

## THE INFLUENCE OF PILOT EXPERTISE ON COMPREHENSION AND DECISION-MAKING

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Experts excel on domain-relevant tasks in part because their knowledge supports comprehension and decision-making. However, few studies have examined the impact of expertise on both comprehension and decision-making. We investigated the impact of pilot expertise on understanding and making decisions about flight-related situations that varied in complexity. Expert pilots (airline and corporate) and novice pilots (General Aviation pilots with little commercial experience) read very brief scenarios that described simple or more complex situations during take-off, enroute, or approach phases of flights by complex commercial aircraft. Participants read each scenario at their own pace, discussed the problem in the scenario and how they would respond if they were pilot-in-command, rated the familiarity and difficulty of the described situation and answered questions about the scenario, and after reading all scenarios answered questions about appropriate solutions to the problem described in each scenario. Compared to the novices (N=28), the experts (N=37) rated the scenarios as more familiar and as less difficult, although both groups perceived the complex scenarios as less familiar and more difficult. The experts more accurately answered questions about the scenarios and made more accurate decisions about how to respond to the problems, although the more complex scenarios were remembered less accurately and prompted less accurate decisions overall. Experts also outperformed novices on a knowledge measure relevant to the decision-making task. The expertise effects were not moderated by scenario complexity. The findings suggest that domain-relevant knowledge facilitates comprehension of flight situations, as well as the ability to make decisions based on this comprehension.

### Introduction

Experts excel on domain-relevant tasks for many reasons, including highly organized knowledge structures that enable them to rapidly build representations of complex, dynamic, and uncertain situations that support comprehension and decision-making despite constraints such as working memory limitations (e.g., Charness, 1991; Ericsson & Kintsch, 1995; Klein, 1993). Expertise benefits may depend on the complexity of the situation. More familiar situations that readily map onto knowledge structures may be easily recognized, so that decisions about appropriate responses are quickly made. However, such strategies may be less likely to occur for less familiar (or more anomalous) situations, where experts must engage in more effortful processes to identify problems and generate solutions (Klein, 1993; Patel & Arocha, 2001). In the aviation domain, expertise benefits have been found for tasks involving communication and decision-making (e.g., Wickens, Stokes, Barnett, & Hyman, 1993; Wiggins & O'Hare, 1995) and the ability to perform multiple tasks (Tsang & Shaner, 1998). However, few studies have examined the impact of expertise on both comprehension and decision-making, even though an insight from research about decision-making in natural situations is that decision-making often depends on situation assessment, or the ability to

understand situations and the constraints imposed on responses to these situations (Klein, 1993; Orasanu & Fischer, 1997; Wickens, 1999). We investigated the impact of pilot expertise on understanding and making decisions about flight-related situations that varied in complexity. We were also interested in whether expertise effects were moderated by complexity. It is possible that expertise effects would be reduced for more complex situations because more cognitive effort would be required to interpret the situation and/or generate appropriate solutions to the problem (Cohen, 1993; Patel & Arocha, 2001). It is also possible that expertise effects would be enhanced in this condition if expert pilots are more adept than novices at integrating their knowledge with information from the situation in order to identify the problem and/or to test possible solutions.

A secondary goal of the study was to explore whether expertise reduced age-related declines in performance, since subgroups of older and younger pilots were created at each level of expertise. Pilot decision-making in familiar situations may be influenced more by domain knowledge than general cognitive ability (Wickens, et al., 1993). Thus, older expert pilots may be able to rely on knowledge in order to offset age-related cognitive declines and maintain decision-making efficiency and accuracy, relative to older novice pilots.

## Method

### Participants

Expert commercial pilots (airline and corporate) and novice pilots (General Aviation with little commercial experience) participated. The complete sample will include equal numbers of younger (20-40 years) and older (45-60 years) participants for each level of expertise. So far, 37 experts and 28 novices have participated, with 17 older experts but only 6 older novices. Therefore, the present paper concentrates on analysis of expertise effects on the comprehension and decision-making tasks. Table 1 shows that the expertise groups did not differ in education, working memory, or processing speed ( $F(1,61) < 1.0$  for all three measures). The mean age of the young expert group was higher than that of the young novices (Expert X Age  $F(1,61) = 7.7$ ,  $p < .01$ ).

Table 1  
Mean Demographic and Cognitive Ability Scores

	YNG Expert N=20	Older Expert N=17	<i>Mean</i>	YNG Novice N=22	Older Novice N=6	<i>Mean</i>
Age	32.6	55.2	43.9	24.7	55.3	40.0
Educ	15.9	16.6	16.2	15.3	16.7	16.0
Working Memory <sup>1</sup>	4.6	4.1	4.4	4.4	3.9	4.1
Speed <sup>2</sup>	30.6	28.5	29.6	31.5	25.8	28.6
Total Flight hours	6247	14270	9672	402	809	489
Hours last 12 months	620	601	611	157	121	149
Total IFR hours	1667	4423	2892	80	106	86
Aviation Knowledge: General <sup>3</sup>	15.5	15.5	15.5	14.9	13.2	14.0
Aviation Knowledge: Specific	11.2	10.9	11.2	10.2	10.1	10.1

1. Mean of listening and reading versions of the sentence span task, a measure of verbal working memory capacity (Stine & Hindman, 1994).
2. Mean of Letter and Pattern Comparison tasks, a measure of processing speed (Salthouse & Babcock, 1991).
3. Twenty-item test adapted from FAA commercial pilot's license examination.

There were 3 measures of expertise: a) flight hours (total hours and hours last 12 months), b) general measure of aviation knowledge (navigation and communication concepts), and c) scenario-specific

measure of aviation knowledge. The latter two declarative knowledge measures were included because expertise is only loosely related to amount of experience (Ericsson & Charness, 1994). Table 1 shows that, not surprisingly, experts had flown more total and recent hours, and also had more instrument hours. While the groups did not differ on the more general knowledge measure ( $F(1,61) = 2.7$ ,  $p = .11$ ), experts outperformed novices on the scenario-specific knowledge measure ( $F(1,61) = 4.8$ ,  $p < .05$ ), which tapped concepts relevant to complex commercial operations.

### Procedure

Participants read six very brief scenarios that described simple or more complex situations during take-off, enroute, or approach phases of a flight by complex commercial aircraft. Simple and complex versions of each scenario were roughly equated for text-base characteristics (e.g., grammatical structure and number of words). The scenarios were developed by airline pilots. The complex situations involved more complex problems with less clear cut solutions, and were thought to require more knowledge about aircraft systems and operations. For example, the simpler version of one scenario described a situation where an aircraft wing struck a crane on take-off, which resulted in no apparent problems; in the more complex version the strike resulted in loss of hydraulic pressure and leading edge device asymmetry. Participants read each scenario on a computer at their own pace, and in a standardized interview discussed the problem and how they would respond if they were pilot-in-command. They then rated the familiarity and difficulty of the described situation and answered questions about explicitly mentioned information in the scenario. After reading all scenarios, they completed a multiple-choice questionnaire about appropriate solutions to the problem described in each scenario. Correct answers were determined by consensus among three airline pilot judges. Finally, participants completed the measure of knowledge about concepts relevant to the decision-making task.

## Results

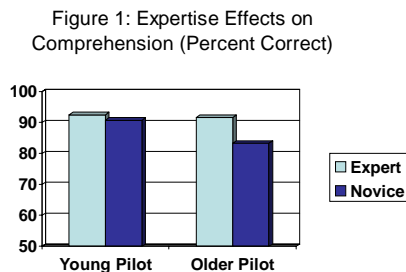
### Scenario Ratings

Compared to the novice pilots, the experts rated the scenarios as more familiar and less complex, although both groups perceived the complex scenarios as more difficult, less familiar, more time-critical, and involving more risk. The ratings help validate the complexity manipulation, and suggest that these scenarios were more related to the

knowledge base of the expert pilots than to the novice pilots.

#### Scenario Comprehension

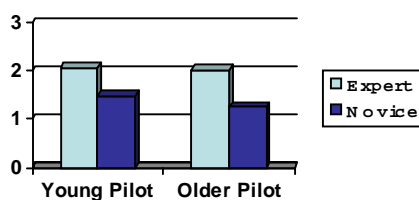
Mean accuracy of answering questions about information in the scenarios was analyzed by an Expertise x Scenario Complexity ANOVA, with the latter variable as a repeated measure. Figure 1 presents mean accuracy for the experts and novices, as well as by age. While overall comprehension was very high, the experts were more accurate ( $F(1,61) = 5.5, p < .05$ ). The more complex scenarios were also understood less accurately ( $F(1,61) = 6.3, p < .05$ ). Expertise was not moderated by complexity ( $F(1,61) < 1.0$ ).



#### Scenario Decision-making

Decision-making accuracy scores (reflecting participants' agreement with the expert judges) were analyzed by an Expertise x Scenario complexity ANOVA with the latter variable as a repeated measure. Expert pilots made more accurate decisions about how to respond to the problems ( $F(1,61) = 20.1, p < .01$ ). Accuracy was lower for the more complex scenarios ( $F(1,61) = 9.7, p < .01$ ). However, expertise benefits were not moderated by complexity ( $F(1,61) = 1.5, p > .10$ ).

Figure 2: Expertise Effects on Decision-Making (Accuracy)



We also investigated whether expertise differences in comprehension would help explain differences in decision-making. To do this, we compared the variance in the decision-making measure accounted for by expertise (dichotomous variable) without and

with comprehension controlled. Expertise accounted for 28.5% of the variance ( $F(1,63) = 26.5, p < .01$ ) when entered first into the model. The variance accounted for was reduced to 23% when the comprehension measure was entered before expertise, a nonsignificant change in  $R^2$ .

#### Expertise and Aging

In an exploratory analysis, we compared the older and younger pilots within each expert group in order to investigate whether age had less influence on experts than on novices, as predicted by theories of cognitive aging and expertise (e.g., Meinz, 2000; Salthouse, 1995). Although the pattern of group differences for the question accuracy measure in Figure 1 suggests that age effects were smaller for experts than for novices, the Age X Expertise interaction was not significant with the current sample size,  $F(1,61) = 2.5, p > .10$ . More definitive analysis of age effects will be conducted on the complete sample.

#### Discussion

The preliminary findings from this study suggest that domain-relevant knowledge facilitates pilots' comprehension of flight situations, as well as the ability to make decisions based on this comprehension. The regression analysis did not find evidence that the expertise benefits on the decision-making task reflected the experts' superior comprehension. This may reflect limitations on the comprehension measure since Figure 1 shows that experts were close to ceiling on this measure. In addition, the measure was more likely to tap comprehension at the level of the explicit textbase representation rather than at the situation model level, which may be more critical for decision-making (Adams, Tenney, & Pew, 1995).

While situation complexity was associated with reduced comprehension and decision-making, there was no evidence that it moderated expertise benefits. This may reflect limitations of the study's procedure. For example, because pilots read the scenarios at their own pace, there may have been trade-offs between comprehension time and performance on the decision-making task. We will examine relationships between scenario reading time and decision-making strategies with the complete sample. We also plan to analyze the decision-making protocols, which will provide a more refined measure of decision-making strategies. This measure should provide a richer picture of age and expertise effects on pilots' decision-making processes as they relate to flight situations that vary in complexity.

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