Proceedings of the 45th Annual Meeting of the Human Factors and Ergonomics Society.
Santa Monica, CA: Human Factors & Ergonomics Society. 2001.

THE 'WHERE' AND THE 'WHY' OF CROSS-COUNTRY VFR CRASHES: DATABASE AND SIMULATION ANALYSES

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General Aviation (GA) accidents involving 'VFR into IMC' continue to be a major source of fatalities with a fatality rate more than four times greater than for GA accidents in general. We report two studies into the causes of cross-country weather-related accidents. In the first study we analyse the records of 77 New Zealand crashes where it could be determined that the aircraft was on a cross-country flight. We compared the characteristics of crashes that occurred after externally-driven events such as engine-failures with crashes where the pilot maintained on-going control over the aircraft. Significant differences were found for distance into the flight, visibility, altitude, crash severity and for the pilots' age and recent flight time. In the second study, 18 qualified GA pilots completed two simulated cross-country flights involving several commonly encountered weather conditions with or without the use of GPS. Detailed measures of decision making, risk assessment and situational awareness were collected during the flights. We discuss the implications of the findings for training and flight safety in general aviation.

The accident rate in general aviation (GA) continues to be substantially higher than that in other sectors of aviation (O'Hare, 1999a). Whilst the GA accident rate appears to be declining in some countries such as the United States (AOPA Air Safety Foundation, 2001) the rate appears to be static or even increasing in others such as Australia and New Zealand (Civil Aviation Authority of new Zealand, 2001). Although only accounting for a small proportion of GA accidents, weather-related accidents continue to have a very high fatality rate with three out of four such accidents in the United States involving a fatality.

Speculation on the causes of these fatal accidents has involved such psychological factors as over-confidence (NTSB, 1989) faulty risk-perception (CAA, 1987) and lack of awareness (Bramson, 1988). Several explanations focus on the idea that as the time and distance into a flight increases so might the pilot's desire to continue to the planned destination. This attraction, it is argued, may adversely affect the pilot's appraisal of the flight circumstances leading to risky decisions. Psychological theories such as the theory of sunk costs (Arkes & Blumer, 1985) provide solid empirical evidence for the suggestion that commitment to a chosen course of action increases with continued investments of time or money. A pilot in the latter stages of a cross-country flight has certainly invested plenty of both.

To the best of our knowledge no one has investigated GA crashes in terms of how far into planned flights the crashes occurred. It is important to determine if there is any evidence for increasing boldness or risk-taking as flights progress. The aim of Study 1 was to examine the records of GA flights which had crashed whilst conducting planned cross-country flights. The views discussed above would suggest that as long as the flights remained under the control of the pilot there would be an increasing probability of crashes occurring later in the flight. To evaluate this hypothesis requires a comparable sample of crashes whose occurrence is dictated by events outside the pilots' control and therefore beyond the reach of any possible psychological factors. Such crashes generally occur in association with sudden and unexpected engine or systems failures. If psychological pressures such as sunk costs or attraction to a goal are determinants of crashes involving poor decision making then these crashes should occur significantly later in the flight than crashes due to mechanical or systems failures. A concurrent program (Study 2) was designed to throw more light on the decision making and situational awareness of pilots conducting simulated VFR cross-country flights with and without the use of GPS navigation.

STUDY 1

Method

An electronic database of all reported aircrashes in New Zealand was developed from data provided by the Civil Aviation Authority of New Zealand (CAA) and the Transport Accident Investigation Commission of New Zealand (TAIC). The basic database supplied by the CAA covered the years 1988 to 2000 (inclusive). The TAIC database covered the years 1988-1994. The two databases were manually merged to form one integrated database. There were 1308 cases recorded in the database. Unfortunately many of the fields were blank as the information had not been entered by the accident investigators.

An initial search of the database was made to locate all potential cases involving a crash during a planned cross-country (i.e. where the intended destination was at least 25nm from the point of departure). All flights involving aerial work such as logging, hunting, firefighting or aerial application were excluded unless the aircraft was on a cross-country flight to or from the place of work at the time of the crash. This initial search yielded 238 potential cross-country crashes. A case was defined as a cross-country flight if there was information in the database to indicate that the departure and intended destination were at least 25nm apart or if the distance between the crash location and either the departure or intended destination was at least 25nm. There was sufficient information in the database to yield 77 confirmed cases that met the criteria.

Each of the 77 cases was coded in terms of whether the pilot was reacting to an immediate and unplanned event, such as a sudden engine failure, requiring urgent action or whether the pilot was in on-going control over the aircraft and its systems at the time of the crash. The first category (n = 31) was labelled 'Externally driven' (ED) and was almost entirely made up of engine failures (n = 23). The second category (n = 46) was labelled 'Controllable exposure to risk' (CER) which included both weather-related crashes (n = 28) and loss-of-control and collision crashes (n = 14). The authors coded the cases separately. Both authors were in agreement on 91% of the cases. Differences were resolved by discussion.

Results

*Distance of Crash into Flight***.** The average distance into the flight when the crash occurred was 78.1 nm for the ED group compared to72.9 nm for the CER group. This difference was not statistically significant ($F(1,75) = .072$, $p = .79$). However, when the CER group are subdivided into weather-related and loss-of-control crashes (see Table 1) we find that there is a difference in the average distance from departure point to crash of 92.5nm for the weather-related crashes compared to 49.7nm for the loss-of-control crashes. Comparing the three groups (EDcrashes, weather-related CER, loss-of-control CER) shows a significant difference in departure-crash distances ($F(2,59) = 3.5$, $p = .03$) and a significant difference in the departure-crash distance as a percentage of the distance to the intended destination ($F(2,59) = 3.4$, $p = .04$).

Crash Characteristics. The two groups of crashes are significantly different in their injury outcomes. There were over twice the number of fatalities (1.6 versus .68) in the CER crashes compared to the ED crashes ($F(1,75) = 3.83$, $p = .05$). The same was true for the incidence of fatal and serious injuries combined ($F(1,75) = 4.6$, $p = .036$). These findings are consistent with previous findings on the very high incidence of serious injury outcomes associated with both loss-of-control and weather-related crashes in GA.

Pilot Characteristics. The mean age of the pilots involved in CER crashes was 37.8 years compared to 47 yrs for pilots involved in ED crashes. This difference of 9.2 years is statistically significant ($F(1,43) = 3.9$, $p = .05$). The CER group was found to have flown more hours in the previous 90 days than the ED group (59.8 versus 31.9 hours), but this difference was not statistically significant at the 5% level ($F(1,54) = 3.7$, $p = .06$). There were no statistically significant differences in terms of any of the other pilot characteristics such as total flight hours.

STUDY 2

Method

Participants. Eighteen pilots holding at least a Private Pilot Licence (PPL) were recruited from local flight training organizations.

Apparatus. The simulation selected for this study was Terminal Reality's Fly!2K incorporating GroundControl and Sky! by Howintheworld (www.howintheworld.com) and the Flyscripts! v1.1 flight data recorder. This program was enhanced with scenery by Peter McLean (www.flyscenery.com). This scenery is based on USGS and US Land Use data to make a highly accurate representation of terrain elevation, land use, and major geographical features. The fidelity of this scenery allows for VFR navigation with relative ease using standard aeronautical sectional charts.

The computer was based around an Athlon Thunderbird 1Ghz processor with 512 MB SD100 RAM and a Guillemot Hercules Prophet GeForce 2 GTS 64 MB video card. The monitor used was a Philips Brilliance 201B 21" CRT. Pilots interacted with the simulator through a CH Products Flight Sim Yoke, Simped-Vario rudder pedals, a Precision Flight Controls PAL console and a mouse.

Procedure. The study was run over two sessions. During the first session the pilot was required to sign an informed consent form, fill-in several questionnaires, including a risk-style measure (Schneider & Lopes, 1986) and complete a short training flight.

The second session began with the pilot being reminded of the procedure for the experimental flights. Written instructions, a weather report, NOTAMS, a laminated sectional chart, aircraft specifications, and all navigation equipment including a nav computer were provided at the outset. The pilot was informed that s/he would be flying with or without GPS depending on group allocation and it was emphasised that the pilot was the pilot-in-command and free to conduct the flight however they wished.

Pilots were required to plan and fly two cross-country flights. The order of the flights was counter-balanced across the two experimental groups (GPS/No GPS) and across the participant type (GPS experience/No GPS experience). The first flight ('Scud-Running Flight') was approximately 110 n.m. in length running north to south down the Pacific coast of Washington State in the United States. The simulated weather was an initial cloud base of 2500 ft dropping to 1500 ft after about 20 n.m. into the flight. A further weather change reduced visibility and lowered the cloud base to 800 ft 42 n.m. into the flight (Decision Point 1). If the pilot chose to continue on from this point s/he would experience further reductions in visibility until about 10 n.m. from the destination (Decision Point 2). The visibility at this point was below VFR minima.

The second flight ('VFR On Top Flight') was approximately 135 n.m. long from Gansner to Little River across the Sacramento Valley to the Pacific Coast. The weather forecast predicted fine weather over the valley but 5000-6000 ft overcast toward the coast with some lowering visibility. The weather was set such that flying high across the valley to clear the western mountains would put the pilot VFR on-top of broken cloud with limited ground visibility approx 82nm into the flight (Decision Point 1). If the pilot continued the flight from this point then a further weather change was experienced about 15 n.m. from the destination of Little River (Decision Point 2). At this point the 6000 ft cloud layer turned solid overcast with light rain and visibility reducing to VFR minima by the time the destination was reached. Had a pilot not dropped below the broken cloud prior to the final weather change then s/he would find him/herself above a solid overcast layer.

Design. The experiment was a two factor mixed design with the flights ('Scud Running' and 'VFR On Top') being a within-subjects factor and the use of GPS a between-subjects factor. The measured variables included a wide-range of flight parameters and questionnaire measures.

RESULTS

We have observed a very wide-range of responses in the two flights. Two pilots 'crashed' and three became lost. The latter were all in the non-GPS group. The decisions made at the first decision point in the scud-running flight are shown in Table 1.

Comparing the numbers continuing on with those not continuing shows a marginally significant difference between those using GPS and those not ($\chi^2(1) = 3.2$, $p = .07$). Similarly, comparing the numbers carrying out a precautionary landing with those not indicates a marginally significant tendency for the GPS group to keep flying ($\chi^2(1) = 3.1$, $p = .079$). The only difference in decision making in the 'VFR on top' flight was a marginally significant tendency for the non-GPS group to select the option to 'orbit' at the first decision point ($\chi^2(1) = 3.6$, $p = .058$). The proportion of pilots continuing the flight was much higher (44%) in the 'VFR on top' flight where the weather change occurred twice as far into the flight as in the Scud-Running flight where only 17% continued.

	GPS	Non GPS
Continued	3	0
Precautionary Landing	1	4
Diversion	1	1
Return to Departure	4	3
Orbit	0	0
Crashed Beforehand	0	1

Table 1. Options selected at Decision Point 1 (Scud-Running Flight)

Predictors of Decision Making. Nine participants elected to continue at least one of the flights past the first decision point whilst the other nine elected not to continue in either flight. None of the demographic or flight experience variables were significantly different between the groups. The measure of risk style was completely unrelated ($r = -.043$) to the in-flight decision making.

DISCUSSION

Our analysis of cross-country general aviation crashes has confirmed previous findings that crashes that occur whilst the pilot is voluntarily directing the course of the flight have disproportionately serious outcomes compared to other types of crashes. We prefer not to call these decisional errors as the processes responsible for these outcomes have not yet been determined. The problems may be due to a number of factors including decision making, risk assessment and situational awareness. We are currently conducting a program of laboratory research designed to illuminate these issues. The analysis also shows the clear survival value of the precautionary landing which were invariably non-fatal.

Since weather-related crashes have been commonly 'explained' in terms of a tendency to unwisely continue flights on into deteriorating conditions we expected to see a significant difference between the distances into a flight where these crashes occurred compared to a sample of crashes precipitated by sudden engine or systems failure. Our data show that the weather-related crashes occurred further away from the point of departure and closer to the intended destination than other types of crashes. The findings are consistent with explanations based on proximity of the goal (i.e., the planned destination) and time already invested in the flight (sunk cost).

Whilst the injury outcomes of the two groups of crashes are significantly different there were very few differences between the two groups in terms of crash characteristics other than height of the crash site above sea level and reported visibility. The most striking difference was in terms of two characteristics of the pilots. Those involved in CER crashes were much younger (by almost a decade) and had much higher flight hours in the previous 90 days. This combination of relative youth and high levels of current flight time has shown up repeatedly in the literature on pilot characteristics and flight safety as a risk factor for crash involvement (e.g., Booze, 1977; O'Hare, 1999b).

Within the CER group, the 'classic' VFR into IMC crashes involved the youngest pilots and the highest number of hours in the previous 90 days. The basis for this group's over-involvement in crashes cannot simply be their flight exposure as this would leave them equally at risk of 'Externally-driven' types of events. A program of flight simulation research has therefore been developed to determine the importance of various psychological factors in the genesis of VFR cross-country crashes.

We have been highly successful in creating two challenging VFR cross-country 'flights' using widely available PC simulation software. Whilst the software is available 'off the shelf' a considerable amount of work was required to customize it to our requirements. The two scenarios present pilots with commonly encountered weather situations which can be treated in a variety of different ways. We encountered a wide range of responses from our sample of participants which appear to be reflective of the wide range of responses found in the real-world environment.

Results from the flight simulation study are suggestive of a tendency for pilots using a GPS navigation system in VFR flight to behave differently from pilots using conventional means of navigation. The relatively small sample size makes it difficult to find statistically significant results at conventional significance levels so the present results are indicative only.

Decision making performance in realistic in-flight settings is not a simple function of pilot age, flight experience or general risk taking style. From the analysis of aircrash data, however, at least two of these (age and recent flight experience) are associated with involvement in crashes that can be characterised as ones where the pilot exercises volitional control over his or her exposure to risk.

There are two possible explanations for the difference between the aircrash database findings and those from the flight simulation study. Firstly, the average total flight hours experience of our flight simulation sample was a relatively low 295 hours, although the average age (37.5 yrs) was very similar to those in the CER accident group (37.9 yrs). The pilots with greater total and recent flight times were not well represented in the flight simulation study so the factors which may be influential for these pilots might not have emerged.

The second possibility is that variables such as age and recent flight experience are only related to flight decision making through more proximal variables such as risk assessment and situational awareness. The importance of these variables in VFR cross-country crashes has been demonstrated by Goh and Wiegmann (2001). In this study of NTSB data, almost 25% of 'VFR into IMC' crashes were described as involving 'inadvertent' encounters with weather, suggesting that misperceptions of weather are an important factor. The over-representation of 'overconfidence in personal ability' in these crashes suggests that risk perception may also be an important factor. During the simulated flights we obtained a great deal of data on pilots' perceptions of the risks and benefits of different courses of action, their confidence levels, their awareness of the aircraft's position in space and in relation to their planned route, their expectations about the weather, and so forth. Further analysis of these data may give us a unique insight into the 'why' of VFR weather-related cross-country crashes.

ACKNOWLEDGEMENTS

This research was supported by Aviation Research Grant 00-G-009 from the Federal Aviation Administration. The contract technical monitor was Dr David Hunter.

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