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AN INVESTIGATION OF THE FACTORS THAT CONTRIBUTE TO PILOTS' DECISIONS TO CONTINUE VISUAL FLIGHT RULES FLIGHT INTO ADVERSE WEATHER

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Pilots' decisions to continue or divert from a visual flight rules flight (VFR) into instrument meteorological conditions (IMC) were investigated using a dynamic simulation of a hypothetical cross-country flight. Issues related to decision-making were investigated. Specifically, differences in situation assessment, risk perception and motivation, between pilots who chose to continue or divert from a VFR flight into IMC situation were examined. Results indicate that the simulation was successful in identifying pilots who would choose to either continue or divert and that differences existed between these two groups of pilots. Accuracy of visibility estimates, appraisal of one's own skill and judgment and frequency of risk-taking behavior were most important in predicting whether a pilot would continue or divert from a VFR flight into IMC situation. Findings suggest that overconfidence in personal ability and inaccurate diagnoses of visibility conditions precipitate VFR flight into IMC.

INTRODUCTION

Aviation accident statistics from the US and other countries (e.g., United Kingdom and New Zealand) (O'Hare & Owen, 1999) indicate that accidents involving visual flight rules (VFR) flight into instrument meteorological conditions (IMC) pose a major safety hazard in general aviation (GA). Goh and Wiegmann (2001) found that between 1990 and 1997, 75% of these accidents were fatal compared to only 18% of other types of GA accidents.

Explanations for why VFR pilots risk flying into deteriorating weather have focused on pilot decision-making. O'Hare (1992) has recognized that good decision-making is necessary to maintain safety in aviation and other authors (e.g., Jensen & Benel, 1977; O'Hare, Wiggens, Batt, & Morrison, 1994; Wiegmann & Shappell, 1997) have also found that fatal aviation accidents are more often associated with decision errors than minor accidents. This study will, therefore, examine the multiple factors that may affect pilots' decisions to continue VFR flight into IMC.

Possible Factors Contributing to VFR Flight Into IMC

Situation assessment. Pilots may inadvertently fly into adverse weather because they make inaccurate assessments of the weather conditions. Research on Naturalistic Decision-Making (e.g., Zsambok & Klein, 1997) has shown the importance of situation assessment and Wiegmann and Shappell (1997) have also found that diagnostic errors accounted for approximately 22% of the flight and flight related mishaps in the U.S. Navy and Marine Corps that were due to human error, and that these accidents were more serious than those which were related to aircraft handling errors.

Risk perception. Despite an accurate assessment of weather conditions, pilots may also continue with a flight into deteriorating weather because they do not appreciate the risks involved in doing so. The U.K. Civil Aviation Authority (1988) has cited "reluctance to admit limited capability", and "lack of appreciation of real dangers" as factors associated with pilot errors that lead to weather related accidents. O'Hare (1990) has also found that GA pilots tended to exhibit low levels of risk awareness, and higher than average self-appraisals of skill and judgment in flying. These findings suggest that risk perception should be addressed in any investigation of VFR flight into IMC.

Motivational factors. Motivation may also bias pilots to fly into adverse weather conditions. These pilots may experience "Get-home-it-is" or other personal or social pressures to complete the flight. These pressures may constitute a part of what McCoy and Mikunas (2000) consider as the "context" that leads to Plan Continuation Errors or "a tendency to adhere to the original plan that interferes with critical analysis, with the ability to evaluate acceptability of the original plan over time, and with the exploration of alternatives".

Limitations of Previous Research

The above factors point to failures at different stages of the decisional process and it would, thus, be logical to examine the relative contribution of these factors to a pilot's decision to continue or divert from a VFR flight into IMC situation. Unfortunately, existing studies of have investigated the factors either in isolation (risk perception in O'Hare 1990; motivation in O'Hare & Smitheram, 1995) or not at all (situation assessment).

The results from existing studies have also been based on static simulations of cross-country flights. These static simulations do not represent the true workload conditions involved in encountering a VFR into IMC situation. It is under such high workload conditions that errors in decision-making arise (e.g., Wright, 1974), and a valid method of investigation would require these conditions to be simulated.

The purpose of the present study, therefore, was to investigate the extent to which situation assessment, risk perception and motivation affect pilots' decisions to continue or divert from adverse weather, using a dynamic simulation of a VFR flight into IMC situation in which weather-related factors change over time.

METHODS

Thirty-two non-instrument rated pilots (age: 18 to 47 years; Mdn=19 years) from the University of Illinois' pilot training program participated in the study. The median total VFR flight experience of the 32 pilots was 60 hrs (range: 30 to 259.4 hrs). All pilots had flown at least one cross-country flight (Mdn=3; range=2 to 13) at the time of the study. Only 14 pilots had actual instrument flight rules (IFR) experience and this ranged from 0.3 to 10 hours.

Participants first completed the pre-experimental questionnaire to assess their impression of their own skill and judgment and risk of flying in adverse weather (O'Hare, 1990). They were then asked to fly two routes using a dynamic, PC-based flight simulation. A Pentium III 450 MHz computer with 320mb RAM was used to run the X-Plane Version 5.01 (Laminar Research Inc.) flight simulation program. Participants used a yoke and rudder pedals to interact with the program. The X-Plane program allowed real time programmable weather, including the selection of cloud ceiling, visibility, wind direction and wind speed. The program also allowed the inclusion of any airport in the world into the simulation. Different types of terrain and real-world structures could also be created. The collection of various flight parameters including altitude, distance traveled and airspeed was also possible.

The first route the pilots had to make was a practice flight to allow familiarization with the controls. The second, experimental flight was a solo cross-country flight from Champaign airport to Illinois Valley Regional airport. They were to imagine this flight was a part of their training required to earn a private pilot's license. In both flights, participants were provided with a map, flight plan and weather information. Flight planning preceded each flight and participants were given as much time as they needed for this.

Participants flew the routes on a Cessna 172 in the simulation. The participants were told to treat the experimental flight as they would any other flight and that while they were to be aware of any possible mechanical failures, weather changes or traffic, these might not necessarily occur. Participants were instructed to toggle a pre-determined switch should they decide to divert for any reason.

Weather conditions at take-off were just above VFR conditions (5 miles visibility, 5000ft mean sea level (msl) cloud ceiling, overcast) until approximately 45 minutes into the flight when conditions deteriorated to below VFR minimums (2 miles visibility, 1500ft msl cloud ceiling). At this point, participants were given a 5-minute window to decide whether to discontinue the flight. If the participant continued flying at the end of the 5-minute window, he/she was considered to have made the decision to continue with the flight. In either case, the simulation was terminated at this point in the flight and participants were asked to complete the post-experimental questionnaire to assess their impressions of the weather and flight environment.

RESULTS

Decision to Continue or Divert

Of the 32 participants, 22 (68.75%) chose to fly into the deteriorating weather, while 10 (31.25%) chose to divert. These proportions exceeded chance expectations as revealed by a Chi-square analysis, $\chi^2(1)=4.5$, $p<.05$, suggesting that pilots in the present study, on average, were more likely to continue than divert the flight.

Self-Judgment

Using a seven point Likert scale, participants provided self-ratings of their skill and judgment, their willingness and frequency of taking risks on both the pre- and post-experimental questionnaires. The pre-experimental questionnaire asked participants to rate these items compared to the "average" pilot in general, while the post-experimental questionnaire items required participants to do the same but within the context of the specific flight scenario they had just encountered in the experiment. High scores indicate a higher self-rating on each item, with a score of 4 indicating a self-rating of "average".

A $2 \times 3 \times 2$ mixed ANOVA was used to analyze participants' responses to these questions. Decision Group (continue vs. divert) was a between-groups factor. Both Question Type (skill level, willingness to take risks, and risk taking frequency) and Questionnaire (pre vs. post) were within-subjects factors. Results of this analysis revealed a significant Decision Group × Question Type interaction, $F(2,30)=5.18$, $p<.01$ (see Figure 1). Pilots in the continue-group had significantly higher self-ratings of skill and judgment ($M=4.64$, $SD=.5$) than subjects in the divert group ($M=4.25$, $SD=.49$), $t(30)=2.05$, $p<.05$, and while those in the continue group tended to have higher ratings of their willingness to take risks ($M=3.85$, $SD=.87$ vs. $M=3.35$ $SD=.94$), this difference was not significant, $p>.05$. Finally, participants in the continue-group tended to rate themselves as slightly less-frequent risk takers ($M=2.94$, $SD=.89$) than participants in the divert-group ($M=3.5$, $SD=.88$), but this difference was not significant, $p>.05$.

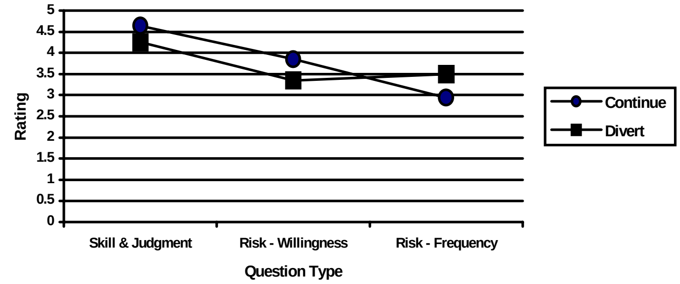

Figure 1. Ratings on skill and judgment, willingness to take risks, and frequency of risk taking as a function of Decision Group.

Hazard Awareness

Participants estimated the likelihood that, given an accident had occurred, it would have been the result of a specific "causal factor". They made these estimates for both accidents in general ("General") and a hypothetical accident in which they might be involved personally ("Personal") in the future. For simplicity, participants made these estimates based on percentages, but these were converted to likelihood estimates, which range from 0 to 1, in the analyses. Graphical depictions of the "weather" and "pilot error" likelihood estimates, which are of particular interest to the present study, are presented in Figures 2 and 3, respectively.

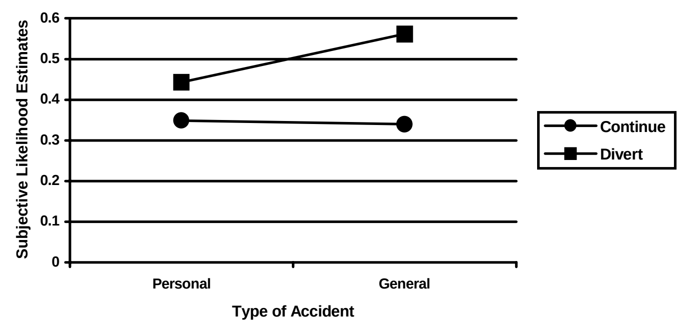

Figure 2. Mean likelihood estimates that an accident would have been caused by "weather" as a function of Group and Type of Accident.

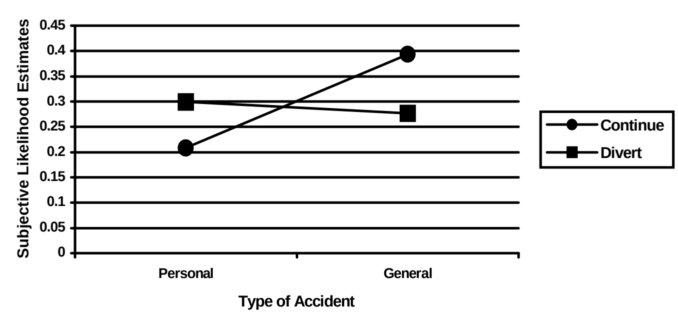

Figure 3. Mean likelihood estimates that an accident would

have been caused by “pilot error” as a function of Group and Type of Accident.

Weather. A 2 (Decision Group) × 2 (Type of Accident: Personal vs. General) mixed ANOVA was used to analyze participants’ estimates pertaining to the “weather” factor. This analysis revealed a significant main-effect for Group, $F(1,30)=4.436$, $p<.05$. Pilots in the divert-group had higher estimates of the likelihood that weather would be a cause of an accident ($M=.50$, $SD=.23$) than pilots in the continue-group ($M=.34$, $SD=.18$). The difference between groups was slightly larger for the “general” variable than the “personal” variable but no significant interaction was observed.

Pilot error. A 2 (Decision Group) × 2 (Type of Accident: Personal vs. General) mixed ANOVA was also performed to analyze participants’ estimates of the likelihood that pilot error would be a cause of an accident. Figure 3 shows the participants’ responses. A significant interaction between these factors, $F(1,30)=6.345$, $p<.05$ was found. The divert-group estimated that “pilot error” was equally likely to be the cause of an accident, whether they were personally involved or not ($M=.277$, $SD=.21$ for general and $M=.299$, $SD=.19$ for personal), while those in the continue-group rated pilot error as significantly more likely to be a cause of accidents in general ($M=.393$, $SD=.24$) than if they were personally involved ($M=.208$, $SD=.19$), $t(21)=3.763$, $p<.01$. As a result, pilots in the continue-group had somewhat lower estimates than pilots in the divert-group on the “personal” variable, but slightly higher estimates on the “general” variable; however, these between-group differences were not statistically significant.

Situational Assessment of Weather Conditions

Analyses were based on how much the pilots’ estimates deviated from the actual conditions. A negative value would indicate an underestimation of the conditions (thinking conditions are worse than they actually are), while a positive value would be an overestimation (thinking conditions are better than they actually are). The mean differences between actual and estimated visibility and cloud ceiling as a function of decision group is presented in Table 1.

Table 1. Mean Differences Between Actual and Estimated Visibility and Cloud Ceiling as a Function of Decision Group

	Continue		Divert	
Weather parameter	M	SD	M	SD
Visibility (nautical miles)	1.41	1.05	0	1
Cloud Ceiling (feet)	2269.5	1206.45	2212.5	994.9

Overall, a significant proportion of the participants ($n=21$) overestimated the visibility ($\chi^2(2)=16.71$, $p<.001$), as well as cloud ceiling, $n=27$, ($\chi^2(1)=24.14$, $p<.001$). A Mann-Whitney test revealed, however, that the continue group’s visibility estimates were significantly higher than divert group’s estimates ($U=33$, $p<.01$). Group differences in cloud ceiling estimates were not significant, $p>.05$.

DISCUSSION

The simulation used in the present study was successful in identifying pilots who would continue and those who would divert in a VFR flight into IMC scenario. The results also suggest that these two groups of pilots have different profiles in terms of confidence in their own skill and judgment, willingness to take risks and frequency of risk taking behavior, estimates of pilot error and weather as hazards in general aviation, and accuracy of situation assessment.

The ratings on skill and judgment and willingness to take risks, suggest that the pilots who continued had greater confidence in their piloting abilities and were hence more willing to fly into the deteriorating weather than the pilots who chose to divert. Since no actual differences in experience and training were observed between the groups of pilots who chose to continue or divert, the differences in self-judgment on skill and ability appear to reflect differences in self-awareness or metacognitive estimates of one’s own abilities. Indeed, Goh and Wiegmann’s (2001) analysis of GA accident records from the NTSB suggest that overconfidence may be a factor or cause that is unique to VFR flight into IMC accidents. The authors found that approximately 7.5% of VFR flight into IMC accidents had “Overconfidence in personal ability” cited as a factor or a cause, but this was true for only less than 1% of other types of GA accidents. Also, in an empirical investigation, O’Hare and Smitheram (1995) found that pilots who continued their flight into adverse weather rated themselves more highly on skill and judgment than those who did not. Together, these findings suggest that pilots who continue flight into adverse weather lack an appreciation for the risks involved in their actions, and this could stem from overconfidence in their flight skills.

The results on hazard awareness indicate that the pilots who continued judged weather and pilot error as less likely threats to flight safety than the pilots who diverted. In addition, the pilots who continued thought they were less vulnerable to pilot error and weather problems than the general pilot population. Together with a less accurate assessment of visibility conditions, it is not surprising that this group of pilots continued into the deteriorating weather.

In summary, the above findings suggest that pilots who continued VFR flight into IMC made errors early in the decision making process in the form of inaccurate assessments of visibility, and this was compounded by other factors such as their greater willingness to take risks, greater confidence in their flight skills, and a reduced sense of vulnerability to weather hazards and pilot error.

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