Rethinking Pilot Attitudes toward Automation

Ten years after Earl Wiener's (1989) classic survey of pilot attitudes toward automation, researchers have once again turned to pilot attitudes to measure how pilots think and feel about the automation in the airplanes they fly. Psychologists have measured attitudes as mediators of human behavior for decades based on the assumption that attitudes and behavior are highly correlated (see Abelson, 1972). Thus, how pilots feel about automation is believed to be both a consequence of what pilots experience on the flight deck, and a cause of how they act in the cockpit. Wiener's (1989) survey was an early attempt to understand how pilots' attitudes toward automation, in the aircraft they fly, affected flight safety. The introduction of increasingly complex automation in modern airplanes has raised concerns about pilot understanding and use of the flight management computer system. Several other researchers have recently adopted Wiener's approach (Funk et al 1999, BASI 1998, Wiener, Chute, & Moses 1999).

Funk and his colleagues (1999) conducted a major review of perceived human factors problems of flight deck automation. They concluded that pilots may have an inadequate understanding of automation, automation behavior may be unexpected, and automation may place excessive demands on pilot attention. Perceived increases in pilot workload were attributed mainly to the attentional demands of the automation. A Bureau of Aviation Safety Investigation (Australia) surveyed 5000 pilots from the Asia-Pacific region on their attitudes toward automation (BASI 1998). They found in general that pilots were very positive about automation, but that automation can still surprise pilots, most pilots like to hand fly some portion of the flight, and mode awareness can be low. System workarounds were another issue in which pilots had to enter fictitious data in order for the automation to process their request. Respondents also reported that crew coordination, especially communication, on advanced automation aircraft is problematic. A recent report by Wiener, Chute and Moses (1999), reported that pilots held positive attitudes toward automation due "in part to the fact that advanced automation, by the time of this study, no longer evoked emotions of uncertainty and with reservations had proven itself to a skeptical pilot population" (p. VI).

In an earlier project (NASA cooperative agreement XXX) we distributed a partial replication of Wiener's original survey questions to pilots flying the Boeing 757/767 for a major U.S. airline. We found remarkable stability in response patterns to the attitude probes and in the pilot interviews when compared to Wiener's findings despite the passage of ten years, two different airlines, different aircraft, and pilot populations more experienced with advanced automated (glass) aircraft (Hutchins, Holder, and Hayward, 1999). While at a superficial level this stability seems reassuring, we find such consistency astonishing. The stability manifests itself in response patterns. Probes that elicited unimodal response distributions in Wiener's study also elicited unimodal distributions in our replication. Probes that elicited bi-modal distributions in Wiener's study also elicited bi-modal distributions in our study. At the time we were unable to explain why some probes elicited unimodal distributions and others had bi-modal distributions.

In the current project we interviewed pilots at a different major U.S. airline who were transitioning to the Airbus A320 from a variety of other airplane types. We asked these participants about their flying experience and expectations about transitioning into an extensively automated airplane. Surprisingly, both pilots who had some experience in automated airplanes and pilots who had no experience at all in automated airplanes expressed the same sorts of concerns about automation.

One plausible explanation for the incredible stability of the attitude data in the 1999 study and for the lack of difference in reported attitudes between pilots with and without experience in automated airplanes in the current study is that professional pilot culture contains a substantial body of widely shared knowledge and belief about automation and its role in the modern airline flight deck. A simple hypothesis is that both interviews and attitude surveys tap this cultural knowledge in addition to whatever pilots may have learned from direct experience. In the sections below, we first identify the cultural schemata that organize pilots' expectations about flying a highly automated airplane. We review the methods and goals of the attitude survey study. We then use these schemata to explain the structure of response profiles observed in the attitude survey data.

Interviews at Airline 1

We conducted a cultural analysis of pilot's preconceptions of the Airbus A319/320 from interviews we conducted at the airline's training center. Several pilots had automated experience (F100, RJ, B737-300), while the remaining pilots had no automated experience (DC9-80, DC8). The cultural models pilots use to organize their discourse about their preconceptions about flying an extensively automated airplane were the targets of our analysis.

A cultural model is constructed from a complex organization of concepts and experiences. A model may be based on a single schema or be constructed from a complex network of schemata. The activation of a schema may invoke the entire model or merely a partial instantiation of the model. These models are conceptually complex and may be used to organize complex activities for an entire domain of cognitive labor (D'Andrade, 1995). For example, Hutchins (1995) has detailed cultural models Micronesian navigators use to guide their crafts across vast stretches of open ocean. The models serve as organizing conceptual structure that can be mapped to physical structure in the world to facilitate mental computations in the performance of complex navigation tasks. The domain of flying also has cultural models that pilots use when they reason and talk about flying.

We interviewed pilots early in their training and before they had flown the airplane. The interview questions were designed to probe for the pilot's flying history and his expectations about flying the Airbus. We transcribed the interviews and identified excerpts relevant to pilots' expectations about the airplane or its automation. For each excerpt, we attempted to identify the underlying conceptual structure guiding the discourse.

Most of what pilots said fit a top-level schema with the following structure (arrows -> indicate relations of implication or expected temporal sequence; generic schema in bold font, instantiations of the schema quoted in normal font.).

Properties of Automation -> nature of experience -> consequences for the pilot

Generic instantiations of the this schema include statements like these:

"It does everything" ->	"you don't do anything" ->	"makes flying easier"
"So much done for you"	"hands off"	
"It's so automated"	"not flying, just monitoring"	"skills erode"
"Tells you when to descend"	"just sit there and watch it do it's thing"	"get spoiled"

The generic counter model is instantiated in the following statements:

Low technology airplane ->	**"more involved" ->**	**better situation awareness**
		"time passes quickly"
		"More up on progress of flight"

We also identified a general spoiled schema:

Normal life -> develop coping ability

Cushy life -> loss of coping skills

Return to normal life -> "spoiled" (difficult to cope)

The "spoiled" schema is instantiated in this manner:

Normal life (conventional airplanes) -> develop coping ability (flying skills)

Cushy life(airbus/automated) -> loss of coping skills ("how did I ever live without this" "it makes you lazy")

Return to normal life (conventional airplane) -> "spoiled" ("It's going to be difficult to go back" "you become addicted to the information")

Pilots bring with them to training a sense of what it means to become comfortable in an airplane new to them. The general structure of their expectation is:
Unfamiliar -> getting used to -> comfort

Specific features of this model are instantiated as:

"Attitude control"	->	"take time to get used to"	-> accustomed

"strange", "weird"

"Don't turn on ignition"

"fly-by-wire" "autothrust"

Another model organizes expectations about the sources of automation surprises. It links mode complexity to cognitive demands on the pilot and then to suprises.

Mode complexity	**-> mode management tasks**	**->automation surprises**
"you have no clue"	"hard to distinguish between	"why is this thing not
"they (modes) pop up"	managed and selected"	descending?"
	"setting up the approach"	

A generic counter schema holds that mode complexity can be managed via procedure.

Mode complexity	**->**	**proper procedures**	**->**	**expected behavior**
		"it's just a matter of having all the		expected behavior (implied anaphoric reference of "it's")
		buttons pushed the right way"		

Complex interface	**->**	**Ease of making an error**	**->**	**could make a subtle error**
		Difficult to detect		
		"mis-set missed approach		level off at 500' without
		altitude		knowing it

Conventional airplanes are conceived as a contrast case. The same top level schema linking properties of automation to the nature of experience and then to consequences for the pilot is still at work. In this contrast case, however, beneficial features of conventional airplanes are highlighted.

Conventional airplane	**->**	**hand flying**	**knowledge of timing**
		Being involved	**situation awareness**

Terminology and displays	interpretation tasks	learning to interpret displays
	"grabbing info from PFD	
	and ND.	

It does everything

"It figures out what you're supposed to know and puts a little message on the screen"

Some pilots bring with them apprehension about control authority:

Automation controls airplane "Two pilots at the controls"

Pilot controls airplane

Computer mediates pilot inputs "I don't want a computer interpreting what I do"

Pilots also have concerns about their authority versus computer authority: Who's in charge? If it's the computer, can engineers anticipate everything? Citing the ATR accident at Roselawn as an example of the computer overriding the intentions of the crew, one pilot said, "they reselected the flaps, but the airspeed was too high and the computer wouldn't let 'em put the flaps back down"

Summary

In the face of this complexity and the problems it seems to cause, pilots should and do apparently develop and use simplified models of what the autoflight system is doing. What resources do pilots bring to training in order to produce meaningful interview behavior? Notice that all these responses were made without any experience in the airplane. These pilots are not yet reporting on their actual experience, they are reporting on the basis of cultural schemata that organize their expectations. Our questions were quite open-ended and did not presuppose much about the organization of knowledge.

Attitude Survey Data Airline 2

The attitude probes contain commitments to specific content. What resources did the researchers draw on in composing the probes? We propose they used their cultural knowledge about the domain of flying automated airplanes. The probes must be culturally meaningful things to ask about, or they will not be taken seriously.

When a pilot reads an attitude probe it activates general schemata of piloting life, or what it means to be a pilot and what it means to fly an automated airplane. And perhaps memory of the structure of specific incidents, but these memories too are shaped by the cultural schemata.

Method

Study participants were pilots flying the Boeing 757/67 for a major US airline. 2909 surveys were shipped to the airline and were then distributed in the company mailboxes of pilots. Pilots returned their anonymous, completed surveys directly to the authors. The survey package consisted of three parts: an experience questionnaire, a set of probes concerning attitudes toward automation, and a set of similarity judgements. Because we were interested in the distribution of attitudes toward automation among the pilots, an experience questionnaire was deemed useful for determining how experience might correlate with pilot attitudes.

The experience questionnaire was also used to determine the demographics of the surveyed population. We chose 15 probes from Wiener's 1989 study that were most closely related to autoflight. Each probe was presented as an assertion over a five point scaled response. We added one new probe to the study: "I always consult the flight mode annunciator to determine which mode the autopilot/flight director is in." We hoped this probe would help us understand the relationship of consulting the flight mode annuciator to other attitudes toward automation such as the probe "There are still things that happen that surprise me".

The similarity judgements of autoflight mode names as they appear on the flight mode annunciator were designed to reveal pilots' understanding of the conceptual relationships between modes. We hypothesized that pilots with positive attitudes toward automation would have a more coherent model of autoflight when compared to those pilots with negative attitudes toward automation, assuming that one would feel more positive about technological systems that one understands.

Experience

Of the 2029 surveys, 562 usable surveys were returned. 254 surveys were from Captains and 267 were from First Officers and 41 did not indicate which seat they occupied. On average, respondents had 11,833 hours of total flight time, 3, 013 automated hours, and 2,657 hours in the 757/67 (TABLE 1).

Table 1. Demographics of the Respondents.

	Seat		Average Hours		
Respondents	Captain	First Officer	Total Hours	Automated Hours	757/67 Hours
562	254	267	11,833	3,013	2,657

It comes as no surprise that captains have more total flight hours and more automated hours than first officers. Captains also have more, but not significantly more, time in the 757/67 than first officers have.

An hypothesis concerning the shape of response profiles

Can the cultural schemata that pilots used to organize their expectations about flying a highly automated airplane help us understand the stable attitudes reported in a range of survey studies?

First consider the schemata identified in the interviews with pilots entering Airbus training, and let us add to that just a few widely shared notions in the industry (for example, the recently promulgated idea that pilots should use whatever level of automation is appropriate to the task).

Consider the case of an individual pilot formulating a response to a probe. A pilot responding to a probe in the attitude survey will activate one or more cultural schemata as resources to be used to formulate a response to the probe. If the set of schemata that an attitude probe activates for an individual pilot are consistent with each other, then the pilot will respond positively or negatively. If a probe activates a conflicting set of schemata, then we expect a neutral response.

No consider populations of pilots. If a probe reliably activates a widely shared set of consistent schemata in the pilot population, then the response profile will be uni-modal, either positive or negative. If positive and negative schematic elements exist together in many individuals (intrapersonal contradiction) then we might expect a large number of neutral responses as well as positive and negative responses. This would produce something like a normal distribution about the “neutral” mean. If, however, the contradictions are present in schemata that reside in different people (interpersonal contradiction) then we predict few neutral responses and a bi-modality of the response distribution. We should probably not expect to be able to distinguish between these latter two cases on the basis of the structure of the schemata. However, the characteristics of the response profiles might provide indications of how the schemata are distributed among the members of the population and about which ones can co-exist in a single mind.

[need to examine the relations among probes as well. The probes that have bi-modal response profiles should be ones in which each extreme response can be seen as part of a coherent model of flying. That is, the positive and negative poles of bi-modal responses should be closely related to other positive or negative poles. The beliefs should cluster. Highly skewed unimodal distributions should also participate in these coherent constellations, but centered unimodal (normal or bell-shaped) distributions should not be linked to coherent constellations. It should be possible to related this to consensus theory. Romney and Weller, 1986].

This hypothesis interests us because in reviewing the data, we were unable to find any features of the probes that united the classes of response profiles. It is also important to remember at this point that these are schemata that came from pilots who were not reporting on experience in an automated airplane rather they were anticipating experience in an automated airplane. So they were not using memory of specific incidents in order to construct what they said.

We made a series of predictions of response patterns we’d expect for each attitude probe. These predictions were grounded in our ethnographic research of pilots’ cultural models. Our predictions and the observed responses are presented in Table X.

Attitude Probe	Response		
	Predicted	Observed	
Flying skills	Bi-modal	Slight bi-modal	HIT
Works great	none		-----
Know mode	Bi-modal	Slight bi-modal	HIT
Company	Uni-modal	Uni-modal	HIT
Free to manage	Slight bi-modal	Uni-modal	MISS
Surprises	Slight bi-modal	Slight bi-modal	HIT
Fewer errors	none		-----
Stay ahead	uni-modal	uni-modal	HIT
Setting up and manage	none		-----
Not reduce workload	bi-modal	bi-modal	HIT
Consult FMA	none		-----
Training	none		-----
Get job done	uni-modal	uni-modal	HIT
Bust altitude	none		-----
Button pusher	bi-modal	bi-modal	HIT
Don't understand	bi-modal	bi-modal	HIT

Table X. Predictions of response profiles based on cultural models analysis.

In the following paragraphs, we treat the probes one at a time.

1. I am concerned about a possible loss of my flying skills with too much automation.

This probe activates the principal generic instantiation of the automation schema. Automation means the pilot doesn't do anything. That means that pilots are not practicing their skills, and skills that are not practiced are likely to atrophy. This model is also embodied in the currency requirements that form a central part of pilots' lives. Pilots must have three bounces in the previous 90 days in order to fly. The model actually reaches far beyond flying culture. People often use a metallic mechanism metaphor to describe their performance when they have not had practice. They say, "I'm rusty". So this model activates a schema that encourages agreement. However, there are also conflicting schematic elements. Pilots pride themselves on their flying skills. Self-esteem by itself may encourage a negative response. Furthermore, many pilots claim that they hand-fly the airplane exactly because they believe that too much automation may cost them their flying skills. These pilots are not worried about losing their skills, because they do not permit automation to become too much. Thus, they will not agree with this probe. These conflicting schematic elements lead us to predict a bi-modal response distribution.

The observed response distribution is slightly bi-modal. HIT.

2. The automation in my current aircraft works great in today's ATC environment.

This probe relies on experience that our pilots do not have. None of the schemas in our study is much activated by this probe, and so we have nothing to say about it.

No prediction.

3. I always know what mode the autopilot/flight director is in.

Knowing one's mode is widely understood to be an important aspect of flying automated airplanes. All of the major manufacturers have stressed this and knowing the mode is a key element of all the training programs for automated airplanes we have seen. Thus, both the pilot's general sense of competence and the specific training content encourage a positive response. There are, however, some conflicting elements. Mode confusions and automation surprises are now accepted categories of events in the flying world. Pilots believe that the modes are complex and that sometimes they change without any command from the crew. Because of these conflicting elements, we predict a bi-modal distribution.
The observed response distribution is slightly bi-modal. HIT.

4. I use the automation mainly because my company wants me to.

The culture of flying says "No" to this. In recent years, the issue of the many challenges to pilot authority have been explicitly discussed in flight safety magazines and in CRM courses. Pilot self-esteem is built around autonomy of decision making. "That what I get paid to do." Also, several airlines, including the one for which the pilots in our study work, have recently changed their automation training philosophy to emphasize that a pilot should use the level of automation that is appropriate to the task. The older model (current when Weiner first did his study) that says, "We bought it, you'll use it." Has been replaced by one in which the pilot shall decide what level of automation to use. There are no conflicting elements in the schemata, so we predict a uni-modal distribution.
The observed response distribution is uni-modal. HIT

5. Automation frees me of much of the routine, mechanical parts of flying so I can concentrate on "Managing" the flight.

This is the core idea behind the human factors side of the marketing of automation. We see in the schemas from the interviews a very strong sense of liberation from the mechanical parts of flying. "You don't do anything.", "just sit there and watch it do its thing." These points are coupled with the idea that automation makes flying easier. Also note, that this probe is not a challenge to self esteem because "managing" the flight is a valued activity in the world of automated airplanes. It is also independent of the loss of flying skills, and perhaps the ability to manage could be seen as compensation for lost flying skills. These things encourage a positive response. There are, however, some

conflicting elements. Engagement with the mechanical parts of flight is believed by some to lead to better situation awareness, which ought to facilitate the process of "Managing the flight". For these reasons we predict mostly agreement, but with some negative responses and possibly enough negative responses to create a bi-modality.
The observed response distribution is uni-modal. MISS.

6. In the automation of my current aircraft, there are still things that happen that surprise me.

This probe activates conflicting schemata from the realm of pilot self-image and the specifics of automation. Being surprised is evidence of a lack of understanding, and pilots are reluctant to admit to such things. Still, in the schemata identified above, the possibility of automation surprises is recognized and illustrated with examples. We therefore predict a bi-modal response profile for this probe.
The observed response distribution is slightly bi-modal. HIT

7. I make fewer errors in the automated airplanes than I did in older models.

Our interviews show two major conceptual elements relevant to this probe. First, in automated airplanes, subtle errors may be possible, and may be difficult to detect. Situation awareness may be better in conventional airplanes. Both of these things could lead to more errors in automated airplanes. Second, though, flying automated airplanes is easier, and that might lead to fewer errors. One pilot also remarked that there are likely to be fewer interpretation errors associated with EFIS instruments. These give conflicting predictions. So we predict a spread of opinion.
The observed response distribution is uni-modal and centered on neutral response. HIT/MISS

Consider what we would have to assume about individual pilot memory of experience in order for a pilot's response to this probe to be taken as being about the relative frequencies of errors in the two types of airplanes. They know they cannot really answer a probe like this, so a lot of them choose neutral.

8. Automation helps me stay ahead of the airplane.

The culture says, "yes". The main schema says that automation does everything, makes flying easier, and pilots get spoiled. However, there is some concern that pilots of automated airplanes might loose track of some aspects of flight. Even if it costs me my flying skills, it does keep them ahead of the airplane. Large positive, small negative.
The observed response distribution is uni-modal and positive. HIT

9. I spend more time setting up and managing the automation (CDU, FMS) than I would hand-flying or using a plain autopilot.

The schemata produced by our interview data do not seem to be directly relevant to this probe. The closest we come is the claim concerning an approach that "its just a matter of having all the buttons pushed the right way." But, this says nothing about the amount of time required to push the buttons.

No prediction.

10. Automation does not reduce workload because there is more to monitor now.

There is a clear indication in our schemata that pilots expect much of the work of flying an automated airplane to involve monitoring the airplane and its systems. They are also concerned about the job of "grabbing information" off the displays. These things would encourage a positive response. But, flying automated airplanes is also seen as easier than conventional airplanes. These conflicting elements lead us to predict a bi-modal distribution.
The observed response distribution is bi-modal. HIT

11. I always consult the flight mode annunciator to determine which mode the autopilot/flight director is in.

The training says that pilots must agree with this probe. The schemata recovered from the interview data do not seem relevant to this issue. There is a wide-spread sense in the industry that pilots actually do not always consult the FMA, and some even believe that they need not consult it. One said, "I press the button and the houses get smaller, that's enough for me." Independent of the interview data, on the basis of other elements of contemporary flying culture, we predict a bi-modal distribution. However, since the pilots being interviewed had not yet flown the automated airplane, the schemata they used provide no basis for prediction.
The observed response distribution is slightly bi-modal. -----

12. Training for my current aircraft was as adequate as any training I have had.

We have no grounds for prediction on this probe.

No prediction.

13. I use automation mainly because it helps me get the job done.

The principal theme of the most elaborated schema in the interview data agrees with this probe. This is what automation is supposed to do. The phrasing of this probe also puts the pilot in an active mode with respect to the automation, and that fits the pilots' self-image of competence and self-reliance. We therefore predict a strong uni-modal response distribution.
The observed response distribution is uni-modal and positive. HIT

14. It is easier to bust an altitude in an automated airplane than in other planes.

One of our interviewed pilots imagined a scenario in which he could level-off at the wrong altitude following a missed approach in an automated airplane. This favors agreement with the probe, but is not an explicit comparison. The schemata identified in the interviews do not seem to be relevant to this issue. We cannot make a prediction.

No prediction.

15. Sometimes I feel more like a button pusher than a pilot.

The culture of flying and the self-image of pilots point to strong disagreement with this probe. However, the interviews also indicate that flying the airplane is just a matter of having all the buttons pushed the right way. We therefore predict a bi-modality. Another reason to predict a bi-modality comes from the roles of the captain and first officer with respect to pushing buttons. Since FOs preflight the box, they end up doing more button pushing than captains do, even if they alternate PF and PNF on each leg. Captains should be in the disagree end of this distribution.
The observed response distribution is bi-modal. HIT

16. There are still modes and features of the autoflight system that I don't understand.

The self-image of pilots encourages disagreement with this probe. However, the perceived complexity of the system and the belief in the existence of automation surprises encourage agreement. We predict a bi-modal distribution.
The observed response distribution is bi-modal. HIT

When we predict a bi-modality based on the notion that the phrasing of the probe runs against pilot self-image, we are not implying that we believe there are no pilots who are justified in honest disagreement with the probe. We are only saying that there are conflicting schemata present and that these should lead to a spread of agreement ratings.

Discussion

The predictions look fairly strong. In six cases, we could not make a prediction based on the interview data. On nine of the remaining 10 cases, we were able to give correct predictions of the nature of the response distribution based on the structure of the schemata identified in interviews with pilots who were entering a training program for an automated airplane. We can account for much of the attitude survey data by understanding the cultural conceptual models of the domain. It is certainly possible that these cultural concepts and expectations might be closely related to actual experiences. However, we must be very careful about trying to read such responses as indicators of what is happening in the actual experience of pilots.

The moral of this tale is this: If you want to know what is actually happening, that is, how pilots are using autoflight systems, what things are going right and what is going wrong, then you had better get out there and observe on the line. The responses to surveys and interviews carry the heavy imprint of the system of beliefs that is current in the culture of those interviewed. Informants are simply not capable of constructing responses any other way.
Our findings suggest pilot response to attitude probes were not as revealing about flight safety issues as anticipated. While the findings do highlight some problematic automation issues they are far from identifying specific issues about automation and how to remedy them. Furthermore attitudes are not indicative of what pilots do versus what they say they do and feel. The attitude probes measure some mix of widely shared pilot

beliefs and actual pilot experience. Without other measures in place, it is not possible to estimate the relative contributions of these two factors.