario-based assessment* was a stronger predictor of *aviation weather performance* than the *traditional weather-related assessment*; b = .89, t(89) = .10.50, p ≤ .001 and the *scenario-based assessment* predicted a significant portion of the variance in *aviation weather performance*; R^2= .56, F(1, 88) = 109.18, p ≤ .05. Additionally, only one of the hypothesized mediators (i.e., *aviation weather experience*) was a significant predictor of scores on the *scenario-based assessment*; b = .067, t(89) = .36, p ≤ .001. However, when the *scenario-based assessment* and *aviation weather experience* were both added to the regression model, *the scenario-based assessment* predicted 56% of the variance in *aviation weather performance* (R^2= .56, F(1, 88) = 55.23, p ≤ .001) and *aviation weather experience* did not mediate the relationship between the *scenario-based assessment* and *aviation weather performance*.

Pearson's Correlation

Table 1 shows the results of Pearson's correlation among the variables. The next section discusses the highlights of these results.

Table 1:

Pearson's Correlation Matrix of Variables

Variable	1. Traditional	2. Scenario-Based	3. Experience	4. Weather Salience	5. Performance
1.	1	-.13	-.22**	.03	.05
2.	-.13	1	.39**	.26*	.74**
3.	-.22*	.39**	1	.17	.36**
4.	.03	.26*	.17	1	.18
5.	.05	.74**	.36**	.18	1

** Correlation significant at the .001 level
* Correlation significant at the .05 level

DISCUSSION

The purpose of this study was to design a scenario-based weather assessment to test GA pilots' weather knowledge and then determine whether that scenario-based assessment better predicted GA pilot performance over the FAA Written Exam. The aviation weather literature supports the need for a GA pilot weather assessment that captures a deeper level of expertise through scenario or application type questions. The results of this study suggest that a scenario-based exam was in fact a better predictor of GA pilot performance compared to a traditional aviation weather assessment. The following sections highlight the results of the study and how each measure played a role in the outcome of the study.

Traditional Weather Assessment

Participants' scores on the *traditional weather-related assessment* did not predict their *aviation weather performance* scores. This finding supports the literature (Wiegmann et al., 2008) suggesting private pilots can score high on the FAA Written Exam while not fully understanding weather phenomena and the implications of weather for their flight. Surprisingly, there was a significant, negative relationship between *aviation weather experience* and scores on the *traditional weather-related assessment*. This finding implies that as pilots become more experienced in aviation weather, they perform worse on the *traditional weather assessment*. If the traditional weather assessment is only measuring a rote level of learning and if student pilots can memorize all of the questions and answers to the private pilot exam's study guide, there is most likely some type of memory decay occurring as evident by these results. That is, lower experience level pilots may perform better on the *traditional weather assessment* if they have recently studied for or taken the FAA Written Exam.

Scenario-Based Weather Assessment

Scores on the *scenario-based weather assessment* positively correlated with *aviation weather experience* which suggests that as one becomes more knowledgeable in aviation weather, the better they will perform on the *scenario-based weather assessment*. Furthermore, the *scenario-based assessment* was the single best predictor of *aviation weather performance* scores over all other predictors. This indicates that the *scenario-based weather assessment* is capturing a larger variety of aviation weather knowledge from pilots at varying levels of aviation weather experience. Compared to the *traditional weather assessment*, the *scenario-based weather assessment* can be used to determine in what areas pilots may need more training. And because the *scenario-based weather assessment* divides the exam into different sections (i.e., preflight through landing), it can make it easier for instructors to give feedback to their students in the areas in which they need more training or education. For example, during the *enroute* portion of the *scenario-based weather assessment*, there is a question that tests the student pilot on their knowledge of how to read both satellite imagery and weather radar for a specific location along the pilot's flight path. If the student pilot is only able to read the satellite imagery but not the radar, it suggests that the pilot needs more training on how to read one product over the other.

Ultimately, the results from the *scenario-based weather assessment* suggest that it is a stronger measure than the current method used for assessing aviation weather knowledge on the FAA Written Exam. If a scenario-based assessment was implemented as the type of test used in the FAA Written Exam for private pilots, it could prevent students from passing the exam who lack the weather knowledge needed to safely maneuver a flight through weather events.

Weather Salience Questionnaire

The sample of 90 student pilots scored below average (compared to the general population) on all 29 questions of the *Weather Salience Questionnaire* as well as the seven subscales for the measure. Additionally, the *Weather Salience Questionnaire* did not have a significant relationship with any of the measures except the *scenario-based weather assessment*. However, the low reliability of this measure calculated with our sample ($\alpha = .63$) suggests that any of the results from this study, with respect to *weather salience*, should be considered lightly. Two conclusions can be drawn about these results. First, the questions on the *weather salience measure* are outdated with respect to technology. Some of the questions refer to using the radio or television to check weather information when it is most likely that our sample of young pilots uses their smart phones or tablets to gather weather information. Second, anecdotal evidence suggests that this sample of student pilots as well as other student pilots do not particularly appreciate weather or weather phenomena. Weather is often associated with a canceled flight, a difficult concept to grasp, or a dangerous situation that could lead to fatalities. All of these reasons could be possibilities for the low weather salience scores. Future studies could develop a stronger and more updated weather salience measure specifically for pilots.

Aviation Weather Performance

The main focus of the *aviation weather performance measure* for this paper is with respect to how well each of our predictors accounted for the variance in *aviation weather performance*. As previously mentioned, the *scenario-based weather assessment* and *aviation weather experience* did contribute to a significant portion of the variance in *aviation weather performance*. However, an interesting finding was that when both the *scenario-based weather assessment* and *aviation weather experience* were added to the regression model, only the *scenario-based weather assessment* contributed to the variance in *aviation weather performance*. This indicates that the *scenario-based weather assessment* is a stronger predictor of GA pilot weather performance than the traditional exam that is currently used. The impact of these results lends guidance for both the aviation industry and aviation educators with respect to assessment design and aviation weather training. These results indicate that when an assessment is designed to include scenario-based or application type questions that require the student pilot to remember from experience and use their knowledge of aviation weather to problem-solve, the student's score on the scenario-based assessment is more representative of their actual aviation weather knowledge and thus aviation weather performance.

CONCLUSION

The results of the study illustrate that a scenario-based exam is a better predictor of aviation performance when compared to the traditional, FAA Written Exam. Furthermore, more experienced pilots performed better on both the *scenario-based weather assessment* and *aviation weather performance* than less experienced pilots. These findings suggest that with more aviation weather training, pilots' decision-making will improve during an actual weather event. In addition, if a scenario-based assessment is used to certify private pilots, it can help identify those pilots who are having difficulties understanding weather and weather technology and aid in developing better weather training programs, targeted at increasing GA pilots' weather knowledge and skills. Ideally, the results of this study can spark awareness with government and industry officials on the importance of capturing a more realistic level of GA pilots' weather knowledge through a scenario-based assessment in order to develop a richer level of knowledge so that all GA pilots have the education and tools to make well-informed decisions during weather-related situations.

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