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WHAT MAKES FLIGHT SITUATIONS RISKY? EXAMINING COMMERCIAL AND GENERAL AVIATION PILOTS' CONCEPTS OF RISK

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Despite its significance to aviation safety, surprisingly little empirical research has addressed how pilots conceptualize risk and how flight experience might influence their understanding. A sorting study was conducted in which expert (= commercial airline) and novice (= private) pilots were asked to categorize aviation incidents in terms of their risk levels. Analyses of their judgments revealed differences between more and less experienced pilots in their conceptualizations of risk. Private pilots classified incidents in terms of the magnitude of their consequences, analogous to the dread factor observed in studies of the general public's understanding of risk. Commercial pilots used two factors: the timeline of a threat and its controllability. These findings suggest that flight safety in the GA environment may be improved by instructing private pilots in the more complex and action-oriented risk concept of commercial pilots.

Introduction

> "*Just after liftoff from Denver, an aircraft waiting to take off reported to Tower that they observed rubber leaving our aircraft. We acknowledged the report and continued with departure. All engine indications were normal. The decision was made to continue to Portland if all other indications were normal rather than risk a heavy landing at a high altitude airport with unknown tire damage. On approaching Portland, after checking weather, we decided to overfly Portland and continue to Seattle, which was our next stop. Seattle was reporting better weather and had longer runways …" (ASRS Report No. 170760)*

Aviation decision making is frequently discussed as a dichotomous situation: it's a "go" if conditions are below a threshold and a "no-go" if they exceed the threshold. As illustrated by the ASRS report shown above, however, most aviation incidents are considerably more complex insofar as they evolve over time and decisions need to take into account potential negative consequences beyond the immediate problem. For instance, the crew's decision to continue with their flight was based on their assessment that this course of action posed less risk than its alternative since returning to their departure airport would have involved a heavy landing with unknown tire damage at a high-altitude airport. Similarly, their subsequent decision to overfly Portland and to continue on to Seattle was motivated by a number of considerations: the risk involved in landing with a tire problem at Portland in poor weather conditions and with short runways versus the risk involved in landing with the same problem in Seattle where the weather was better and the runways were longer. In contrast, failing to consider potential negative implications of a given problem and one's actions may lead to accidents as the following general aviation report shows.

> *An instructor was on a cross-country flight with a primary flight student. The student expressed concern over the remaining fuel, but the instructor said not to worry, they should have plenty of fuel to get back to their home airport. Although they flew over several suitable airports on the route of flight, the aircraft crashed due to fuel exhaustion within a few miles of the home airport, injuring the instructor and destroying the aircraft (J. Davison, Personal Communication, January 2003).*

The flight instructor apparently did very little analysis and instead simply assumed that they had sufficient fuel for continuing the flight as planned. Had she performed a risk assessment similar to that done by the commercial airline crew, she might have considered such items as: greater fuel burn due to stronger than forecast headwinds or longer flight time/distance than planned, and what they would do if they arrived at their home airport with minimum fuel and found it closed. In addition, as an instructor, she might have considered the lesson taught to the student – to continue a flight under uncertainty rather than choose the more conservative option and add fuel as a safety measure.

The research described in this paper sought to determine whether experts (commercial airline pilots) conceptualize risk differently than do novice (general aviation) pilots. A second aim was to identify the factors that pilots consider when assessing the risk involved in aviation incidents.

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Risk assessment is essential to aviation decision making and ultimately to aviation safety. How commercial pilots respond to a threat, whether they avoid it or seek to mitigate it, was shown to depend on their assessment of the safety risk rather than on personality characteristics or crew role (Fischer, Orasanu & Davison, 2002). If they considered the threat to flight safety to be serious, they took a cautious approach and adopted a new course of action, such as diverting, thereby preempting the threat. On the other hand, if they painted a less negative picture, they continued with their original plan but took actions to mitigate the risk. Similarly, Wiegmann, Goh and O'Hare (2002) observed that private pilots' decisions to continue a visual flight rules (VFR) flight into instrument meteorological conditions (IMC) was related to poor situation assessment in addition to flight experience. These findings also attest to the inherent subjectivity of risk assessment. As others (c.f., Slovic, 1992; Yates & Stone, 1992) have pointed out, risk reflects an individual's assessment and thus cannot be objectively measured and expressed in a standardized quantity like airspeed or altitude.

Surprisingly, despite its significance to aviation safety, little empirical research has addressed how pilots conceptualize risk. Previous work examined the effect of varying risk levels on crew performance and crew interactions (Fischer & Orasanu, 2000; Orasanu, Fischer, and Davison, 2002; Orasanu et al., 1998). Other work investigated how pilots' attitudes towards risk and their perceptions of risk related to risk-avoiding or risk-taking decisions (Goh & Wiegmann, 2002; Jensen, 1995; O'Hare, 1990; O'Hare & Smitheram, 1995). However, much less is known about the ingredients of pilots' perceptions of risk. What do pilots look for and what factors do they take into account when they assess the risk involved in an incident?

From a normative point of view, risk assessment involves two components: the probability that some loss will occur and the magnitude of the loss (Yates & Stone, 1992). For example, risk estimates that are used in investment planning assume that the risk associated with a particular financial investment can be calculated by multiplying the probability of a loss with its magnitude. On the other hand, research by Slovic (1987) found that the general public considers different factors in judging the risks associated with a host of activities ranging from the mundane, such as skiing, to public policy issues such as the operation of nuclear power plants. Most important to people was what Slovic labeled "dread." People were particularly concerned about the extent to which an activity could have catastrophic consequences affecting the lives of many people as well as future generations. In addition, their risk judgment was influenced by the degree to which a risk was known and thus deemed controllable. Unlike the general public, experts were found to be less concerned with the magnitude of a loss but instead seemed to be more influenced by the probability of a loss as their judgments correlated highly with technical estimates of annual fatalities (Slovic, Fischoff & Lichtenstein, 1979).

Differences between experts and novices concerning the representation of core concepts have also been noted in numerous domains ranging from chess to physics, medicine and political science (Chase & Simon, 1973; Chi, Feltovich & Glaser, 1981; Patel & Frederiksen, 1984; Voss, Lawrence & Engle, 1991). A recurrent finding is that experts' conceptual representations are complex, interconnected structures that are organized around fundamental principles and specify conditions of use (Glaser & Chi, 1988). In contrast, novices tend to have shallow representations that encapsulate isolated facts. As a result, during problem solving, experts typically focus on features and patterns that are relevant to solving the issue at hand and are not distracted by superficial characteristics of the specific problem. Novices, on the other hand, are likely be distracted by problem-specific and irrelevant aspects and consequently "miss the point" in solving the problem. Our current research investigated whether similar expertise effects would be found in pilots' risk assessments.
Data reported here came from two studies. The first involved risk judgments obtained from commercial pilots who participated in a larger project designed to identify mental structures used in problem solving and decision making (Fischer & Orasanu, 2002). The second data set comes from a replication of that study with general aviation pilots. Participants in both studies categorized descriptions of aviation incidents under two conditions--free sorting and directed sorting. In the free sorting task, they were instructed to group together incidents that were similar in terms of decision making. In the directed sorting task, participants were told to form groupings based on specific aspects of the problems, such as time available or risk levels. This paper will report only on the findings from the directed sorting task that focused on risk levels.

Method

Participants

Twenty-seven commercial pilots from one major U.S. airline took part in the original study. Nine were captains, 10 were first officers and eight second officers. The captains had on average 24 years of

experience in Part 121 operations (SD = 4.6 yrs); first officers had 9 years (SD = 4.6 yrs.), and second officers 5 years (SD = 3.6 yrs.). All of the commercial pilot participants were male.

The 20 general aviation (GA) participants were private pilots with no advanced-pilot certificates or ratings. Average flight experience totaled 155 hours (SD = 133.14, median experience 100 hours). The average age of the GA participants was 29 (SD = 14.81, median age 23). Half of the GA pilots were female.

Material

Ninety-seven incident reports on crew decision making were retrieved from the Aviation Safety Reporting System (ASRS) data base. A stratified random sample of 22 scenarios was selected to reflect phases of flight in the report set. The following distribution of scenarios was obtained: Preflight = 3; Taxi = 2; Take-off = 4; Climb = 4; Cruise = 4; Descent = 2; Approach = 3. The scenarios were shortened comprising only the first decision event mentioned. All the information that the reporter had provided regarding flight context and precipitating event was included. The actual decision, however, was not revealed. For instance, subjects saw the following description: *A wide-bodied aircraft weighing 43,000 lbs experiences a #3 engine compressor stall at 138 kts on takeoff; V1 is 142 kts*. Each description was printed on a 5 X 8 inch index card.

Procedure

Participants received the stack of 22 index cards. They were asked to judge how risky each described situation was and then to group together in piles those scenarios that they thought were similar in terms of their risk levels. Participants were instructed to create no more than 10 piles and to sequence the piles from least to most risky.

Results

Pilots' categorizations of the scenarios were converted into disassociation scores reflecting the psychological distance or dissimilarity between scenarios. An Individual Difference Scaling (INDSCAL) Analysis on captains', first officers', second officers' and private pilots' disassociation scores indicated that while all commercial pilots conceptualized risk in the same way, private pilots used a different set of features in their risk judgments. Consequently, the risk judgments by private and commercial pilots were examined further in separate analyses to determine the specific factors underlying each group's risk assessment.

An INDSCAL Analysis on the commercial pilots' data suggested that risk judgments were related to the perceived timeline of a threat and pilots' assessment of their ability to control the threat. With respect to the timeline of a threat, incidents that were imminent and that required an immediate response were contrasted with incidents that did not pose an imminent threat and where the crew consequently had some time to decide on a response. Commercial pilots' second risk component, controllability, was apparent in the contrast of incidents in which pilots could avoid a threat (= sure control), with instances in which the threat was unavoidable and there was more or less a fair chance of successfully mitigating it. Though common to all commercial pilots, captains, first officers and second officers weighted the two components differently in their risk judgments. The INDSCAL analysis showed that captains emphasized the timeline of a threat more than its controllability. The reverse preference was observed for first officers, while second officers apparently weighted both components equally.

In contrast to commercial pilots, private pilots' risk concept was found to be one-dimensional. A Multidimensional Scaling Analysis indicated that in judging the risk involved in incidents, private pilots focused primarily on the magnitude of negative outcomes. They contrasted incidents that had little or no negative implications for flight safety with incidents that posed a significant threat and could have catastrophic consequences. Thus, the private pilots' concept of safety risk mirrored the general public's understanding of risk insofar as both seem to emphasize the perceived catastrophic potential of threats.

Discussion and Conclusions

Experience influenced the basis for pilots' risk assessments. Like experts in other domains, commercial pilots in our study showed a more complex understanding of safety risk than the less experienced, more "novice" private-pilot group. We found that commercial pilots' risk concept takes account of the dynamic nature of aviation incidents. To them a threat is not simply a matter of the here and now, but also has a timeline. They distinguished threats that are imminent and require a quick response from those that loom in the distance and therefore leave some room to maneuver. A second component of commercial pilots' risk concept was the degree to which a threat can be controlled. The least risk was perceived in those incidents in which no threat was imminent and negative

consequences could be avoided altogether. The most risk was perceived when a threat was imminent and it was not clear whether the threat could be successfully controlled.

Private pilots seemed to have a more static understanding of risk. Their risk assessment was predominantly a function of the severity of a threat. Incidents that involved little or no threat to flight safety were judged to be least risky. Incidents that posed a significant threat to flight safety were considered high risk. Controllability of a threat, and thus risk management, was not part of their risk concept. While cognitively simpler and easier to apply to incidents, the simplicity of private pilots' risk concept comes with a price. By viewing risk as static, future risks may be overlooked and may only be recognized when they are imminent and pressing, leaving little time for planning. Furthermore, by perceiving risk in isolation, without reference to its controllability, the private pilots in our study seemed to say that risk is something beyond their control. That is, they viewed risk as something that happens to them, while commercial pilots looked at it as something over which they can exert at least some control.

Several implications for the training of private pilots may be derived from our findings. Training should emphasize that threats have a timeline. While some threats are imminent, others develop over time. Awareness of possible threats seems to be especially critical during pre-flight planning as many general aviation accidents result from short-sightedness during that phase of flight such as failure to consider weather trends and their implications (AOPA, 2003). If pilots recognized these threats early, they would be in a better position to control them. They could preempt them by not taking off, or they could mitigate possible negative effects by, for example, changing their route of flight. By training private pilots to look ahead and to plan for future threats, their decision making will likely improve, which should translate to a lower accident rate.

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