Flying Glass: A Qualitative Analysis of Pilot Perceptions of Automated Flight-Decks After 20 Years

Jim Mitchell

School of Management
University of Western Sydney
Sydney, Australia
j.mitchell@uws.edu.au

Leopold P Vermeulen,
and
Prevendren Naidoo

Dept of Human Resource Management
University of Pretoria
South Africa

Abstract

In 1991, 2001, and 2008 surveys were conducted to determine pilot perceptions of automated flight decks or "glass cockpits." Results from these similar surveys indicated that a number of factors identified remained the same. However, over time, some changes in perceptions were noted. The 2008 survey provided airline pilots the opportunity to write comments and express their ideas and concerns about aspects of the glass cockpit. This paper provides a qualitative analysis of their comments identified as a number of themes. Their perceptions of themes such as situational awareness, automation and technology, skills, stress, workload, and computer literacy are examined. Overall, the perceptions of the glass cockpit are positive. However, there remains an underlying caution concerning several aspects of piloting including perceived loss of manual flying skills, stress, and extreme workload resulting from the potential over-reliance and pervasiveness of computerized technology on the flight deck.

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During the 1970s and 1980s there was a rapid development of automated apparatus, which were being incorporated in large aircraft. Significant developments included inertial navigation systems (INS), flight guidance systems, auto-throttle systems, ground proximity warning systems (GPWS) and various crew alerting systems (Wiener, 1989). In general terms, the new technology manifested itself as "the glass cockpit (displays driven by computer graphic systems)" (Wiener, 1988, p. 435). Wiener (1989) also indicated that as the level of automation increased there was "a growing discomfort that the cockpit may be becoming too automated" (p.1). Issues such as an over-dependence on automation, deteriorating flying skills, and diminished situational awareness began to be considered. Since the late 1980s considerable research has been given to the impact of new technology and pilots' attitudes towards automation on flight decks. Particular research focus was on training, that is, the conversion of pilots from the use of gauges to operating automated systems, safety, design aspects, situational awareness, the role and responsibilities of pilots, workload, levels of skill, and operational aspects (James, McClumpha, Green, Wilson & Belyavin, 1991).

Over a period of seventeen years (1991, 2001, and 2008) three similar surveys have been conducted in order to assess pilot attitudes or perceptions on issues of flight deck automation. The results of the first two surveys have been published as journal articles and the third formed the basis of a Master's thesis. This article provides a brief comparison of the quantitative results and then focuses on an analysis of the qualitative data from the 2008 survey.

The James et al. (1991) survey of active United Kingdom commercial pilots (n=1372), using principle components analysis of the five point Likert scale, identified four main factors. These were Understanding/Mastery, Workload, Design, and Skills and accounted for 31.48% of the total variance (James et al., 1991). Understanding/Mastery consisted of "comprehension, expertise, knowledge, and use of the system." Workload entailed "workload, demand, stress, and task efficiency." Design referred to "ergonomic efficiency, design and displays," and skills encompassed "handling skills, crew interaction, and self-confidence" (p.3.5). Among other things, the authors found pilots' perception of their own understanding and mastery was higher the more experience the pilots had on type and that younger (under 40 years of age) pilots felt they had a relatively better understanding of the glass cockpit systems. Attitudes towards the impact of computerization on workload tended to be favorable and more so among the older cohort. In respect to design, increased hours on type revealed a less favorable attitude due to the discovery of design shortcomings revealed in day-to-day operations. Older pilots were less concerned that there may be a degradation of skills due to automation. Because their skills were more ingrained, older pilots indicated that their situational awareness was better than the younger or less experienced pilots. Concerns that automation degraded flying skills were more strongly held among younger pilots.

Using an adapted version of the James et al. (1991) questionnaire, Singh, Deaton and Parasuraman (2001) surveyed 163 pilots at Embry-Riddle Aeronautical University. Retaining the five point Likert scale and principle components

analysis, the researchers identified six factors: workload, design, skill, feedback, reliability, and self-confidence. Although there was "an overall inclination toward advanced automation," a majority of pilots indicated "there was too much automation in the advanced automated aircraft" (Singh et al., 2001, p. 210). The researchers also identified attitudinal differences between British and American pilots. "For example: British pilots prefer to fly advanced automated aircraft on which they rely too much, whereas Americans don't like automated aircraft and they least rely on them" (Singh et al., 2001, p. 210). Although conducted ten years apart there are similarities and differences in the results of the two surveys. Sample size and cultural differences, although not examined extensively, may account for attitudinal differences and perceptions of automation in the cockpit. A later survey is compared.

In 2008, a survey was conducted with South African airline pilots. Again, the questionnaire was adapted from the James et al. (1991) survey and took into account the ten critical issues (cf. http://www.flightdeckautomation.com) in relation to flight deck automation and operations (Naidoo, 2008). The researcher opted for a seven point Likert scale and an exploratory factor analysis was used. Shepherd (1998) contends that a seven or even a nine-point scale tend to give the items more granularity. This is supported by Gravetter and Wallnau (2002) who argue that using a larger number of intervals (seven in this case), allows the researcher to conduct a more accurate calculable investigation. The factors were identified as Comprehension, Training, Trust, Workload, and Design. Comprehension refers to the understanding of the flight management system and grasp of consequences relating to their actions and inputs. Training highlighted the need for a level of training for a pilot to acquire an adequate standard to operate automated flight deck systems. Trust indicates the confidence the pilot has in the automated systems. Workload refers to the ability of the pilot to program the various functions of the flight management systems. Design refers to the presentation of automated systems and includes ergonomic design, color, and ease of use.

Comparison of the factors identified by the three surveys indicates a strong commonality in the results. Workload, skills, and design are common labels with understanding/mastery, self-confidence, and comprehension sharing similar components. Feedback, reliability, and trust also appear to share common items. Overall, the results indicate that common threads permeate pilot perceptions of automated flight decks. These are consistent over time even allowing for differences in national cultures. Table 1 compares the factors identified by the three surveys.

Table 1

Comparison of factors in three surveys

	Survey		
	James et al. (1991) (UK)	Singh et al. (2001) (USA)	Naidoo (2008) (South Africa)
Factors	Understanding/mastery Workload Design Skills	Workload Design Skills Feedback Reliability Self-confidence	Comprehension Training Trust Workload Design

Aim of the Study

The Naidoo questionnaire also allowed written comments to assess the airline pilots' perceptions of flight deck automation. Section 3 of the questionnaire consisted of two open-ended questions. Here the respondents were provided with an opportunity to list the various aircraft types they have had experience on and to provide either positive or negative comments on their experience in operating glass-cockpit aircraft. This section offers additional information for a qualitative analysis of the written statements from the participants. The analyses of these written comments from pilots operating aircraft of the highest level of automation (such as B737-800 and A320) will enhance the quantitative analysis of the three surveys and add to our insight into and deeper understanding of pilots' subjective experiences of flying glass. In the light of the above discussion, the aim with this study was to explore and describe the views of a sample of South African airline pilots regarding their subjective experiences of the advance glass-cockpit environment.

Method

Research approach

A qualitative research design was implemented to ensure that the primary aim of this study was successfully achieved. Although there is no agreement on an exact definition of qualitative research (Strauss & Corbin, 1990), this study can be considered qualitative in nature. According to Marshall and Rossman (cited in Wilson 1998, p. 2) qualitative research is divided into four taxonomies: exploration, explanation, description, and prediction. In descriptive research, the phenomenon under investigation can be described in such a way that the readers understand the experiences, perceptions, views, and feelings of participants. In this study, the descriptive approach was used to analyze, describe, and give meaning to the salient themes and patterns related to airline pilots' experiences and perceptions of flight-deck automation.

Credibility as a criterion was strongly imposed during the design, data collection, analyses, and reporting phases of the study. The term credibility replaces validity in qualitative research (Pitney, 2004). To enhance the credibility of the investigation all participants were assured of the confidentiality and anonymity of the research process, all the biographical information and comments of the participants

were documented in a standardized format, and a uniform process was used to analyze the content of written comments. Furthermore, the analysis of the data and interpretation of the results was done by the expert qualitative researcher in the team, while the other researchers provided critical input during the design, execution, and reporting phases of the study.

Participants

The research group represented a purposive sample of current airline pilots at a major South African carrier operating both Airbus and Boeing type aircraft. Two hundred and forty five male pilots and 17 female pilots responded to the 2008 Naidoo survey, of which 172 provided written comments of their views and experiences in operating glass-cockpit aircraft. Table 2 outlines the biographical data of those respondents who wrote of their perceptions of the glass cockpit and other concerns.

Table 2

Respondent biographical data

Respondents		Males	Females	Total
		163	9	172
Age	– Average	45.6	31.8	45.1
	- Range	26 - 62	25 - 42	25 - 62
Years Exp.	– Average	25.4	12.0	24.9
	- Range	4 - 46	5 - 25	4 – 46
Total Hours	– Average	13147	5556	12908
	- Range	1500 - 27000	2700 - 14000	1500 - 27000
Digital Hours	– Average	4968	3278	4945
	- Range	13 - 14000	1700 - 7000	13 - 14000

As expected, male pilots outnumbered female pilots by around 14 to 1 (7.1%). Internationally, females represent about 5.2% of the airline pilot population (Kristovics, Mitchell, Vermeulen, Wilson & Martinussen, 2006). Females who responded are, on average, younger and therefore are less experienced in both flying hours in non-glass cockpit aircraft and glass cockpit (digital) aircraft.

Data collection and procedure

The data gathered was qualitative in nature and consisted of written comments that included 11,579 words. The participants' commentaries vary from a five-word statement to a 385-word essay concerning their glass cockpit experiences. All biographical data and comments were recorded, initially in an Excel spreadsheet, and then the comments were transferred to a Word document and uploaded into a computer-aided data analysis program. To ensure dependability (reliability) of the findings, crosschecks were done by the researchers during the capturing and transfer of the original data. In qualitative research, the term dependability is more appropriate than reliability because the aim is not to ensure

the replication of the study, but whether the findings are reasonably based on the original data (Pitney, 2004).

Data analyses

Various qualitative analysis procedures and interpretive techniques are available. In order to bring structure and meaning to the large volume of collected data in this study, it was decided to employ computer-aided qualitative data analysis software (CAQDAS). CAQDAS is typically used in projects that have non-numerical, unstructured data, such as data in the form of text, e.g. transcripts from interviews, essays, written comments, graphics, and other multimedia formats. The researchers decided on using the NVivo 8® software package to analyze the data. NVivo 8® is software program for qualitative text analysis and is designed to assist researchers organize, manage, code, and analyze qualitative and mixed-methods research data. This program was used to facilitate the uncovering of the multifaceted themes hidden in the data. Initially, the factors identified in the three surveys were anticipated as themes that would occur in the comments. The document was then scanned for key words. Other themes were identified using key words and phrases that arose out of the comments. Comments were then coded against each theme and then analyzed. All comments from the survey quoted below are cited verbatim.

Results

The analysis of these comments revealed similar thoughts and concerns to those found throughout a number of writings such as in Hutchins, Holder & Hayward (1999); Funk, et al. (1999); and Knight (2007). While over a period of almost twenty years, it appears that there have been some significant changes in perceptions some concerns remain the same for "glass cockpit" pilots. The qualitative analysis resulted in the identification of 17 major themes within the document. Table 3 identifies the themes and the breakdown between male and female pilots in the number of references within each theme.

Table 3

Breakdown of major themes between male and female airline pilots

	Males	Females	Total
Glass cockpit	93	3	96
Use of Acronyms	73		73
Situational awareness	60	7	67
Aircraft type	66		66
Skills	52	3	55
Automation	44	3	47
Safety	34		34
Training	29		29
Operations	23	1	24

Stress	20	1	21
Technology	17		17
Workload	13	4	17
Failure	11	1	12
Experience	10	1	11
Manufacturers' Philosophy	9		9
Errors	6		6
Control	5		5

Table 4 details the breakdown of the comments by age for the six most mentioned themes. References to automation and technology have been combined, as have stress and workload. Combining stress and workload is consistent with the elements of the factors identified in the quantitative analyses of the 1991 and 2001 surveys. Comments from female pilots have been included in each total as there were only six females in the less than 35 and 3 in the 35-44 age groups.

Table 4

Comments by age for the six most mentioned themes

Main Themes	Age Group				Total
	Less than 35 (n=27)	35-44 (n=57)	45-54 (n=51)	55-65 (n=37)	
Glass cockpit	10	37	29	20	96
Situational awareness	12	22	20	13	67
Automation/ Technology Technology	9	19	24	12	64
Skill	4	21	19	11	55
Stress/ Workload	3	8	22	5	38
Safety	1	13	14	6	34
Total	39 (11.0%)	120 (33.9%)	128 (36.2%)	67 (18.9%)	354 (100.0%)

Acronyms and Aircraft

Aircraft make and type identified the manufacturer's aircraft and type the pilots had or were flying. Some comments reflected pilots' preference in terms of the aircraft they flew, that is, Boeing or Airbus. Similarly, while the use of acronyms was high, these mainly described, in "pilot speak," various technological aspects of the aircraft. Further, all occupations develop a discourse that is specific to the needs of the industry, the organization, and the occupation. Aviation pilots use a large num-

ber of acronyms as a shorthand method to identify various aspects of their work. Examples from the comments include OPS (operations), MCDU (multi-purpose control display unit), FMC (flight management computer), EFIS (electronic flight instruments system), PFD (primary flight display), EGPWS (enhanced ground proximity warning system), SOP (standard operating procedures), HUDS (heads up displays), FBW (fly by wire), and many others. In addition to the practical aspects of using the acronyms, it also provides the pilots with a discourse that readily identifies them as belonging to a professional body or "in-group" and excludes those who do not speak their language. To speak and understand the language provides individuals a level of legitimacy within that occupation or cohort.

Glass cockpit

Glass cockpit is defined as "an aircraft cockpit that has a number of multicolored displays instead of conventional instruments" (Kumar, DeRemer, & Marshall, 2005, p. 311). While references to the glass cockpit were the most common, they were often used to describe its role in relation to other themes. However, there were a number of instances where comments focused solely on the glass cockpit. "Glass cockpits are much more user friendly," "Glass cockpits provide a huge improvement," "Glass Cockpit is great," and "I love flying glass" are representative of the positive comments made about glass cockpits. There were no comments that could be construed as a negative in the pilots' view of the glass cockpit. It was seen as "the way forward" and that "Glass is the only way to go."

Situational Awareness

Clearly, references to the glass cockpit and situational awareness dominated the responses. The definition of situational awareness used in analyzing the comments is drawn from Endsley (1988) (cited in Garland, Wise, and Hopkin, 1999). "Situational awareness – the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (p. 258). Not only were they the dominant themes, there is a strong association between them. Of the 96 references to the glass cockpit, 43 also referred to effective and increased situational awareness. Comments included "Glass cockpits provide a huge improvement in situational awareness when compared to older generation cockpits." "Situational Awareness is greater in the glass cockpit." "Far better situational awareness." "Glass-cockpit is excellent for situational awareness." The overall responses were strongly positive in the pilots' appreciation of the benefits of the glass cockpit in its enhancement of situational awareness. On the other hand, and in reference to younger, less skilled pilots, "Automation can mask a lack of situational awareness (also in younger pilots who lack skills)." Overall, their comments help to alleviate concerns expressed by Wiener (1989), Federal Aviation Administration (1996), and Ishibashi (1999) that diminished situational awareness could result from the introduction of glass cockpit technology. The loss of situational awareness remains a possibility regardless of pilot attention as happened in the recent Turkish Airline crash (The Boeing Company, 2009). Female pilots' comments were favorable to an increase in situational awareness when flying glass cockpit aircraft. Comments generally were evenly distributed over the various age groups. Younger pilots tended to have fewer comments in these areas.

Automation and Technology

While initially identified as separate themes, references to automation and technology revealed a use of the terms interchangeably. Wiener (1988, p. 436) indicates, "By cockpit automation we generally mean that some task or portions of tasks performed by the human crew can be assigned, by choice of the crew, to machinery." This included the use of computer technology. He also indicated the eight reasons for flight–deck automation:

1) Availability of technology
2) Safety
3) Economy, reliability, and maintenance
4) Workload reduction and certification of two-pilot transport aircraft
5) More precise flight maneuvers and navigation
6) Display flexibility
7) Economy of cockpit space
8) Special requirements of military missions (p. 444).

Continuing rapid development of high technology has provided a greater level of technological sophistication in today's aircraft.

Comments on current automation and technology indicate a favorable opinion. These include "Never have too much automation." "Thumbs up to Glass cockpit and automation." "Best thing since sliced bread." "Automation is vital for future air transportation." "It is inevitable that aircraft become more automated to allow the pilot to manage better."

There was also a strong undercurrent of caution in the application and use of automation and technology. "Automation on the other hand, can be taken too far." "Technology is there to assist – not fly the aircraft. The technology is only as good as the information programmed into it." "We however don't need to [be] slaves of the automation." "However crew need to guard against complacency and too much reliance on automation."

Overall, comments about automation and technology were positive but had a cautionary undertone. This is a consistent theme over the 20 or so years since the introduction of the glass cockpit. These comments reflect concerns from Wiener (1988, 1989), James et al. (1991), Kabbani (1995), Endsley and Strauch (1997), Billings (1997), and Funk and Lyall (1999). It remains an issue today and probability will remain an issue as people from all occupations are confronted with the introduction of new technology and automation of mechanisms and procedures.

The overall distribution would suggest that pilots, regardless of age, tended to have similar perceptions and concerns as to the impact of the glass cockpit and its technology and automation. The continued development of technology and its applications in the design and manufacturer of aircraft would appear to draw continued concerns as new types of automation are built into aircraft. Future developments of unmanned aerial vehicles (UAV) in non-military environments may have broader concerns for the piloting profession (Baker, 2009).

Skill

Another theme discerned from comments was that of Skill. This theme was identified in 55 comments. The potential loss of flying skills due to the introduction of automation has attracted the attention many writers including Wiener (1989), James et al. (1991), Rudisill (1995), and Roessingh et al. (1999). A general concern was the loss of flying skills as automation took over many of the functions that previously determined the acquisition and level of piloting skills. As James et al. (1991) pointed out, automation reduced pilot involvement and potentially changed the nature of pilot involvement. Comments from the current survey confirm that there is still concern for the loss of skills. "Pilots can loose the basic flying skills required due to lack of 'hands on' actual flying." "One loses [sic] flying skills." "I miss the flying!! But realize this is the way to go." "But manual flying skills deteriorate over time." "Over automated which is, and will continue to degrade the pilots handling skill over time!" "Automation does degrade flying skills to a level lower than most professional pilots would like their own level to be."

While in favor of the application of technology and automation as reflected in the generic glass cockpit there remains a concern for the loss of manual flying skills. Some suggested that they be allowed to "turn off" the automatics and fly the aircraft manually to retain these skills. As one suggested "to preserve basic flying skills, more encouragement should be extended to manually flown visual approaches at airfield with which the crew are well acquainted and when there is not increased pressure from other traffic."

Stress and Workload

The level of workload has been identified as an important determinant of human error (Kantowitz & Casper, 1988). Human factors research found that people are most reliable under moderate levels of workload whereas extreme or sudden increases in workload increase the incidence of errors occurring. There was general agreement that the introduction of the glass cockpit and its associated technology and automation has reduced the levels of workload experienced by pilots. "Reduced workload." "Reduces in-flight workload dramatically." "It relieves you of some work load." "Reduced the workload in the dynamic environment that has become more complex." "Generally all the toys make life easier."

A number of comments also linked the reduction in workload with a diminution in levels of stress and fatigue. "Modern automation greatly increases situational awareness at the same time reduces stress and fatigue." "Overall workload during the flight is a lot less and less stressful." "Automation allows for less stress in cockpit." "Overall workload during the flight is a lot less and less stressful." "Glass-cockpit aircraft definitely aid in ease of workload which helps reduce fatigue." "Fatigue on long-haul flying is definitely reduced." However, there was this comment. "You are more likely to become fatigued on the flight deck during long range cruise when there is virtually nothing to do compared to a less automated cockpit where there is more work for the flight deck crew to do."

While there are periods of reduced workload, a concern for errors and failure of the automatics was expressed as being stressful. "High work load and stressful situations allow possible error factors to creep in." "Biggest negative: the more sophisticated the system, the more stressful it is when it fails!" "A shortcoming of present automation systems (autopilots in case) is that they are not yet 'intelligent'

enough to cope with extra-ordinary situations. These situations are still left to the skills of experienced or talented pilots."

An additional concern was that junior or relatively inexperienced pilots had difficulties in coping when the automatics fail and there is a corresponding increase in workload. "Junior pilots are not as experienced. That is why they cock it up in a glass cockpit when they remove the automation. It is pilot problem, not a place problem." "It is often noticeable with younger pilots rapidly gaining R/H seat status in large jets being less proficient than read [sic] with basic flying." "Younger pilots are far more comfortable with automation." "Automation can tend to lead to complacency especially in younger pilots with less hands-on experience." "Piloting skills are a function of AB initio training quality and experience levels, not exposure to 'glass'." It may be the case of a generational issue in that more experienced pilots see those with less experience as possibly contributing to errors and being unable to cope when the automatics fail.

Safety
Safety is always a concern in aviation. The survey conducted in 1991 by James et al. revealed a concern for flight safety from the introduction of automated systems. Issues such as the possibility of faulty data, difficulties in detecting malfunctions, unquestioning belief in the information presented, and complacency were identified. By 1995, research indicated that there was a general consensus that automation had increased the level of flight safety (Rudisill, 1995). Results from the current research indicate that glass cockpit aircraft were much safer to fly than non-glass cockpit aircraft. Comments include "Generally glass-cockpit aircraft have made airline flying a lot safer." "Probably the most important advancement the industry has made in the last ten years – the sky is a lot safer." "Automation increases safety to a large extent." "In general glass cockpits have made aircraft much safer and more reliable." "It is really helpful at the usual dangerous airfields in Africa."

While there is a general recognition of the benefits of automation to increase safety there was also an underlying concern. Complacency and over-reliance on the technology continues to be a worry for pilots. "In my opinion complacency is a threat and we need good self discipline in order to remain vigilant." "I believe that automation can easily lead to complacency. The pilot must exercise self-discipline in order not to be complacent and to stay ahead of the aircraft." "However, I strongly believe that complacency can creep in (and almost always does) where technology is relied upon too much. Young pilots are particularly susceptible to this in my view."

Training
Wiener (1989), and the two surveys by James et al. (1991) and Naidoo (2008), identified that the introduction of automation as having an impact on both the transitioning from automated to less automated aircraft and back and pilots training. Roessingh et al. (1999) raised issues concerning the identification of skills critical to the operation of glass cockpits. These included knowledge of automation/decision making, crew resource management, manual flying/determination of appropriate SOPs/knowledge of SOPs, and standard cockpit handling. Current pilot perceptions continue to identify training and transitioning as an ongoing problem for them. Many of the 29 comments were strongly worded. "The conversion from 'Traditional' to 'Glass' was grossly inadequate, rushed, insufficient technical cover-

age, and very poorly managed." "The amount of information provided during train-ing on technical aspects of the aircraft is insufficient." "Modern conversions are ex-tremely frustrating and time consuming. Trying to understand some of the detailed and intricate systems is like trying to teach yourself calculus or trigonometry – it is possible but far from efficient or ideal."

Other comments were positive. "Pilots who have never flown 'glass' before find it extremely daunting before embarking on their conversion. However, the transi-tion to glass could not be more simple." "Transition from conventional round-dial instruments cockpits to glass is over-rated." "Was told it is a difficult conversion and it was not!" The level of ease or difficulty involved in training and transition for the pilots may well be a function of their computer literacy and not their pilot-ing skills. Details of the pilots' perceived level of their own computer literacy was sought through the Naidoo survey.

Computer literacy
Table 5 details the respondents' perceptions of their current computer literacy based on the ratings of excellent, above average, average, and poor. There is an assumption that the pilots are comparing themselves against the level of computer literacy of other pilots rather than that of the general population. The majority of both males (50.1%) and females (55.6%) rated their level of computer literacy as average while 7 (4.0%) males rated themselves as having poor computer lit-eracy. Two pilots who rated themselves poor also made the following comments - "Found it a difficult transition initially, but very happy now" and "Airbus Automation slightly more sophisticated than Boeing but far more complex for pilots." "Easier for younger generation as they grew up with computers." A problem for pilots new to automation is for them to become "task-saturated," that is, focusing on program-ming information into the Flight Management System (FMS) and using the FMS during the flight (Meintel, 2004).

Those that rated themselves excellent, above average, or average had a range of both positive and negative comments, but there is little or no evidence that their level of computer literacy impacted their ease or difficulty during their training or transitioning to automated aircraft or back again. It would seem that pilots require specific and in-depth training in computer literacy both in the broad sense of understanding computers, and in a narrower sense of understanding the computerized technology of the aircraft. This is supported by Rigner and Dekker (2000) who identified that pilots require training of new knowledge in both techni-cal and non-technical skills together with cross-cockpit coordination in the use of computers. Casner (2005) and Dekker and Nahlinder (2006) found that pilots who learned on small, but technically advanced aircraft, were readily able to transfer their learning and skills to large commercial jets.

Table 5

Respondents' perceptions of their current computer literacy

Gender/Age	Excellent	Above Average	Average	Poor	Total
			Rating		
Male					
<35	5	6	9	1	21
35-44	8	20	24	2	54
45-54	4	15	29	3	51
55-64	2	13	21	1	37
Total	19	54	83	7	163
Female					
<35	1	1	4		6
35-44	1	1	1		3
Total	2	2	5		9
Overall total	21 12.2%	56 32.6%	88 51.2%	7 4.0%	172 100.0%

Operations

Roessingh et al. (1999) identified Standard Operating Procedure (SOP) as an issue that needed to be addressed. They found that airlines utilize aircraft differently from how it was designed, were selective in its capabilities, and either prescribed the use of the automatics or left it to the crew's discretion. In the current survey, pilots were in favor of SOP. "SOPs are a vital part of the operation." "Flight SOP is enhanced by well trained crew in a glass environment." "Company SOPs have generally (in consultation with aircraft manufacturers, etc) been well thought out." "If you don't apply the correct procedures on the flight deck then the glass cockpit and the FMS [Flight Management System] could be an accident waiting to happen."

Others raised concerns about some aspects based on both the company and the aircraft manufacturers. "My company tends to be rather conservative & infeasible [sic] to constructive comments with regards to potential operational improvements. 'More of an ear' should be put towards pilots comments." "The problem is our SOP's discourage us from hand flying and that do [sic] have a negative impact on confidence and ability to physically fly the aircraft."

The application of SOPs also depends of the type of aircraft being flown and the manufacturer's philosophy underlying the aircraft's development and operations. Several pilots commented on these differences between Boeing and Airbus and displayed varying preferences. "Boeing mindset is better i.e. 'when in doubt fly the A/C' airbus's when in doubt use the automatics' - Boeing philosophy keeps the pilot in the picture - airbus tries to remove him/her." "1. Boeing FMS much easier to program and use than Airbus. 2. Airbus aircraft should have a single guarded switch to give a pilot full authority of flight controls if needed." "I enjoy the Boeing

philosophy because I still have the final say in the operation of the aircraft." "The Airbus operation of PF/PM [pilot flying/pilot monitoring] per sector is the way to go."

The different philosophies of the aircraft manufacturers, Boeing and Airbus, have an impact on the SOPs and the benefits and difficulties pilots experience in the daily operations. "The differences between Boeing and Airbus flight deck philosophies are mainly in the amount of control that is afforded the pilot." Pilots, in their view, need to be in control.

Overview

A quick review of the quantitative results from the three surveys indicates a high level of commonality of the factors identified. Differences in the number and labeling of factors may be the result of the modifications made to the 1991 survey that manifest themselves in the 2001 and 2008 survey results. However, the content of each factor gives the results their commonality. The qualitative analysis of the 2008 survey provides an extension and enhances the quantitative analysis of the three surveys. As indicated in the quantitative analysis, workload, skills, and design are common labels with understanding/mastery, self-confidence, and comprehension sharing similar components. Feedback, reliability, and trust also appear to share common items. The qualitative analysis addressed the major issues identified by airline pilots.

Generally, in all themes identified, pilots possessed positive perceptions of glass cockpits. While they were mainly positive, there was a concern or underlying caution about certain aspects of flying glass. They recognized that the introduction of computerised technology that manifests itself as the glass cockpit was of benefit and, overall, improved the nature of the work. The greatest benefit, as they saw it, was improved situational awareness. Many of the pilots identified this benefit but they were also well aware of the limitations and problems that could arise. These situational awareness problems such as complacency and over reliance on the technology were identified as occurring primarily with younger, less skilled pilots. However, this did not exclude the older, more experienced pilots from being immune from loss of situational awareness. Another major issue was the perceived loss of skills, particularly manual flying skills. There was a genuine concern for the diminution of skill levels among the pilots. Being able to "turn off" elements of the technology and fly manually, and being allowed to do so via the airline's SOPs, was seen as a possible solution. Another solution may involve aircraft manufacturers rethinking their philosophical approach to aircraft design.

Excessive stress and extreme workload caused by systems failures retain a level of concern. These were countered by a majority of opinions that saw stress and workload being generally at a lower level than in conventional aircraft. Similarly, safety was recognized as being improved by the utilization of appropriate technology. Again, the concern for safety was linked to complacency, an over-reliance on the technology, and a loss of situational awareness. Linked to this was the identification of poor or inadequate level of training, particularly during the transition stage from conventional to automated flight decks of which the level of understanding of computer technology played a part.

The 2008 survey of South African airline pilots sought information on their perceived levels of computer literacy. Although only 4% indicated that their computer literacy was poor, overall comments indicated that their confidence and ability in the understanding and use of computers could have been better. This has implications for training other than flight training, and the results indicate that an in-depth level of understanding and use of broader computer technology and applications would be of benefit. This would help, for example, in understanding the different approaches to automating the flight deck adopted by both Boeing and Airbus. Pilots had their personal preferences to the type of aircraft flown and the SOPs appropriate to each aircraft but there seemed to be a general agreement that, ultimately, the pilot should have control of the aircraft and not leave it to the computer to fly the aircraft.

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