TAKING RISKS AND TAKING ADVICE: THE ROLE OF EXPERIENCE IN AIRLINE PILOT DIVERSION DECISIONS[1]

Dr. Marvin S. Cohen
Cognitive Technologies, Inc.
4200 Lorcom Lane
Arlington, VA 22207

INTRODUCTION

A commercial airliner was enroute from Chicago to Spokane when bad weather forced the Spokane airport to close. The Captain contacted the company dispatcher by radio, who advised him to continue to Spokane, hold there, and then (if the weather did not clear) to proceed to the alternate, Seattle. Landing at Seattle would provide better connections for the passengers than a third possibility, landing at Portland. The Captain, however, made an instant decision to go to neither Spokane nor Seattle, but to divert to Portland.

Had a less experienced Captain followed the dispatcher's recommendation, or delayed even for a short while in deciding to reject it, a dangerous situation might easily have developed. The Seattle airport was itself falling under bad weather and was closed shortly afterward. If the pilot had entered a holding pattern at Spokane or diverted to Seattle, fuel limitations would have made it impossible for him subsequently to divert to Portland or anywhere else.

The present research asks how pilots make decisions of this kind, what factors determine whether they are made well or poorly, and how they may be improved. Such decisions are representative of a small but important class of situations in which goals conflict, there is uncertainty, and time is of the essence: (1) Because they involve competing goals, a given decision is likely to be good in some respects and bad in others. In diversion decisions, for example, fuel economy and passenger convenience may conflict with safety. (2) In diversion decisions, the degree of danger may itself be unclear, involving an uncertain judgment about evolving weather. (3) Finally, such decisions must be made under time pressure. What makes some diversion decisions especially hard is that the decision to change must be made immediately if it is made at all.

Despite the high stakes and difficulty of these decisions, they have suffered relative neglect from the research community. Cockpit automation and aviation human factors have focused largely on more basic tasks, such as controlling and navigating the airplane, and on more dramatic problems, such as avoiding mid-air collisions. Research on decision making by experimental psychologists has typically dealt with inexperienced subjects performing artificial tasks. Specific concepts for improving diversion decisions during the cruise phase of flight have received attention only during the past few years.

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Two quite different approaches to human decision making have emerged in recent research and might be applied to training or supporting pilot diversion decisions. The first approach emphasizes general-purpose problem-solving and decision-making strategies (e.g., decision analysis). The second approach emphasizes domain-specific knowledge, the ability to recognize situations and quickly retrieve associated responses. A third approach, however, is possible. It emphasizes the importance of *specialized methods* - i.e., strategies for making decisions in specific types of situations. Pilots might develop such strategies (in addition to a stock of recognitional templates) over the course of their experience in a domain. Such strategies, based on specific experience rather than on general principles, would help decision makers handle novel situations, which do not directly match their store of past experiences. Cockpit displays and pilot training might focus, at least in part, on helping less experienced pilots adopt the strategies that experienced pilots have found effective.

METHOD

Subjects

Fifty active-duty commercial airline pilots served as subjects. The subjects divided into two equal-sized groups in terms of years of commercial airline flying experience: *more experienced pilots* - those with 20 or more years experience, and *less experienced pilots* - those with less than 20 years experience. The actual distribution of this variable was bimodal, with only 2 subjects in the 15 to 19 years experience range. Rank (as Captain, First Officer, or Second Officer) was highly correlated with the two categories of experience. Thus, 20 of the 25 more experienced pilots were currently Captains, while 18 of the 25 less experienced pilots were First Officers

Materials

The experiment was conducted with paper and pencil. Subjects received a packet containing a background questionnaire, instructions, and one page for each of 10 scenarios. They filled in their experimental responses in blanks provided on each scenario page. Completing the entire questionnaire took between 10 and 30 minutes.

Each pilot was asked to imagine that he or she is captain of a flight that is currently enroute on a west-to-east flight. Earlier, this flight had experienced inflight delays, reducing fuel reserves. Subsequently, the pilot receives unexpected information about a zero-visibility, zero-ceiling fog bank moving from east to west toward the destination and alternate. It is uncertain where the fog bank will be at the time the aircraft is scheduled to arrive in the area. Since the destination is farther east than the alternate (closer to the fog bank), the possibilities are: (a) the fog bank will reach neither the destination nor the alternate, (b) it will reach the destination but not the alternate, or (c) it will reach both the destination and the alternate. For each scenario a weather prediction is graphically presented, consisting of a worst-case, expected-case, and best-case prediction for the weather at the time the flight is expected to arrive at the destination. Ten scenarios are presented, comprising the three possible fog-bank locations (neither destination nor alternate affected, destination only affected, destination and alternate affected) crossed with best-case/expected-case/worst-case, with the constraint that in any given scenario the expected case prediction is (by definition) the same or better than the worst-case prediction and the best-case prediction is (by definition) the same or better than the expected-case prediction. The actual scenario conditions were the following:

Scenario #	1	2	3	4	5	6	7	8	9	10
Worst case	DA	DA	DA	DA	DA	DA	D	D	D	
Expected case	DA	DA	DA	D	D		D	D		
Best case	DA	D		D			D			

DA = both destination and alternate affected
D = only destination affected
[blank] = neither destination nor alternate affected

In each scenario, the pilot has a now-or-never choice of diverting to a third airport (which is unaffected by the weather problem) or continuing on toward the destination and alternate. If diversion to the third airport does not take place now, fuel limitations will make it impossible. No other airports are available. For half the pilots, the company dispatcher recommends diverting to the third airport (mentioning non-safety-related factors such as adequate runway capacity, facilities for maintaining the aircraft, connecting flights, and passenger facilities). For the other half of the subjects, the dispatcher recommends continuing on the original flight plan (mentioning the lack of adequate runway capacity, etc.).

Design

The major independent variables in the study were: (1) dispatch recommendations (divert/do not divert), which was varied between subjects, and (2) scenarios, which was varied within subjects, and (3) years of commercial flying experience, which was treated as a covariate. Two minor independent variables were (4) the order of this study with respect to another study not reported here, and (5) the order in which scenarios were presented (from scenario 1 to 10 or from scenario 10 to 1).

The dependent variables were (a) the subject's decision in each scenario whether to divert to the third airport or to continue, and (b) the subject's assessment of confidence in his or her decision, on a scale of 0 to 100. Analyses were performed in terms of both dependent variables. Results were identical in terms of the significant and insignificant results reported here.

RESULTS

Diversion Decisions and Advice

An analysis of variance was applied to the diversion decision data from scenarios 3 through 9, since all pilots diverted in scenarios 1 and 2, and no pilots diverted in scenario 10. There was a highly significant main effect of scenarios ($F(6,204)=12.096$; $p<.001$), and a significant three-way interaction of scenarios, dispatch advice, and experience (F(6,204)=3.283; p=.004). No other effects were significant up to the .05 level.

In scenarios 7 through 9, the pilot will have a place to land even in the worst foreseeable circumstance. In these scenarios the experienced pilots were more likely to divert if dispatch recommended diversion and more likely to continue if dispatch recommended continuation. By contrast, diversion decisions by less experienced pilots were unaffected by dispatch recommendations. A *post hoc* test of the advice-by-experience interaction for scenarios 7, 8 and 9, confirms the existence of an interaction of experience and advice in those scenarios (F(1,34)=5.281; p=.028).

In scenarios 3 through 6, there is a worst-case chance that continuing the flight will result in a "no options" situation, i.e., both available airports may be closed. Diversion decisions in these scenarios, even by experienced pilots, were unaffected by dispatch recommendations. A *post hoc* test of the effect of dispatch advice in scenarios 3 through 6 was insignificant (F(1,34)=.173); p=.680). A test of the advice-by-experience interaction for scenarios 3 through 6 was insignificant (F(1,34)=.548; p=.464).

Strategies

More insight into the effect of experience and advice on diversion decisions can be gained by identifying the decision strategies used by individual pilots. Strategies can be divided into three classes, based on the role of worst-case reasoning:

- Risk-taking strategy: A worst-case prediction of no options (both destination and alternate in fog) is not sufficient for diverting. This strategy might lead to continuation even in scenarios 3 through 6.

- Cautious strategy: The worst-case of no options is sufficient for diverting, but not necessary. This strategy might lead to diversion in scenarios 7 through 9 in addition to scenarios 3 through 6.

- Worst-case strategy: The worst-case of no options is both a sufficient condition for diverting and a necessary condition. These pilots will divert in scenarios 3 through 6 and continue in scenarios 7 through 9.

As shown in Figures 1 and 2, there was an approximately equal number of pilots in both the more experienced and less experienced groups that were willing to accept the risk of a no-options situation. Diversion was significantly less than 100% in scenarios 4, 5, and 6 for both experience levels ($p > .001$ for scenarios 5 and 6). The number of risk-taking pilots was not affected by dispatch advice at either experience level. Risk-takers took into account more modes of prediction (worst-, expected-, and best-case) than non-risk-takers ($p = .025$), and more experienced risk-takers used more predictive data than less experienced risk-takers ($p = .008$).

The less experienced non-risk-taking pilots divided fairly evenly into those who used a worst-case strategy and those who used a cautious strategy -- independently of dispatch advice. For less experienced pilots, the percentage of diversions was significantly greater than 0% in scenarios 7 and 8 regardless of dispatch advice (scenario 7, $F(1,24)=11.294$, $p=.003$; scenario 8, $F(1,24)=4.571$, $p=.043$). These pilots often chose to divert even though (a) dispatch recommended continuation, and (b) there was no possibility of a no-options situation. The pilots who adopted this cautious strategy tended to be influenced not only by worst-case predictions, but also by best-case predictions. For example, they would divert unless the best case involved a promise of both destination and alternate clear of fog.

More experienced non-risk-taking pilots, on the other hand, adopted different strategies depending on dispatch advice. They were likely to adopt a worst-case strategy when dispatch recommended continuing, but to adopt a cautious strategy when dispatch recommended diversion ($A^2(2) = 8.14$; $p=.027$). For these pilots, the rate of diversion was not significantly different from 0% when dispatch recommended continuation (scenario 7, $F(1,12)=1.000$, $p=.337$; scenario 8, $F(1,12)=2.182$, $p=.165$) . But diversion was significantly above 0% when dispatch recommended diversion, even though the worst case involved an open airport (scenario 7, $F(1,11)=15.400$, $p=.002$; scenario 8, $F(1,11)=7.857$, $p=.017$). The cautious experienced pilots tended to be influenced by the expected case -- unlike the less experienced cautious pilots, who were more influenced by the best case. For example, they would divert unless the expected-case involved both destination and alternate clear of fog.

DISCUSSION AND CONCLUSIONS

Three groups of subjects appear to handle uncertainty and dispatch advice in qualitatively

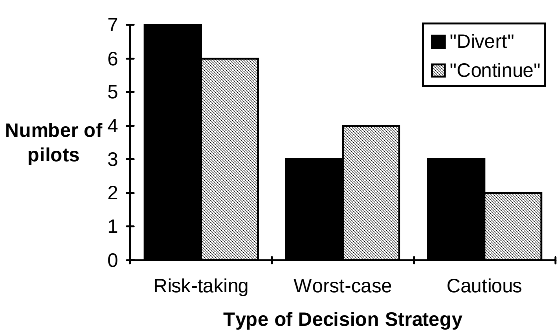

Figure 1. Less experienced pilots.

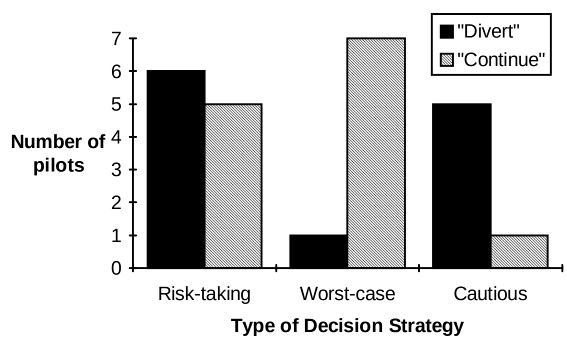

Figure 2. More experienced pilots.

different ways: (1) risk-takers, (2) less experienced non-risk-takers, and (3) more experienced non-risk-takers.

Risk-taking pilots seem to have utilized a *tradeoff* strategy, constructing an assessment of the overall desirability of continuing across the various predictions. They were more likely than the non-risk-takers to consider multiple possible outcomes (e.g., worst-case *and* expected case *and* best case) in their decisions. These pilots were willing to accept a worst-case possibility of no options, as long as the expected case or best case was good. Conversely, they sometimes chose to divert if the expected case or best case was not so good, even though there was no possibility of a no-options situation (and even though dispatch might have recommended continuing). The more experienced risk-taking pilots incorporated a larger amount of information into these tradeoff calculations than the less experienced risk-taking pilots.

The less experienced, but non-risk-taking pilots divide into two subgroups: worst-case and cautious. These pilots made no use of advice from dispatch, nor did it influence the way they processed the predictive information. As a result, there were unnecessary diversions by pilots using the cautious strategy, when dispatch recommended continuing and there was no danger of a no-options situation. There were also potentially unwise continuations by worst-case pilots, when there was little chance of landing at the destination and dispatch recommended diverting.

Only one group, the non-risk-taking experienced pilots, took dispatch advice seriously. Indeed, they seem to have centered their decision making process around the dispatch recommendation. They took it as a starting point, and then looked for information to critique or rebut it. If no flaws were found, the dispatch recommendation was implemented. If flaws were found, they considered the alternative option and examined it for potential flaws.

A strategy of this sort accounts nicely for the data from this group. When dispatch recommends continuation, these subjects attempt to rebut the advice by looking at the worst-case outcome of continuing. If the worst-case prediction involves destination and alternate under fog (the no-options situations of scenarios 1 through 6), the dispatch recommendation cannot be implemented, and these subjects choose to divert despite the recommendation. If the worst-case does not involve both airports under fog (scenarios 7 through 9), the recommendation is implemented. On the other hand, if dispatch recommends diversion, these pilots seek to rebut it by examining what they are likely to miss if they divert, i.e., the expected-case of continuing. If this looks good (e.g., neither destination nor alternate under fog), then the option of continuing is considered despite the recommendation to divert. As a check against flaws in that option, however, the pilots also look at the worst case. If the worst-case prediction involves no landing options, they return to the dispatch recommendation and divert.

In this way, a strategy of provisional acceptance of dispatch advice and attempted rebuttal leads naturally to a worst-case strategy for advice to continue and a cautious strategy for advice to divert. Such a strategy enabled these experienced pilots to take advantage of the information provided by dispatch without slavishly following it when it violated safety. It also enabled them to minimize their cognitive workload, i.e., to look at the expected case only when it was relevant (to rebut dispatch advice to divert).

This strategy conflicts in several ways with normative analytical models of decision making: (a) Options are evaluated sequentially, not compared to one another all at once. (b) Possible outcomes are considered selectively rather than exhaustively (e.g., only worst case, or worst case and expected-case). (c) Possible outcomes are not combined into abstract probability-weighted averages, but used concretely to envision outcomes and assess options. (d) Competing goals are dealt with by a strategy of provisional acceptance and critiquing, rather than by quantitative weights and tradeoffs.

The results support the view that experienced decision makers may solve problems in a way that is qualitatively different from the approaches of less experienced decision makers. The results also support a concept of expertise that goes beyond a stock of specialized recognitional templates, to include *domain-specific methods* for processing information. Such methods involve monitoring and assessing the quality of a solution, and modifying it if necessary. Such *metacognitive* skills evolve through long experience (20 years in the present study). They may enhance both the accuracy and the efficiency of decision processes.