Time-Stressed Decision-Making in the Cockpit[1]

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Abstract

Forty-one commercial airline pilots executed flight scenarios that varied the time available for deciding whether and when to divert to an alternate airport. Pilots with the most flight experience were the most responsive to variance in available decision time: they diverted relatively early when time was short, and later or not at all when time was plentiful. Greater experience was also associated with efforts to fill gaps in the available information and test assumptions. A framework is proposed that predicts these effects as a function of (1) skill at situation recognition and rapid response, (2) metacognitive skill at detecting and handling uncertainty, and (3) sensitivity to the opportunities to switch between these two skill sets.

Introduction

As a plane streaks towards a landing on a snow-slicked runway, some passengers may hope that the person at the controls is the lank, grizzled veteran they saw in the cockpit while boarding, not the jaunty young officer sitting beside him. It is easy to forgive passengers this bias; everyday experience and cognitive research teaches that experience tends to produce expertise. In domains such as music (Ericsson, Krampe, & Tesch-Romer, 1993), athletics, and chess (Charness, 1995), the best predictor of skill is the number of hours of deliberate, attentive practice a form of experience that can produce expertise in a decade (Ericsson, Krampe, & Tesch-Romer, 1993; Chase & Chase, 1973). In commercial air flight, the topic of this paper, Orasanu (1995) has found that the quality of decision making by airline pilots was positively correlated with years of military aviation experience and rank with the commercial carrier.

Skill born of experience is often attributed to the gradual accumulation of meaningful patterns of domain events linked to appropriate interpretations or responses. Recognition-based models (e.g., Klein, 1989, 1993) leverage empirical evidence of human skill at pattern-matching. However, they do not account for evidence that decision makers notice and resolve conflicted matches to multiple patterns, test and refine their understanding when necessary, and construct new knowledge (Schank, 1982; Pennington and Hastie, 1988). For example, Serfaty (1993) found that experienced Army planners did not perceive more similarities with prior situations than did less-experienced planners, did not generate plans more rapidly, tended to see the situation as more complex, were less confident in their solutions, and felt the need for more time. These results are inconsistent with a simple recognitional model.

The *Recognition/Metacognition Framework* (Cohen & Freeman, 1996) accounts for a larger range of human decision-making behaviors than do simple recognition models. The R/M Framework necessarily acknowledges the role of pattern-matching, or recognitional decision-making. However, it also recognizes an alternative decision-making strategy governed by metacognitive skill at critiquing and refining situation knowledge. This skill consists in identifying and reducing uncertainty of three forms: gaps in critical information, unreliable assumptions, and conflicting interpretations of the evidence. These skills help decision makers to develop more complete and consistent assessments, and these in turn support better decision-making. Finally, the R/M Framework provides a mechanism (called the *Quick Test*) for shifting between recognitional and metacognitive decision-making strategies (Cohen, Parasuraman, & Freeman, in press). This mechanism (1) tests for the presence of *uncertainty* that is significant enough that its reduction could potentially change a decision; (2) tests whether a change of decision could decisively affect the outcome (where the swing in the outcomes defines the *stakes*); and (3) compares the potential benefits of reducing uncertainty to the cost of taking *time* to do so. For example, assume that a helicopter pilot travelling at high speed into enemy territory unexpectedly glimpses a pair of tanks on the field below. The pilot is uncertain whether the targets are enemy or friends, a question that greatly influences the outcome of engagement: a successful strike vs. a fratricide. However, taking the time to examine the tanks by slowing down endangers the pilot and the mission. The pilot determines that the cost of the delay is low relative to the value of reducing uncertainty to ensure mission success, gathers sensor data that confirms the tanks are enemies, and destroys them. Thus, the pilot exercises recognition skills, the Quick Test (by considering uncertainty, stakes and time), and the metacognitive skill of identifying and filling information gaps.

To test the explanatory power of the R/M Framework, we conducted an experiment in which we examined the correlation of years of experience in a domain with (1) sensitivity to available decision time and

(2) metacognitive skill at recognizing and reducing uncertainty.

Experimental Procedure

A convenience sample of 41 commercial airline pilots executed a flight scenario that required them to decide whether to divert their commercial jet from its destination at Dulles (IAD). Pilots began the problem by entering a holding pattern near Dulles (IAD), and then awaited clearance to land through repeated delays. Complicating the decision of whether to divert were a runway accident at IAD in mid-scenario; severe weather conditions that gradually made it "illegal" under FAA rules to land at the alternate, BWI; and the potential for traffic backups that might delay landing at the remaining alternate, Norfolk (ORF), and other airports. Some key information was given to participants in briefing papers, some was announced during the scenario by the experimenter in the role of Air Traffic Control, some was available during the scenario only upon the pilot's request (to Air Traffic Control (ATC), the company dispatcher, or others), and some information (such as remaining flight time, and thus, the required diversion time) could only be inferred or computed from other information. (See table 1).

Time pressure varied between pilots in two versions of the scenario. Twenty-one officers executed a version of this scenario in which there was sufficient fuel to wait out delays at IAD until well beyond the scenario's unannounced ending at 36 minutes. The remaining 20 officers were given sufficient fuel to wait until only the 29 minute mark, at which point they needed to divert to an alternate in order to land with an adequate backup load of fuel. There was no difference between scenarios except in the amount of fuel provided.

During data analysis, subjects were segregated into two groups (less experienced pilots vs. more experienced) by dividing them at the median level of flight experience, 26 years[2]. These groups were labeled less experienced and more experienced. In regression analyses, experience level served as a predictor along with available decision time (low vs. high, represented by scenario version). Criterion variables were several behavioral indices, including the likelihood and timing of diversion and requests for maps (or plates) and weather reports.

Results & Discussion

Sensitivity to time is a central feature of the R/M Framework. Two sets of results pertaining to time were particularly interesting. First, the timing of pilots' diversion decisions reflected an interaction of experience with available decision time. The more experienced officers diverted relatively early when decision time was short, and later when decision time was plentiful ($F_{1,37}$ = 4.480, p = 0.041). The diversion times of less experienced pilots were unrelated to available decision time. Furthermore, when time was plentiful and diversion was unnecessary, more experienced pilots were slightly less likely to divert at all ($F_{1,37}$ = 3.074, p = 0.088). There are two plausible explanations for these effects. Experience might make pilots more accurate at estimating time from available fuel, fuel consumption rate, and remaining flight time. This was not the case. Accuracy of time estimates did not vary reliably with experience. The most plausible alternative explanation is that experience may foster sensitivity to the need to estimate time and to respect those estimates. While this experiment provides no direct evidence concerning sensitivity to time, this interpretation is consistent with our findings in interviews with tens of military officers in situations distinguished by high variance in time stress between high-stakes tasks (Cohen, Freeman, & Thompson, in press; Freeman & Cohen, 1994).

The second result of interest regarding time concerned how officers used scarce decision time. In the scenario in which decision time was short, more experienced pilots were less likely than the rest to request approach plates (maps) for ORF ($F_{1,37}$ = 2.750, p = 0.106). However, when more experienced pilots did request plates for ORF, they did so more promptly after the critical announcement of a ground accident at IAD than did less experienced officers ($F_{1,4}$ = 7.149, p = 0.056). This is consistent with predictions of the R/M Framework that decision makers under time pressure will forego collecting information that will not change decisions and swing outcomes. In this scenario, most if not all pilots learned from dispatch that ORF was a safe destination, and even when time was plentiful few pilots requested ORF plates. Clearly, most pilots felt that examining ORF plates would not change their decisions, and that the information on the plates would come at an unacceptable time-cost. Experienced pilots who did feel that the ORF data would influence their decisions and the flight outcome made the most of the available time by requesting ORF plates quite promptly.

The second feature of the R/M Framework that was of interest in this study was metacognitive skill at identifying and handling sources of uncertainty. In particular, we were interested in effects of experience on the ability to address gaps in the available information and test assumptions.

Pilots with greater experience were more likely to detect missing information and quicker to pursue the data they needed. For example, these pilots were more likely to request information concerning local air traffic which might compete with them for landing clearances (regardless of available decision time) (t_{39} = 2.427, p = 0.020). They were more likely and faster to request detailed approach plates for IAD, though these were not statistically reliable patterns. They also asked about the availability of alternate airports not mentioned in the briefing materials (such as military air bases) earlier when time was scarce, and later when it was plentiful, while less experienced pilots exhibited the reverse pattern ($F_{1,10}$ = 2.892, p = 0.120). We interpret these data as evidence that more experienced pilots had a superior ability to locate gaps in their knowledge and to request information in a more timely manner.

Pilots with more experience were more likely or faster to test assumptions about the reliability of potentially dynamic data than were other pilots. Announcing a runway accident at IAD, ATC gave a suspiciously short estimate (13 minutes) of the time required to clear the runway and issue further clearances. Pilots with more experience more promptly requested updated estimates of expected clearance (t_{20} = -3.186, p = 0.005). (The likelihood of such requests did not vary with experience). More-experienced pilots were also more likely to request updates to weather reports concerning IAD, a wise precaution given the rapidity with which the storm front eventually closed BWI as a legal alternate. We interpret these patterns of behavior as evidence that more experienced officers examined their understanding for weak assumptions concerning potentially dynamic forces, and tested those assumptions with explicit queries for information.

In sum, the experiment provided evidence that individuals with more experience were more cognizant of available decision time, and that this sensitivity influenced both their information gathering efforts and their decisions. In addition, the data demonstrate that greater experience is associated with skill at identifying and addressing sources of uncertainty in situation understanding, particularly gaps and assumptions. These are key elements of the Recognition/Metacognition Framework. Thus, the research validates components of the framework, indicating its promise as a tool for understanding decision-making under time pressure.

Time	**13:00**	**13:00:15**	**13:00:45**	**13:02**	**13:14**	**13:17**	**13:25**	**13:31**	**13:35**
Dulles (IAD) **Destination**	Crosswinds & snow at IAD. *Only a single runway is open at IAD.*	Cleared to cross next intersection near IAD	Expect holding at intersection	Holding instructions		Accident at IAD, closing the only open runway.	*Accident not yet cleared.*		Scenario ends
Current EFC				*13:20*		*13:30*	*13:32*	*13:36*	
Baltimore-Washington Int. (BWI) 1st alternate	Poor weather. Only runway is very short. Glideslope out of svc.	*Weather at BWI deteriorates.*			*Weather at BWI drops below legal landing minimums.*	*Weather at BWI remains below minimums.*			
Norfolk (ORF) 2nd alternate		*Excellent weather, runways available.*			*Dispatch will recommend ORF.*	*Latest time to divert:* *Low-fuel condition: 13:29* *High-fuel condition: 13:53*			
Other airports		*Not available as alternates.*							

Table 1: Scenario events announced to the pilot are in standard type. Information that pilots had to infer or request is marked in italics. EFC = Expected Final Clearance given by ATC.

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[2] Dividing a sample at the median of experience is a conventional method of grouping subjects when no objective index of expertise exists.