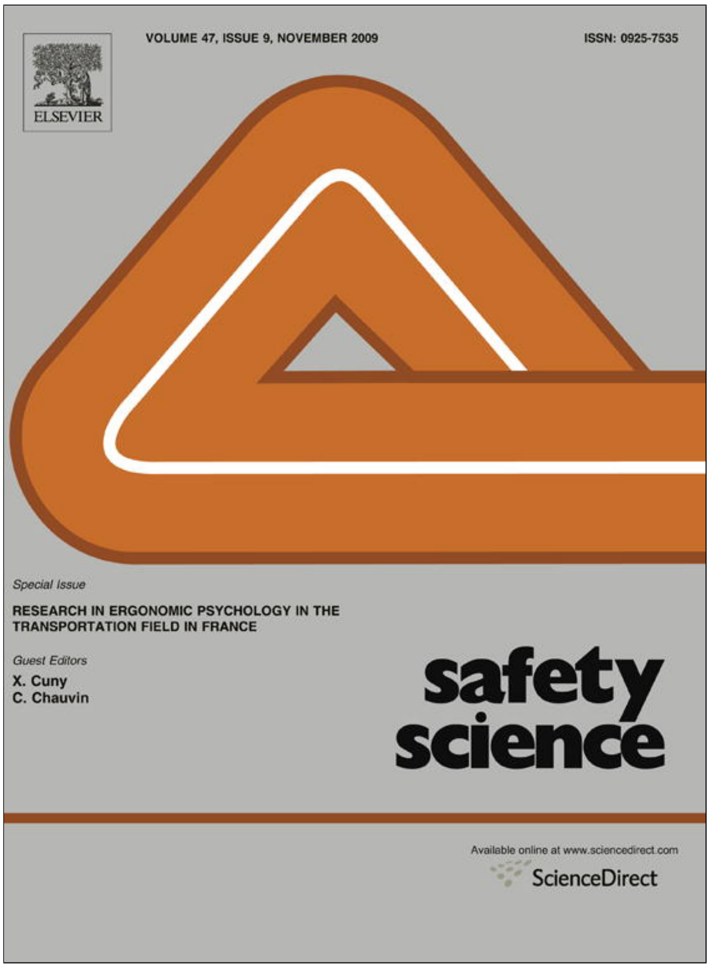
ELSEVIER
VOLUME 47, ISSUE 9, NOVEMBER 2009
ISSN: 0925-7535
Special Issue
RESEARCH IN ERGONOMIC PSYCHOLOGY IN THE TRANSPORTATION FIELD IN FRANCE
Guest Editors
X. Cuny
C. Chauvin
safety science
Available online at www.sciencedirect.com
ScienceDirect

Safety Science 47 (2009) 1241–1247

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

Information seeking in documents by pilots: Assessment of the reliability problems caused by the transition from paper to electronic

Marie Ans [a], André Tricot [b,*]

[a] Master of Cognitive Ergonomics and Linguistics Engineering, University of Toulouse, 5, Allées Antonio Machado, 31 058 Toulouse cedex, France
[b] CLLE – Work and Cognition Laboratory, University of Toulouse, 5, Allées Antonio Machado, 31 058 Toulouse cedex, France

ARTICLE INFO

Keywords:
Information seeking
Electronic documents
Pilots
Flying
Reliability

ABSTRACT

Information seeking is completely ignored in research on aviation psychology and more generally in issues of air transport safety. But information seeking occupies a central place in the pilots' work. And this activity is undergoing an important development: the transition from paper to electronic documents. A contribution to the assessment of this transition is presented here. The assessment is focused on deterioration of information access, understanding and exploitation, and their possible negative consequences in terms of reliability. The exploitation of the documentation by pilots, and particularly the information seeking activity, are described and linked to their contexts (i.e. the main tasks of flying that require information seeking). Then an users test is presented where some information-seeking tasks are evaluated in terms of cost and errors, by comparing electronic and paper documents. The results show that electronic documents provide new functions that seem useful but also that too many new functions generate difficulties. Then it seems that pilots need some time to learn how to use these new documents. Reducing attention needed to perform a task such as calculation is risky. Some aspects of information seeking by the pilots should be better analysed and evaluated.

1. Introduction

Flying aircrafts is a complex human activity. Psychology and ergonomics have studied many aspects of this activity, such as communication with air traffic control, and errors. This activity is characterized in particular by the fact that a normal consequence of the acquisition of professional expertise, i.e. automation, is regarded as a bias and fought through various means (e.g. Mosier et al., 1998; Skitka et al., 2000), including pilot training and information seeking in documents. But if pilot training is widely studied (e.g. Ji and Salvendy, 2001; Olson and Austin, 2006), information seeking is completely ignored in research on aviation psychology and more generally in issues of air transport reliability and safety (see for example Ale et al., 2006). This information seeking activity, which occupies a central place in the pilots' work, if only because of the time pilots spend on it, is undergoing an important development: the transition from paper to electronic documents.

Indeed, the arrival of airplanes such as the Airbus A380 has completely modified the process of diffusion of the documentation for pilots. The A380 is equipped with an electronic system, which provides all the documents and training information related to the plane, and flying. In this paper we relate the work that we realized for an airline company which bought the A380 and envisages replacing all the paper documentation by electronic systems for its fleet. The aim of this paper is a contribution to the evaluation of the risks of the transition phase of this project.

It is known that information seeking in documents is likely to represent difficulties for users (e.g. Lee, 1999; Teo et al., 2003; Ling and van Schaik, 2006; Stronge et al., 2006) and that the transition from paper to electronics can increase these difficulties: difficulty to find relevant information, much too much non-relevant information found, longer to find relevant information, information found not understood or even not identified as relevant, impression of being lost in the document (see Chevalier and Tricot, 2008, for a review). These difficulties have been interpreted as caused by the lack of textual indices necessary to identify the organization of content, at a micro-level (Goldman et al., 1996) or at a macro level (Potelle and Rouet, 2003), but also by the lack of expertise of the reader in the domain (see Chen et al., 2006 for a review). Both causes interact and can be interpreted as cognitive overload phenomenon (DeStefano and LeFevre, 2007).

It therefore seems legitimate to ask whether the switch from paper to electronic documents does not affect the work of pilots and does not present risks, particularly during the transition phase, i.e. when the pilots are discovering and learning to use the new information system.

* Corresponding author. Tel.: +33 5 62 25 22 23; fax: +33 5 62 25 20 18.
E-mail addresses: marie.ans@free.fr (M. Ans), andre.tricot@toulouse.iufm.fr (A. Tricot).

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doi:10.1016/j.ssci.2009.03.007

The aim of this research is to begin analysing how pilots seek information in documents, in order to contribute to an assessment of the effect of the transition from paper to electronics. It is particularly important to assess whether the transition to electronic documents is likely to deteriorate access, understanding and exploitation of information, and therefore have negative consequences in terms of reliability.

To reach this goal, we describe the exploitation of the documentation by pilots, and particularly the information seeking activity. We try to determine the main tasks of flying that require information seeking, the context (constraints and parallel tasks), the goals, and the information seeking process. Then we present a users test where some information-seeking tasks are evaluated in terms of difficulties and errors, by comparing electronic and paper documents. This comparison between the uses of well-known documents (paper) and un-known documents (electronic) is a good way of assessing the problems linked with the transition phase.

2. The operational documentation in the pilot's activity

2.1. Status of operational documentation in pilot's activity

The operational documentation fills a central position in the pilot's activity. First, the documentation plays a central role when the pilot is trained. Second, once the pilot has received his licence, the documentation is his main work tool: the pilot keeps a version at home to update his knowledge; all manuals are available in airports for flight preparation; all manuals are available in cockpits to support flying. To realize a flight, the pilot executes a set of successive and very various tasks, like verifying the flight feasibility, ordering the flight's data (e.g. weather and airport state) or aiming the plane at the take-off point. To complete each task, the pilot must follow stringent procedures to, for example, verify an authorization, seek information which is necessary for a calculation or a decision-making process. All procedures and information are contained in the operational documentation.

Then, information seeking represents a very important part of the pilot's activity. This activity can be divided into several steps, and each step corresponds to several information-seeking tasks, that can be systematic or exceptional. In Table 1, we give a description of each step in chronological order. Each step is characterized by a main objective to reach (i.e. the main flying subtasks) and associated with one or several information-seeking tasks, and with one or several risks.

When the pilot seeks information, he could perform other parallel tasks like internal and external communication, control the electronic system of the plane, control the external environment, and fill data into the electronic system of the plane.

2.2. General description of the operational documentation

The operational documentation consists of many manuals and guides, which represent about 40 kg of paper. In original paper format, the documentation is structured as follows, in three parts:

- Part (A) is common to all pilots and contains airline regulations: general procedures and information specific to airlines. It is a ring binder and it is divided into chapters by colourful interposed papers; the information format is principally textual information. The most used chapter is called "utilizing processing" and, in operational context, it used principally to follow a general process, which allows pilots to know which other information he must find in part (B) and part (C) of the documentation.
- Part (B) is specifically for the pilot licence, i.e. specific for each plane type and allowing the flying of the plane. Part (B) is equal to four ring binders called "Limitation and process", "Plane performance", "Minimum required equipments and systems" and "Plane description". The information forms are texts, schemas, calculus guides, checklists, etc.
- Part (C) is common to all pilots and contains all documents linked to navigation, airports and air routes. This is divided as follows: airport folder (charts, airport data and specific procedures), books of information for flying over countries, emergency airport catalogue (location and maps of emergency airports related to each arrival airport), emergency sketches (for each airport, schemas of emergency runway), dangerous areas book, P9 folder (data tables to determine take-off and landing parameters).

All parts are used in flight and, generally, to reach an objective the pilot requires much information, which is distributed in different parts.

2.3. Information seeking in documents as a general activity and as a pilot's activity

Generally, humans seek information in documents when they lack the necessary knowledge to carry out a task. The artificial memory (documents) seems to play the role of additional natural memory (individual's or group's knowledge) in the context of completing a task. Information seeking in documents could be considered as an alternative to solving problems, another activity implemented by humans when they lack knowledge to perform a task (see Pirolli and Card, 1999 for example).

Information seeking generates difficulties: In particular, electronic information systems such as databases, hypertext, CD-ROMs, and Web sites offer new features and extraordinary access to documents. More progress has been made during the past fifteen years than over the preceding centuries. As the quantity of documents increases, the number of users without training in information seeking in electronic environments also increases (Koenemann and Belkin, 1996).

Information seeking requires three types of knowledge (Tricot and Rouet, 2004).

First, information seeking requires knowledge about the content. It is not possible to seek information without having knowledge in the field. To seek effectively, individuals must at least be able to represent the goal of research and interpret the information found.

Second, there must be general knowledge in the field of information technology and documentation. For example, the user needs to know what resources are available to seek information and what specific type of resource is best suited to achieve his goal. Even if this second kind of knowledge is not essential, it makes the difference between a well-structured information seeking strategy and an "all-out search", often less effective.

Third, the user needs more specific knowledge about how each resource or each information system works. The use of search engines and other software requires a very specific procedural competence.

Information seeking is implemented in many different contexts, but it seems possible to describe the main steps of this activity (e.g. Blackmon et al., 2005; Fu and Pirolli, 2007; Rouet and Tricot, 1996):

- The individual is doing a task, and recognizing a lack of knowledge to carry out this task, he decides to seek information in a document, because he supposes that this information will help me realize the task.
- Then the individual will have to conceptualize and implement this need to transform it into a question, a query. This mental representation of a goal probably contains a conceptual compo-

Table 1
Main steps of the pilot's activity and corresponding information-seeking tasks and risks.

		Main objectives	Information-seeking tasks	Main risks
Airport		(1) Check the flight's feasibility	Seek information on the weather, the plane's state, the airport's state (runway, radios, etc.), check if the flight is authorized and in which conditions	Risks linked to the information seeking of distributed targets: these information-seeking tasks involved finding several pieces of information in different documents to reach the objective. Indeed, the main risk is that the pilot must retain the last information until he finds the next
		(2) Itinerary preparation	Seek the itinerary, find airport maps, take off and landing regulations, emergency airports	Risks linked to the information seeking of distributed targets
		(3) Calculation of the required fuel	Seek the weight to be carried, the weather, the air route, etc. Seek the procedure to perform the calculation	The main risk is to find a wrong value of required fuel and/or make a mistake in the mathematic calculation
Cockpit	Parking	(4) Preparation of the navigation documents	Check the presence of the emergency navigation documents	No risk, except if the pilot does not follow the procedure and does not verify it
			Seek and sort out the normal navigation documents (in chronological order of use)	In the folder of the normal navigation document, the pilot must select only the documents which correspond to the flight, e.g. in the folder there are many documents for the approach and their names are very similar: e.g. RNAV SID RWY 08L/R (Runway 8) and RNAV SID RWY 09L/R (Runway 9) are on recto and verso of the same document. The main risk is to display the wrong side to the pilot
		(5) Take off preparation	Check that conditions allow take off	Risks linked to the information seeking of distributed targets
			Seek information to calculate the take off speed. This speed must be entered in FMS[a]	To make a mistake during the calculation of the speeds
	Runway	(6) Navigation	Follow the maps to aim the plane at the point of take off	The risk is dependent on the preparation of the navigation documents
	Flight	(7) Flight procedures	During flight, the pilot consults different procedures. Only the emergency procedures must be kept in memory	Risk linked to the information seeking of distributed targets

[a] The Flight Management System (FMS) assists pilots during the flight. It is a computer that provides data and information about navigation, flight planning, aircraft control functions.

nent (what will I seek?) and a procedural component (how do I seek it?).
- Then, this request may be made explicitly in the case of the interrogation of databases, search engines, even questioning a human being. But many systems (hypertext) or features (index, tables of contents) offer the interesting possibility of not imposing the formulation of a request.
- The individual then proceeds to a selection of sources relevant from a list (the result of the application or subject index for example), comparing them to his representation of informational goals. This decision to select one document over another is based on limited treatment elements of the document title, keywords, but also paralinguistic indicators (words in bold or colour). If the list (result, index, table) contains a relevant document (or a limited number) the individual will select this document to examine it in greater depth. If the result contains partially relevant documents, too many or too few relevant documents, the individual will generally revise his strategy, for example by reformulating his request, in order to clarify, complement or generalize it. Finally, if the list does not contain any relevant documents, the individual will not only revise his formulation or change the functionality he is using, but sometimes he will change his goal.
- When the individual has selected one or more documents, he must understand the content (which is very difficult when multiple sources of information have to be understood, Rouet, 2006) and assess how this content corresponds or not to his task (Can he achieve the task? How does this content satisfy his information need? In short, is it relevant?).

Research in the field of information seeking highlights pilots' information seeking activity. Pilots are experts in the content (i.e. flying) and in the use of documentation (they use it every day). So, the first source of problem comes from the new information system they have to use. This problem can interact with the fact that flying is a very demanding activity: because information seeking can be considered a secondary task, the use of new electronic documentation puts the pilot in a very demanding dual-task situation. The second main source of problems is linked to the fact that pilots carry out tasks that involve the seeking and the processing of many documents.

2.4. Reliability issues

The particularity of using documentation is that pilots must struggle against the automation process. Although many procedures are repetitive and systematic, pilots are forced to search and read all the procedures in the documentation to perform the tasks. In other words, sometimes pilots have to seek information even when they have the corresponding knowledge, i.e. when they do not have any problem.

Moreover, during training, pilots learn to use the documentation: they must know how and where to find the relevant information, but they must never simply rely on their memory because it is considered dangerous.

In fact, pilots obviously memorize some knowledge. First, of course, all emergency procedures are memorized. But the pilot has memorized which flight data allows him to achieve this task, how and where he can find the procedure and necessary values to realize it, and what sort of objective he must reach.

In sum, the documents are, first, an information base from which contingent decisions about the flight and the aircraft will be made and revised and, second, a knowledge base that contributes to the training of the pilot. If information is wrong, if it does not correspond to the need, if it is not understood, then the decision may be biased.

3. Methods

The aim of the empirical evaluation is to assess the difficulties and errors linked to the transition from paper to electronic documents. Our aim is not to evaluate the usability of the electronic documents, but how difficult it is to discover and learn to use these new devices. Our hypothesis is that every pilot (novice or expert) will have difficulties because electronic documents are not only new devices, but also use different means of presenting information and functions. We use a ''heuristic evaluation'' or ''users' test'' method (Nielsen, 1994; Rengger, 1991) a qualitative method that is effective to identifies most of users' errors and problems of use (Nielsen and Landauer, 1993; Virzi, 1990), for example in the domain of documents use (Spool and Schroeder, 2001). The method is quite simple: identifying a set of representative tasks and an optimal way to achieve them; ask to a small sample of users to achieve these tasks; observing (or filming) users when they are achieving the task; having an interview with the user during and/or after the task; identifying problems, errors and opinions about the device. In sum, the users' test method is experimental because an experimenter lay down participants to achieve some tasks, but it is not experimental because there are no hypothesis, no independent variables and ill defined dependant variables.

3.1. Participants and procedure

The airline company with which we have worked was in a phase of process transition. Indeed, they were changing the documentation format, from paper manuals to electronic applications. At the moment of the study, prototypes were developed for each part of the documentation.

For each flight step, we observed the pilot's information-seeking tasks, with paper and electronic documentation. Then, we interviewed pilots and documentation specialists, and built a scenario with them, which corresponds to a complete flight (preparation and execution of the flight). Here, we only present the information seeking representative tasks. These tasks are ordinary and repetitive.

Eight pilots participated in the experiment. All were pilots on Airbus planes. Their age and experience were different, because we wanted to study the difficulties encountered by pilots of different levels of expertise, from beginners to experts. Because of the aim of our experiment, i.e. to study the transition from paper to electronic, none of the pilots knew the electronic documentation system.

Pilot 1: Co-pilot; Experience = 8 months.
Pilot 2: Co-pilot; Experience = 1.5 years.
Pilot 2: Co-pilot; Experience = 4.5 years.
Pilot 4: Captain; Experience = 18 years.
Pilot 5: Captain; Experience = 15 years.
Pilot 6: Captain; Experience = 15 years.
Pilot 7: Captain; Experience = 14 years.
Pilot 8: Captain; Experience = 18 years.

The tasks were carried out on paper or electronic documents: each task was carried out on paper by four pilots and on electronic by the other four pilots. Each pilot realized half the tasks on paper, half on electronic documents. The hands of the participants were filmed, so that we saw how they used the documents. For electronic documents, activity on the screen was also recorded with software. The time implementation of each task and its success and its difficulty were measured. Debriefing interviews were conducted after the realization of the tasks (the questions were about the systems, their respective qualities and faults).

The experimentation lasted 2 h (1 h45 min + 15 min for the debriefing).

We now present the four tasks proposed to the participants. Then we present qualitative results; because of the sample's size, we did not process quantitative data. We focus our qualitative analysis on the way the pilots perform the tasks, their difficulties and errors, and their comments about the systems.

3.2. Tasks

The tasks were designed with a pilot (an expert in charge of the pilots' training in the airline company) and the members of the ''electronic documentation project'' in the same company. These tasks are representative of the main tasks involving documents use, but depend on the availability of the electronic documents: the whole electronic documentation was not available at that time.

3.2.1. Flight preparation

One of the goals of flight preparation consists in bracing for an emergency landing if the landing at the official arrival airport is impossible. The pilot must check whether the runway of the emergency airport will allow landing. The weather, the plane type, the passengers, the freight, etc. must also be checked.

For this task, the pilot must:

– Read the general procedure (part (B), chapter 2). It is the same procedure for each flight preparation but the pilot is obliged to read it. To find this page, the pilot processes by dint of approximate and successive approaches of indications on the top of each page: he has a partial memory of the information, linked to the spatial representation of the documentation.
– With regard to the flight data, the procedure again directs the pilot towards another page (a number of pages in fact), which provide him with the landing conditions at the emergency airport. There, a data table gives the required landing lengths for different weather and flight conditions.
– Then the pilot finds the length of the emergency runway (in part (C), airport folder): the airport folders are sorted in alphabetic order. Each folder contains about 20 pages (charts, radio data, minima of visibility, etc.). The documents are sorted in a specific order. The charts of the airport are divided into many parts (north, south, east, west). The pilots quickly find the information (e.g. length). They know how the documents are sorted, and as the targeted airport chart is situated in the middle of the other documents, they seek directly in the middle. Then, the chart gives a schema of the airport with the name and length for each runway. The pilot compares the length of the emergency runway with the required length in part (B), already open.

For this task, the electronic and the paper documents are very similar. The application used for the flight preparation is available on the intranet. This intranet contains the three parts of the documentation, and the documents are in fact the original scanned documents, available in PDF format. The structures of parts (A) and (B) are represented by arborescence and the different chapters are represented by hypertext links.

3.2.2. Navigation support

For the navigation documents, we have studied precisely the preparation of the documents in the cockpit. This task consists in executing different sub-tasks. First, the pilot has to find the airport folders: he picks up the folders of the departure and arrival airports, and he checks the presence of the emergency airport folder. These folders are sorted in alphabetical order in many ring blinders, and placed under the pilot's seat in the cockpit. Second, the pilot must pull out of the folder, the required documents for navigation and place them in a clip in front of him. The documents must be arranged in chronological order of use: first the departure documents (general information, airport chart for the runway taxiing, minima values of visibility, documents for airway navigation in departure area, approach chart for emergency instant return) then the arrival documents (general information, minima document, approach chart, airport chart for the runway taxiing).

3.2.3. Parameters of take-off calculations

This task is complex and requires a lot of attention on the part of the pilot. It consists in determining the three speeds of take-off and filling in the FMS with the values previously obtained.

This process is executed a few minutes before the plane's departure. First, the pilot begins to seek and read the take-off authorization. For this objective, the pilot reads in the flight folder the flight conditions (weather, load, etc.). In part (B), he seeks the chapter that allows him to determine if the flight is authorized. This is a table with two entries (length of runway and conditions). Then, in part (C), he seeks information about the take-off runway. According to the flight folder data and the length of the runway, the pilot can determine if the flight is authorized. The table also indicates another location in part (B) with the corresponding calculation guide to determine the take-off speeds.

The calculation is complex: the pilot must follow both and in turn, the guide and P9 paper (i.e. a document that contain complex tables of data about weather, wind, etc.) allowing to determinate the three speeds of take-off in which he will match many data to determine an approximate result. As this task implies an important risk of error, the two pilots process the calculation and compare their results. If it is not the same result, they begin again. Precisely, the calculation is done as follows. The pilot seeks the P9 papers he needs (only one paper in fact: all P9 papers are conserved in many ring binders): they are sorted by airport, next by runway number, next by ramp runway, next by motor plane, next by flap position, next by wind direction (direction of the plane). The P9 contains two tables of data: the pilot consults the second table, about contaminated runway conditions (when runway is iced for example); or he consults the first table, about normal conditions. The P9 contains a table of data with three entries: an interval of temperature, an interval of runway length and an interval of wind strength. By matching these data, the pilot determines a cell out of fifty cells; it contains the results, the three speeds for the take-off. If the conditions allow it (in "authorization to take-off" procedure), the pilot can decide to take off with limited pushing to economize some fuel. In this case, he must calculate a fictive temperature and then, new speeds.

3.2.4. Procedure seeking on the A380

Part (A) and (B) of the electronic documentation, taken aboard in the cockpit was available only for the A380. Only part (B) has been implemented. This application represents the biggest change. First, the application is linked to the electronic system of the plane. Second, all content has been created for real electronic use. But the real asset of this document is inherent to a specific function. This function allows the choice of the level of precision of a page. In fact, the pilot can choose between three levels of precision for the displayed information: low, medium and high, and each point is detailed according to the pilot's choice. Another function is new for pilots: research by keywords in a search engine. The results list is displayed in the index of part (B) with an indicator for the page that contains the keywords. In each page, the keywords are highlighted.

We have tested the application with pilots who did not know the A380 manual. As it is a different plane from others, the documentation is different. A large part of the structure is common, but some parts are added and the organization is different.

4. Results

4.1. Flight preparation

Many problems seem to be caused by the transition from paper to electronic documents. First, the pilots have a lot of difficulty locating the sought chapter in arborescence (i.e. the index of the hyperdocument's content): there is no similarity with spatial representation of the documentation. Second, when the pilots read the procedure (point of start of the information sought), the location of the next information to read is indicated. But as the page does not contain hyperlinks (the majority of pilots clicked on the page numbers), the pilots must seek the new target in the arborescence. Many pilots had difficulties finding the new target and some of them forgot the sought target after a few seconds.

When seeking the airport chart, the process is really different. For this research, a form of requirements is available: menus and fields allow the user to fill in the sought airport, and a result list is displayed. The pilots perform the task without difficulty.

4.2. Navigation support

With the paper documentation, the pilot performs this operation quickly because the order of the documents in the airport folder is constant for all airports and the number of papers is inferior to 50. The second paper of the folder is an index (the first is the minima document because it is used for an anterior task) but they do not use it to find documents. We have observed a very constant strategy among pilots: they fold some of documents to read many indications at the same time.

With the electronic documentation, the objective was to imitate the clip concept. First, the pilots select the departure and arrival airports in the application. They also select the emergency airport if they want; with paper, the task consists in verifying if the documents for the emergency airport are available, but this procedure has no longer any sense with electronic documentation. Second, for the departure and arrival airports they must select only the required documents. When the pilots choose a selected airport, the list of all documents is displayed. They can confine the research by means of a feature that allows one to obtain documents by genre (only airport charts, only approach charts, etc.). The list contains the names of the documents and these are the same as the paper document names. For each document, the pilot can preview it, or add it directly to the electronic chart clip to use it later. After selecting all documents for all airports, all clips are completed and the pilot can navigate between airports clips.

When the pilots use the chart clip, many features are available; they have been implemented to copy the paper process. These features allow: (1) Consultation of the selected documents (they are similar to the paper documents). As for the complete list of documents, the list of the clip must be displayed completely or by genre of documents. (2) Access to non-selected document, to consult it without adding it. (3) Adding/removing documents in the clip by the same procedure describing previously. (4) Seeking a new airport to display these documents and possibly adding this airport to create a new clip. (5) Directly adding an airport to create a clip.

Pilots have no problem to select airport and prepare the first clip. The process is linear and it guides the pilot. But when the pilots have completed the first clip, some of them seem disorientated. In fact, a feature has been implemented to allow for any possible case (consulting without selecting, adding an airport which has not been selected at the launch of the application, etc.) but finally too many functions are available for the pilots. Including all functions specific to electronic documents (navigation with "back" "forward", different zooms, full screen, "home", etc.)

results in a screen that contains about fifteen buttons with text or icons. Of course, the pilots had very little knowledge of the application during the experiment. It is possible that a radical change of process would lead to a better performance in this task, rather than a simple imitation of the paper process. Imitating the paper process leads to disorienting the pilot.

4.3. Parameters of take-off calculation

The corresponding application implies a very important reduction of attention for pilots. Indeed, the application consists in filling in all data (airport and plane, ramp runway, flaps, temperature, etc.). Then, the results are given by the system. An FMS view is available and the pilot copies the screen to fill in the FMS.

All pilots who performed the calculation with the electronic system perform the task perfectly despite not knowing the software, and of course the time gained was significant.

However, we have detected two critical points. First, when the pilot opens the application, the last filled in data are displayed. This feature has been implemented for many reasons; for example, if a change of runway occurs after the calculation, the pilot must begin the calculation again, and then, only the runway field has to be modified. Moreover, the pilot may have to suspend the calculation to execute another task with another application. Keeping the data in memory means that the pilot does not have to start the calculation again all over again from the beginning.

However, this process does not seem safe. Even if the pilot follows the data entry carefully, he could skip over a field because there is no mark to assist him in the progression of the data entry. This point raises a question: what is safer? Preferring efficiency of the operation, simplifying actions and reducing cognitive workload linked to the repetition of the calculation; or resetting all data each time to be certain that the pilot does not forget data?

The second point is more linked to the understanding of the process. Indeed the complexity of the calculation with paper documentation requires the pilot to have perfectly understood the process: he has to understand the function of each data (temperature, wind, length of runway) in the calculation. Then, when he gets the result, the pilot can easily detect if it is correct or not. For future pilots, the automation of this process could involve them not having a real representation of the computed speeds and their being less able to detect errors.

4.4. Procedure seeking on the A380

The pilots easily found all information to perform the tasks of the test. The architecture of the information is in line with their representation, so they rarely made mistakes. The search engine was frequently used and with efficiency. Finding the information was therefore easier with a hyper document using all electronic functionalities. However we may wonder whether the possibility of a direct and easy access to the targeted information does not come with more risks than the paper document, where the pilot is forced to read the procedure to reach the targeted information.

5. Discussion and conclusions

This study is a simple users' test. It is then impossible to generalize the obtained results. But these results are relevant: they provide useful information about some problems and errors linked to the context of transition to paper in pilot's documentation.

Information seeking in documents plays an important but little-known role within pilots' activity. It concerns various operational and training aspects. Our experiment on the transition from paper to electronic documentation shows that:

– designing electronic documents as an imitation of paper, or as a simple transfer of paper into PDF format, is not necessarily a good solution,
– electronic documents provide new functions that seem useful; but too many new functions generate difficulties and
– reducing attention needed to perform a task such as calculation is not necessarily a good solution (it is possible that a wrong value will not be detected). It would be interesting to carry out an experiment to compare the differences in errors between electronic and paper documentation, in particular in conditions where pilots are interrupted during calculations.

Our analysis of the pilots' information-seeking tasks shows that risks are linked to the fact that pilots have to seek distributed targets, i.e. to find several pieces of information in different documents to reach their objective. Indeed, the main risk is that the pilot must retain one piece of information while seeking the next. The literature on information seeking shows that seeking and processing multiple sources is a very difficult task that may lead to cognitive overload and deterioration of comprehension (Rouet, 2006).

So, transition from paper to electronic documents is not a simple change. It is a real transition and pilots need some time to discover and to learn how to use these new documents.

Some particularly complex information-seeking tasks, involving the simultaneous processing of several documents, should be better analysed and evaluated. This type of research would complement the literature devoted to ergonomic evaluation of the effects of computerization of other aspects of pilots' activity in the cockpit, such as communication (Brannick et al., 2005) or treatment of multiple information sources (Crawford and Neal, 2006), or outside cockpit, such as training (Talleur et al., 2003).

Many others studies should be conducted in the domain of information seeking in documents by pilots, in order to identify all the problems and errors, and their consequences. A much more precise method should be used to identify the risks of errors and the effects of pilot expertise. Both the transition phase and the next step (the "no paper" times) should be studied.

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