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VISUAL FLIGHT RULES (VFR) FLIGHT INTO INSTRUMENT METEOROLOGICAL CONDITIONS (IMC): A REVIEW OF THE ACCIDENT DATA

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ABSTRACT

General Aviation (GA) accident statistics indicate that visual flight rules (VFR) flight into instrument meteorological conditions (IMC) is a major safety hazard within general aviation. Little research has been conducted to identify the factors that influence VFR pilots' decisions to risk flying into deteriorating weather. As accident reports provide a naturalistic source of such information, this paper presents an analysis of 409 GA aircraft accidents involving VFR flight into IMC that occurred between 1990 and 1997. Fatality rates, pilot demographics and accident cause-factors are highlighted and compared to other GA aircraft accidents. Theoretical and practical implications are discussed.

INTRODUCTION

General aviation accidents involving VFR flight into IMC accounted for approximately 19% of all GA fatalities in the United States between the mid-1970s and mid-1980s (NTSB, 1989). However, 72% of these VFR flight into IMC accidents were fatal, compared to an overall GA accident rate of 17% during this same time period. The GA accident records in other countries (e.g., United Kingdom and New Zealand) also indicate that VFR flight into IMC is a major safety hazard within general aviation (O'Hare & Smitheram, 1995).

Unfortunately, research into the factors affecting pilots' decisions to fly into adverse weather is scant. Nonetheless, a variety of possible explanation for VFR flight into IMC have been proposed in the literature, several of which provide legitimate hypothesis that might be tested using either laboratory or archival (i.e., accident database) research. These include situation assessment, risk perception, decision framing, and social pressure.

Situation assessment. According to the situation assessment hypothesis, pilots risk pressing on into deteriorating weather simply because they do not realize that they are doing so. In other words, pilots continue VFR flight into IMC when they misdiagnose the changes in, or severity of, the weather. Presumably, had they known that the weather was deteriorating into IMC, they would not have flown into it. A growing number of researchers have found that situation assessment and awareness are the most important aspects of good decision making processes in dynamic problem solving situations (Klein, 1989; Klein & Klinger, 1991). For example, previous research on information processing failures in aviation (O'Hare, Wiggins, Batt, & Morrison, 1994; Wiegmann & Shappell, 1997) have shown that errors early in the process (e.g., diagnostic errors) result in more serious accidents than errors made later in the process (e.g., handling errors). The loss of situational awareness that precipitates a "VFR into IMC" event may be due to a variety of reasons including a lack of experience interpreting real-time weather by low-time or "fair weather" pilots. Another reason may be the gradual transition from minimum VFR conditions, to marginal VFR conditions, to IFR weather that could make discriminations between weather conditions difficult. In general, then, VFR flight into IMC can be seen as a failure of recognition-primed decision making (Klein, 1993).

Risk perception. Another explanation for why pilots would continue VFR flight into IMC is that pilots are overconfident in their abilities and do not fully appreciate the risks of flying into adverse weather. Indeed, much of pilot training involves teaching pilots to feel confident in their ability to control the aircraft in all flight regimes. However, an unfortunate by-product of this training may be a degree of overconfidence in one's skill level and an unrealistic optimism about the chances of avoiding harm through personal control. Several studies have shown that people tend to rate their chances of being involved in an accident much lower when the threats are perceived as being controllable by personal actions. Indeed, a report by the U.K. Civil Aviation Authority (1988) cited several psychological factors contributing to pilot errors related to weather conditions which included "excessive optimism," a "reluctance to admit limited capability," and "lack of appreciation of real dangers". O'Hare (1990) obtained similar findings using the Aeronautical Risk Judgment Questionnaire (ARJQ) which was developed to obtain data on pilots' perceptions of their abilities, willingness to take risks, and hazard awareness. The results of the ARJQ indicated that general aviation pilots exhibited both relatively low levels of risk awareness and generally high optimistic self-appraisals of abilities and judgment.

Decision framing. In essence, continued VFR flight into IMC can be regarded as equivalent to a risky gamble involving chances of success or disaster. The decision to divert or make a precautionary landing, on the other hand, can be regarded as leading to a somewhat certain outcome. According to the decision-framing perspective, the choice pilots will make under these circumstances depends upon how the problem is represented and what frame is used to interpret the situation. If pilots frame their decision of whether to continue flight into deteriorating weather in terms of potential losses of diverting (such as time wasted, money spent, or fuel used up), then they will be more likely to be risk-seeking in their choices. In contrast, if pilots frame the decision to divert in terms of anticipated gains (such as ensuring the safety of the aircraft and its occupants), then they should be more likely to act in a risk-averse manner. Indeed results of a laboratory study by O'Hare and Smitheram (1995) showed that decisions to continue a VFR flight into adverse weather conditions were less likely when the prospects or possible outcomes were framed in terms of gains rather than as losses. These researchers have suggested that in a real world flight environment, decision frames may be induced by the proximity of the pilots' goals, such as the destination airport. As goal achievement gets closer, there may be a natural shift to the loss frame when bad weather is encountered, resulting in an increase in "get-home-itis" or what is also known as the "sunk cost" effect.

Social pressure. Similar to decision-framing, social pressures may bias pilots' decisions to continue with a flight even though an assessment of the situation suggests they should do otherwise. In the case of VFR into IMC flights, pilots may feel pressured to reach their destination sooner rather than later when passengers are onboard. In addition, they may also feel the need to impress passengers with their flight skills, especially when faced with difficult flight conditions. Indeed, O'Hare and Smitheram (1995) have noted that there are "numerous examples in the air crash files of low flying 'beat ups' and 'buzzing' that have led to disaster that would not have occurred without the presence or anticipated presence of an audience to observe the maneuvers." However, the extent to which social pressures play a role in VFR flight into IMC has yet to be fully examined.

Purpose of the Present Study

To date, very few studies have been conducted to empirically examine the plausibility of these different accident causation theories, in terms of their ability to account for the actual factors that contribute to VFR flight into IMC accidents. Consequently, without such an empirical understanding of these factors, decision-making training within pilot training programs continues to be based largely on common sense and intuition. Not surprisingly, such programs have been relatively ineffective in reducing the occurrence of these accidents.

While laboratory experiments present one method of investigating the conditions surrounding VFR flight into IMC in a controlled environment, accident reports offer useful insights from "real world" data as well. Indeed, the NTSB has an accident classification system that classifies VFR flight into IMC events, thus allowing the direct identification of the probable causal factors associated with these accidents. Still, few studies have been conducted to examine this dataset since the original report published by the NTSB in 1989. Therefore, the purpose of the present study was to further examine the actual characteristics and causes of accidents involving VFR flight into IMC in light of the possible theoretical explanation of these events postulated in the literature.

METHOD

Case Selection and Sampling

VFR flight into IMC cases (VFR-IMC sample). A comprehensive review of all accidents involving Code of Federal Air Regulations (FAR) Part 91 aircraft between January 1990 and December 1997 was conducted using database records maintained by the NTSB and the FAA. Of particular interest to this study, were those accidents attributable to VFR flight into IMC. The analysis was also limited to fixed wing, general aviation airplanes and therefore excluded helicopters, gliders and experimental aircraft. Of these, only those accidents in which the investigation was completed, and the cause of the accident determined, were examined. A total of 409 accidents met these criteria for further analysis.

Other GA aircraft accidents (GA sample). To identify any unique characteristics of VFR-IMC accidents, the data from these accidents was compared to other non-VFR-IMC accidents. The accident database structure allowed for some global comparisons to be made using the entire dataset, however, other more detailed comparisons could not be extracted readily from the database. Therefore, a stratified proportionate sampling method was used to select 409 GA aircraft accidents for making these comparisons. This sample was stratified proportionately according to the year and state in which the VFR into IMC accidents had occurred, in order to ensure that the two groups of accident types

(VFR-IMC vs. GA sample) were matched in terms of time and location of occurrence.

RESULTS

Accident Frequency and Fatality Rates

Between 1990 and 1997, approximately 50 general aviation (GA) aircraft accidents were classified each year by the National Transportation Safety Board as being the result of visual flight rules (VFR) flight into instrument meteorological (IMC) conditions. While this number did not constitute a large proportion of the approximately 1900 GA aircraft accidents each year during the same time period, the risk of incurring fatal injuries was higher in the VFR-IMC accidents.

As seen in Figure 1, fatality rates for VFR flight into IMC accidents and other GA aircraft accidents remained relatively constant over the 8-year period. More importantly, the fatality rates of VFR flight into IMC accidents (approximately 80%) were also consistently higher than that of other GA aircraft accidents (approximately 19%) during that time period.

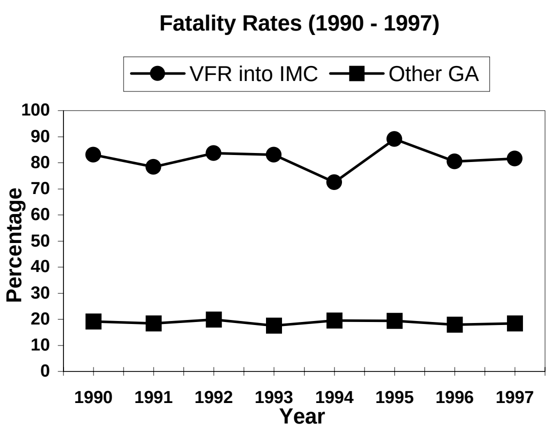

Figure 1. Fatality rates of VFR flight into IMC accidents and other types of GA aircraft accidents that occurred in 1990-1997.

Categories of VFR-IMC Accidents

Within the NTSB classification system, VFR flights into IMC are further categorized into various types. These include: (1) Continued, (2) Inadvertent, (3) Attempted, (4) Performed, (5) Intentional, (6) Initiated, (7) Encountered, and (8) Unclassified. The 409 VFR-IMC accidents identified in this study consisted of 149 continued, 92 inadvertent, 57 attempted, 45 performed, 34 intentional, 23 initiated and 6 encountered. Three cases were not further classified in this sample. It should be noted that all but two of these categories (i.e., inadvertent and encountered) suggest that the intent of the pilot was anything other than a "willful" penetration or continuation of the flight. When combined, these inadvertent and encountered VFR-IMC accidents accounted for 24% of the cases.

Factor-Causal Categories

In a previous report on VFR flight into IMC accidents that occurred in the mid-1970s to mid-1980s, the NTSB (1989) classified the factors/causes that were cited in these accidents under five broad categories. These categories were: (1) Aircraft, (2) Facility, (3) Environment, (4) Flightcrew, (5) Other Person.

Table 1 provides a breakdown of the percentages of VFR-IMC accidents in the present study that had at least one causal factors from each of these five causal categories. A general description of these categories, and a summary of some of the factors/causes subsumed under these categories is also included. As can be seen from the table, the largest percentage of VFR-IMC accidents in this study involved casual factors associated with the Environment, followed by Flightcrew, and finally Aircraft and Other Person. None of the VFR-IMC accidents had causal factors associated with Facility.

Table 1. Examples of factors/causes subsumed under categories used in NTSB (1989).

Categories and Examples of Factors/Causes
Aircraft (0.5%): factors/causes related to physical problems with the aircraft *e.g., fluid, fuel, vacuum system, flight/navigation instruments, landing gear, fuselage*
Facility (0%): factors/causes related to the facilities and other tools used by pilots *e.g., airport navigation aids, enroute charts*
Environment (69.2%): factors/causes related to weather or objects in the environment *e.g., terrain condition, light condition, runway light*
Flightcrew (23.7%): factors/causes related to activities the flightcrew has to perform. The activities are grouped under the following sub-categories *e.g., obtaining and using weather information, aircraft handling, planning and decision-making*
Other Person (0.5%): factors/causes that result from or involve the errors committed by other people *e.g., preflight briefing service, meteorological service, radio communication*

Top 10 Factors-Causal

Table 2 shows the top 10 factors/causes of the 409 VFR flight into IMC accidents in our study, in terms of the proportion of the accidents having these factors/causes.

Table 2. Top 10 factors/causes of VFR flight into IMC accidents in terms of the proportion of the accidents having these factors/causes

Factors/Causes	Category[1]	% Cases
Weather Conditions	E	69.2%
Terrain Conditions	E	24.9%
Spatial Disorientation	F/P	23.7%
Aircraft Control	F/A	23.2%
Light Conditions	E	23.0%
Lack of Total Instrument Time	F/T	15.9%
In-Flight Planning/ Decision	F/PD	12.7%
Preflight Planning/ Decision	F/PD	11.2%
Weather Evaluation	F/O	11.2%
Altitude/Clearance	F/A	8.1%

[1]E: Environment; F: Flightcrew; P: Psychological/Physiological; A: Aircraft Handling; PD: Planning/Decision-Making; O: Obtaining and Using Weather Information

Of the top 10 factors/causes, three (weather, terrain and light conditions) are from the "Environment" category, while seven are from the "Flightcrew" category. Of particular note, however, is the finding that the top three flight crew factors (i.e., spatial disorientation, aircraft control, and lack of total instrument time) pertain to the consequences or causes of the accident after the pilot had penetrated IMC. The remaining flightcrew factors pertain to errors made prior to encountering IMC, the lowest of which is weather evaluation.

To investigate whether the top 10 factors were unique to VFR flight into IMC accidents, the proportion of accidents associated with these 10 factors/causes were compared with that of the GA sample. Table 3 shows this comparison. A review of this table reveals that other GA accidents share four of the 10 top factors/causes of the VFR-IMC accidents. However, a larger percentage of VFR-IMC accidents are associated with these common causes/factors than other types of GA accidents. It should also be noted that "over confidence" did not make the top ten list of either type of accident, however, it did rank 11th for VFR-IMC accidents, accounting for approximately 7.5% of these accidents versus less than 1% of the GA sample.

Table 3. Proportion of VFR-IMC and GA samples with the top 10 VFR flight into IMC accident factors/causes.

Factors/Causes	VFR	GA
Weather Conditions[1]	69.2%	22.50%
Terrain Conditions[1]	24.9%	19.80%
Spatial Disorientation	23.7%	0.98%
Aircraft Control[1]	23.2%	6.40%
Light Conditions	23.0%	4.89%
Lack of Total Instrument Time	15.9%	0.50%
In-Flight Planning/Decision[1]	12.7%	5.90%
Preflight Planning/Decision	11.2%	4.90%
Weather Evaluation	11.2%	1.20%
Altitude/Clearance	8.1%	1.50%

[1]These factors are among the top 10 factors/causes related to accidents from the GA sample.

Pilot Factors

Pilot flight experience. A median test was performed on the total number of flight hours of accident pilots in order to explore whether pilots involved in VFR-IMC accidents and other sorts of GA accidents differed in terms of flight experience. Cases which had an entry of 0 hours for total flight hours were excluded from analysis, generating n=402 and n=397 for the VFR-IMC and GA samples respectively. The median flight hours for the VFR-IMC sample (Md=580hrs) was significantly lower than that of the GA sample (Md=900hrs), $p<.01$.

Pilot certification. No information pertaining to the possible instrument ratings of accident pilots was obtainable from the database. However, pilot certification was available for each pilot and was therefore used as an additional measure of pilot experience. A Chi-square analysis revealed a significant relationship between type of accident and pilot certification. A larger proportion of pilots involved in VFR-IMC accidents (n=293, 71.6%) had only private pilot's licenses or below (e.g., student license) than pilots involved in other types of GA accidents (n=237, 57.9%), whereas a larger proportion of pilots involved in other types of GA accidents (n=172, 42.1%) had certifications above private pilot (e.g., commercial) than pilots involved in VFR-IMC accidents (n=116, 28.4%), $\chi^2(1)=16.81$, $p<.01$.

Other Factors

Presence of passengers. The presence of passengers in the aircraft was also examined and used as an indicator of social pressure. The hypothesis was that pilots carrying passengers may feel greater pressure to reach their destination or demonstrate their skill, and hence are more likely to engage in VFR-

IMC. The results indicate that a significantly higher proportion of VFR-IMC accidents (n=222, 54.3%) had passengers than other types of GA accidents (n=183, 44.7%), whereas the reverse was true when considering accidents with no passengers, $\chi^2(1)=7.4$, $p<.01$.

Phase of flight. The exact location of the accidents in terms of their distance from the departure and destination airports was not available in the database. Therefore, the phase of flight in which the accidents occurred was used as a crude estimate of how far into the flight the pilot had flown or, at least, the relative proximity to the destination airport. This analysis was performed to examine whether motivational or cognitive framing factors might lead to greater risk taking behavior. However, the Chi-square analysis indicated no significant relationship between the type of accident (VRF-IMC vs. GA sample) and the phase of flight in which the accident occurred, p>.05.

DISCUSSION

Overview of Results

The results indicate that the rate and severity of VFR flight into IMC accidents has remained high since the mid-1970s and 1980s (NTSB, 1989). Furthermore, the types of accident causal factors associated with VFR-IMC accidents have not changed significantly over the past several decades. Together, these results suggest that interventions have either not been implemented or have been unsuccessful in curbing pilots' decision to continue VFR flight into adverse weather conditions. Nonetheless, the analysis of the accident data reported here does provide some support for several of the theoretical explanations that have been proposed to account for VFR flight into IMC and hence may provide insights into possible interventions.

Situation Assessment

The VFR-IMC accidents examined in this study were categorized by the NTSB into various types, with 92 being classified as "Inadvertent" and six as "Encountered". These two types accounted for almost 24% of all the VFR-IMC accidents from 1990-1997. This finding suggests that pilots in these accidents may not have realized that the weather had deteriorated, since the NTSB categorization suggests they did not fly into IMC intentionally. This finding bears support for the explanation that erroneous assessment of weather conditions may cause at least some pilots to fly into IMC unwittingly.

Furthermore, it was found that the median flight experience of pilots involved in VFR-IMC accidents was significantly lower than that of pilots involved in other types of GA accidents. Those with fewer flight hours may have less experience interpreting real-time weather and hence make more erroneous evaluations. Indeed, weather evaluation was cited as a factor or a cause in approximately 11.5% of the VFR-IMC accidents. These findings are in line with Klein's (1993) work on recognition-primed decision-making which suggests that more experienced individuals are more efficient and proficient in assessing situations than those with less experience.

Risk Perception

Approximately 7.5% of VFR-IMC accidents have "Overconfidence in Personal Ability" cited as a factor or a cause, compared to less than 1% of other types of GA accidents, suggesting that overconfidence is a unique factor or cause of VFR-IMC accidents. This supports the notion that pilots who fly VFR into IMC lack appreciation of the risks involved in flying into adverse weather conditions. In addition, given the NTSB categorization of VFR-IMC accidents into various types, approximately 76% of VFR-IMC accidents appeared to involve intentional flight into adverse weather. These findings, together with other laboratory findings that pilots who continue into adverse weather conditions generally rate themselves more highly on skill and judgment than those who do not (O'Hare and Smitheram, 1995), strongly support the explanation that VFR flight into IMC is due to faulty risk perceptions of pilots. Consequently, pilots' perceptions of risk should be further investigated in laboratory experiments simulating VFR-IMC flights.

Social Pressure

The finding that a larger proportion of VFR into IMC accidents involved aircraft that had passengers onboard than did aircraft involved in other types of GA accidents, suggests that social pressure is a viable issue to explore when investigating pilots' decision and motivation to fly VFR into IMC. While previous laboratory studies (O'Hare & Smitheram, 1995; Wiegmann & Goh, 2000) indicate that social pressures are generally downplayed by pilots, it is possible that pilots are generally unaware of or reluctant to acknowledge the effects that social pressures play in their risk taking behavior. Nonetheless, the results of the present analysis indicates that social pressure warrants further investigation as a possible factor related to pilots' decisions to continue VFR flight into IMC.

Decision Framing

In a real world flight environment, decision frames may be induced by the proximity of the pilots' goals, such as the destination airport (O'Hare & Smitheram, 1995). As goal achievement gets closer, there may be a natural shift to the loss frame when bad weather is encountered, resulting in an increased likelihood to take risks. However, since the exact location of the accidents examined in this study could not be determined from the accident data, the phase of flight in which the accidents occurred was used as a crude indication of the pilot's proximity to the destination airport. Still, no significant relationship between phase of flight and accident type was observed. Nonetheless, given the potential lack of sensitivity of this measure to possible motivational and framing effects, decision framing should not be discarded as a possible explanation for VFR into IMC accidents based on these data.

Implications and Future Direction

The results of the present study provide some support for several theoretical explanations of why pilots would risk "pressing on" into deteriorating weather conditions. These explanations point to failures in various stages of the decision-making process, as well as the role that social pressures play in influencing risk taking behavior. However, additional laboratory and field research is needed to develop a better understanding of how these factors combine to precipitate the decision to fly VFR into IMC. The end result should be the development of decision-making training and other safety programs that are more focused on the underlying causes of VFR flight into IMC. Furthermore, since VFR into IMC accidents share several common causal factors with other types of GA accidents, the safety programs developed to address VFR flight into IMC will likely benefit all of general aviation.

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