Book Section:

Barnard, Y (2009) Human factors in the display and use of aeronautic information from different sources and of different status. In: De Waard, D, Godthelp, J and Kooi, FL, (eds.) Human factors, security and safety. Shaker Publishing , Maastricht, the Netherlands , 143 - 158. ISBN 978-9042303737

Human factors in display and use of aeronautic information from different sources and of different status

Yvonne Barnard
Institute for Transport Studies, University of Leeds, LS2 9JT Leeds, UK
Tel. +44(0) 113 343 3611
Y.Barnard@its.leeds.ac.uk

Abstract

In aeronautic operations and maintenance a large amount of information is provided by documentation and instruments which is needed for the safe operation of an aircraft. However, a development is taking place towards the use of multiple sources, with information being integrated in one display, and the construction of meaningful knowledge in interaction with the user, providing support for decision making and diagnostics. Combining information from different sources means that information could differ in status, age and certainty. The advantage of combining information is in providing the user with a clear picture of the situation, highlighting information that is context-relevant, and ensuring all available information is provided. A wide range of human factors issues is related to perceiving, interpreting and using information from different sources and of different statuses. Cases from different studies are presented in order to address common human factors and design recommendations. These studies deal with the development of demonstrators of information presentation as well as interviews and evaluations with users. Topics include maintenance manuals connected to aircraft systems, electronic flightbags, and cockpit displays. The paper addresses the human factors issues identified, and indicates directions for solutions for information presentation, such as layered information, contextualisation, and integrated information.

Introduction

In flight operations and aircraft maintenance, a large amount of information is provided by documentation. Traditionally, information was provided in paper manuals. In flight operations pilots are also supplied with information from the cockpit instruments and from air traffic control. It is up to the operator to combine information from different manuals and sources to decide which action to take or how to perform a task. Now that documentation is becoming available in electronic formats, new possibilities arise to combine information from different sources, and to provide operators with integrated and complete information (Barnard & Chandra, 2004; Barnard et al., 2004). The advantage of combining information lies in providing the user with a clear picture of the situation, highlighting information that is context-relevant, and ensuring all available information is given. However, there may also be a danger attached to having information from different sources, especially when the information is contradictory. For example, information about the weather conditions in a destination area may be based on different predictions by different meteorological services. Combining information from different sources implies that information provided may differ in status, age and certainty. In this paper first different sources of information will be discussed, and examples will be given of information provided by electronic systems for both flight operations and maintenance. Then several human factors are presented, related to the use of information from different sources and of different status: perception and interpretation, situation awareness and workload, dealing with uncertainty, dealing with factual and interpreted information, and biological aspects. In the subsequent section several display solutions are discussed, especially the concepts of layered presentation of information, contextualisation of information, and providing an integrated picture. The paper concludes with a discussion of advantages and risks of providing integrated information, and a short discussion on transfer to other domains.

Different sources and properties of information

Information may come from different sources. Aircraft instruments convey information about the status of the aircraft and its systems, and about the environment, for example information from the weather radar. Manuals, both operational and maintenance ones, provide information coming from the manufacturer. Often different manufacturers are the sources of documentation, because an aircraft may contain a variety of systems from different origins. Other sources also provide information, both in real time and previous to operations, in the form of bulletins, for example meteorological services. Operators may communicate with others, for example with air traffic control, airlines, colleagues, other aircraft, etc.

An example of information coming from different sources is information about the weather. Pilots may receive information about bad weather conditions in the destination area from their aircraft's weather radar, from a cockpit display showing weather information, from a meteorological bulletin received before the flight, warning from air traffic control, information from their own airline, they may have access to internet, and pilots from other aircraft may send out messages. In their flight manuals they also have information on how to deal with certain weather conditions. The pilots need to combine all the information in order to establish a clear picture about the situation at the airfield of their destination, and to decide whether they may safely land there or whether they should start making provisions for diverting to a different airfield. All the information concerned is not of the same nature. The information is of different ages, different scope, and is of differing certitude. The weather radar gives real-time information about the weather ahead of the aircraft; weather bulletins give information about the weather forecast in a larger area.

Next to information coming from different sources, information may also be interactive or not. Older versions of electronic documentation contain pre-composed information: information previously composed into a static composed state (non-interactive). Their displays have consistent, defined and verifiable content, and fixed formats. Newer forms may also contain variable information that can be updated during operations. Software applications allow for selecting and rendering in a number of dynamic ways. In the new generation of information systems, the information displayed will consist of these two kinds of information, providing a mix of interactive and pre-composed information. The question to be asked is whether operators are aware of the nature of the different information elements, and how they integrate and use this information. Users cannot only consult information, but may enter into a dialogue, a conversation, with an information system. Both the system and the user may take the initiative to start a dialogue and determine how the conversation is to be continued. Just as for conversations between humans, both partners have to obey to basic conversation rules in order to be intelligible to each other (Novick & Ward, 2003).

Examples of systems providing information from different sources

In this paper two different applications are discussed that provide information from different sources: electronic flightbags and electronic maintenance manuals. By looking at different aeronautic domains a more general vision may be obtained of underlying human factors problems, and new directions for solutions may be found. Both flight and maintenance manuals are used for understanding given situations and (potential) problems, and for providing support in decision making and performing tasks to address the problems. Although maintenance and flight operations are very different processes, some commonalities may be found in the way in which information can be presented in an efficient and easy to understand manner. A major commonality is the safety-critical aspect; wrong interpretations of the information may lead to major disasters and even loss of human lives. In both operations, some tasks are performed under time-pressure while other tasks allow for more reflection and time to search for information. In flight operations, there are also extremely urgent tasks, to be decided and performed within minutes (or even seconds).

Electronic flightbags

An EFB is an electronic information management device that is used by crew members to obtain information currently provided in paper form. EFB devices can display a variety of aviation data, and perform basic calculations (e.g. performance data, fuel calculations, etc.) The scope of the EFB system functionality may also include various other hosted databases and applications. Physical EFB displays may use various technologies, formats and forms of communication (Shamo, 2000; FAA, 2003; Chandra & Yeh, 2006; Yeh & Chandra, 2007). Applications that are currently available in EFB’s on the market are: Electronic charts, Electronic checklists, Electronic documents, Flight Performance Calculations, Flight Planning, Surface Moving Map, Video Surveillance, Weather information of all sorts, Logbooks, Electronic mail, Terrain awareness system, Note-taking, and Traffic display. This list is not exhaustive, new applications are currently becoming available (Barnard et al., 2007a). Pilots use the information provided by the EFB in order to make decisions about the flight, or to understand what is going on. This may take place during the flight, but also in preparation, or in debriefing after the flight. The EFB may also be used for learning purposes, either in formal training or in self-learning processes (Barnard et al., 2002).

Maintenance manuals

Maintenance operators use a set of maintenance manuals, such as the AMM (Aircraft Maintenance Manual), IPC (Illustrated Parts Catalogue), and troubleshooting manuals. These manuals are available in an electronic format and use a viewer to give access to different manuals. Next to the manuals, information is available about the particular aircraft to maintain, and its history and configuration. Also statistical data are becoming available about the frequency of maintenance problems. Data for maintenance manuals come from the manufacturer of the aircraft, different aircraft systems often being manufactured by different companies, for example, the engine may come from a different company. As modern aircraft integrate more and more electronic systems, the number of producers of hardware and software may increase. A more radical step in having to deal with information from different sources is the development of intelligent aircraft systems which are able to perform self-diagnosis, and may even be able to do self-repair to some extent. We are moving towards a situation in which maintenance manuals are connected to the aircraft system under maintenance. When a part of the procedure is accomplished this is automatically detected and indicated in the electronic manual. For troubleshooting such options are feasible as well. In this way the logging and reporting process will become automatic. If the system cannot detect a part of the procedure itself, the operator has to give input. The system to be maintained may also take the initiative, and directly open the right procedure necessary to perform the right maintenance action, either because it is time to do so or because a fault has been detected (Barnard et al., 2007b).

Human Factors involved in using data from different sources

When an operator uses information in order to make decisions or to perform a task, he/she has to take the following steps. The operator has to assess the situation and interpret it in order to determine whether he/she should take an action, and if so, what kind of action. Based on the interpretation the operator has to search for information that is relevant. He/she has to filter it from all the information and noise available. When information is found, it needs to be interpreted with regard to the task the operator wants to perform, in other words, the information found should be matched with the operator's interpretation of the system. The usefulness and validity of the information selected needs to be evaluated. Finally the operator uses the information in making decisions and/or performing a task. If, for example, there is a malfunction in a system, the operator has to assess the nature of the malfunction, and search for information in the manual on how to remedy it. The operator has to make sure that the malfunction described in the manual, and the task proposed by it, are indeed what he/she was looking for. Finally the operator uses the information from the manual to remedy the malfunction. This example is rather straightforward, but things may become much more complicated if information comes from different sources and with different statuses. If a pilot has to decide whether to go to the airfield with this malfunction while bad weather has been predicted, he/she will have to put quite some effort into the matching and evaluation step. In all these steps a variety of human factors issues play an important role.

Perception and interpretation of information

Already in the phase of perceiving and interpreting information, errors may be made. Novacek et al. (2001) found that pilots have difficulties with the graphical display of METARs (Meteorological Aeronautical Report), because of the limited information they provide, difficulties in interpreting the display, or their inability to present information timely. Easy perception is a pre-requisite for correct interpretation. However, correctly perceived information does not necessarily lead to a correct interpretation. Potentially dangerous situations may be shown in such a way that it is very easy to perceive them. For example, an area in which a thunderstorm is located may be coloured red. However, there is a danger that in the pilot's interpretation the areas around the danger zone are safe. This may not necessarily be the case, for example because danger has not been detected or because it is relatively smaller, but the situation still contains risks. Absence of a danger alert does not mean that a situation is one hundred percent safe. The weather display in the experimental study of Novacek et al. (2001) in principle provided sufficient weather information, and was easy to use, but many pilots did not fully understand that the weather they had to deal with was indeed bad and dangerous, and thus made incorrect decisions. This is in line with Forman et al. (1999) who found that pilots do not always fully understand weather information.

In order to be able to make decisions in certain situations, both flight and maintenance operators have to build a mental model of the situation their aircraft is in and the events that will take place in the future. So there are two representations of the real situation, the first being the representation made by the aircraft systems, and the second the representation the operator has of the situation, mediated by the representation given by the system. In both representations an abstraction is made out of the richness of detail in the real situation. If the operator does not have sufficient, or correct, information, his/her mental model will be incomplete or even incorrect. If, on the other hand, the systems provide too much information, the operator's mental model will inevitably be a simplification of the real situation (Barnard et al., 2006).

Situation awareness and workload

Having good and easy access to information (such as about routing and runways) may reduce workload considerably. However, if information is displayed in a cluttered way, or if one of the aircrew does not have good visibility, workload may increase (Theunissen et al., 2005). Chandra and Yeh (2003), who perform evaluation studies of commercially available EFBs, identify requirements and recommendations concerning workload. Cf. page 6: "Using an EFB requires effort that may be different from that of using paper. There may be effort involved in locating and orienting the display for use and there is effort in looking at the display, processing the information, and making any necessary entries. Data entry can produce particularly long head-down times and high workload. Visual scanning of the EFB (without data entry) does not require as much effort, but may still be an additional task for the pilot, depending on the function." The additional workload required to use an EFB may distract the pilot from higher priority time-critical tasks, which is particularly detrimental during high workload phases of flight. Next to improving usability, a way of reducing workload is providing only high priority information in high workload phases of flight (Schvaneveldt et al., 2004; Chandrah & Yeh, 2003).

Information is needed to enhance situation awareness, the perception of elements in the environment in a certain frame of time and space, the comprehension of their meaning, and the projection of the status into the future. The time horizon for the projection into the future may differ, both the very near future, for example conflicting trajectories of aircraft, or the more long-term future, for example the weather conditions at the airport of arrival for a long haul flight. The situation awareness of pilots could be enhanced by providing information on potential future aircraft situations related to weather, terrain and traffic, preparing the crew for difficult situations by providing the appropriate procedures or information at an early stage. Lindholm (1999) expresses the need to correlate aircraft situation information (weather and anti-collision functions) with the flight planning. Each phase of flight (taxi, take-off, departure, climb, cruise, descent, approach, landing, and taxi) requires different kinds of information (Nomura et al., 2006). Also, airplanes move rapidly between geographic regions and weather systems. This means that relevant information about the airplane's surroundings can change quickly.

There may be a direct link with the workload issue. If an information system provides too much information, or in a non-optimal way, the operator may be induced to spend too much time and mental effort in regarding the projected future events, instead of on the immediate task, thus loosing situational awareness of the current situation.

Dealing with uncertainty

Even the best information systems will not always be able to give complete information about the environment, sometimes information about the weather and its evolution is not available or incomplete. This uncertainty may be caused by the system not being able to capture sufficient information, or because the system is not capable of delivering an interpretation of sufficient certainty. Comerford (2004) recommends presenting pilots with "hazard zones", in which different kinds of information are integrated. If there are no data or insufficient data to determine whether a zone is hazardous, she proposes to create and display an "insufficient data" zone. The pilots may, if they wish, access a list of weather variables that are available about that zone, but that are insufficient to define together a hazard zone (or not), and so interpret the situation themselves. In this case the system should also indicate the reason for the uncertainty. Comerford (2004) argues against providing zones with varying degrees of hazards. These kinds of indications may easily lead to misinterpretation. Human beings are not very good at interpreting uncertain data and probabilities. Another option is to indicate go and no-go zones. The problem here is that a "go" zone is not undoubtedly safe, there are always risks, and pilots should not be given false ideas of security.

Information may be of different ages. For example, terrain and traffic information on cockpit displays is usually up-to-date (only a few seconds old) but the age of weather information varies. The weather data captured by cockpit instruments is up-to-date (less than a minute old) but the age of data up-linked from the ground may vary between tens of seconds and several hours. These data should be treated differently. However, dealing with time issues is difficult for most people (Cellier et al., 1996). Weather situations also evolve over time. It is not always easy to form a good representation of this evolution. An important problem in the Novacek et al. study (2001) was the delay in information. The weather information displayed was sometimes 7 to 14 minutes old. This meant that the position of a storm in relation to the aircraft and to the airport was not correctly displayed. The pilots were looking at images that were playing in different time frames. As representation and interpretation of time is in itself already difficult, having to keep in mind (and thus in the mental model) that the position of the aircraft is a few minutes advanced in relation to the position of a displayed weather phenomenon seems rather complicated, especially in a stress situation.

Dealing with factual versus interpreted information

An information system may present factual information or interpreted information. Factual information consists of raw data, without an indication to the user of what to do with it. Interpreted information is information that has already been processed by the system, presenting the user with an interpretation that is related to the task to perform. For example, a weather system may present factual data indicating the location and speed of strong winds, but it may also give interpreted information such as indications of the danger these phenomena present, the position of safe airports, etc.

It is important that the user is aware of whether the information system is providing either factual or interpreted information, in order to know the level of interpretation he/she has to perform him/herself. If the information takes the form of dynamic images or icons, this may become even more important (Curry et al., 1998). If symbolic information behaves in such a way as to give the impression of being realistic, such as, for example, icons representing thunderstorms moving from one area to another, the user may be inclined to think this is a realistic image of the real situation. However, the symbols may just represent areas in which there is a potential risk, or a weather forecast. The pilot may even be inclined to view the information displayed as a map, which can be used to navigate around the storm, even if this use was not intended by the manufacturer (or allowed by the airline and the authorities).

Note that giving detailed factual data may even be impossible. Comerford (2004) cites work on weather types where 200 different types are distinguished. It is impossible to show the pilot all these different types, nor would he/she know how to deal with them. So weather information presented is usually interpreted information. Weather types are often not isolated; weather often consists of multiple types of weather (for example wind, rain and lightning combined). According to Comerford (2004) knowledge is lacking about what the main, combined, weather types are that are most important for aircrews. Also, allocation of different conditional weights to weather phenomena is needed.

Biological aspects

Finally, operators are not just cognitive beings engaged in information processing, but humans who have bodies with biological properties. The biological aspect of humans' reactions to information should not be neglected. Vaa (2005), studying car driving, emphasises this issue. The human body may be seen as a monitoring system, the body is constantly receiving, detecting and interpreting information both from the environment and from the body itself. The biological nature of humans ensures that this mechanism performs automatically, using all the senses available in order to ensure the safety and survival of the organism. However, this monitoring system is not faultless, especially when dealing with highly technological environments which are outside the scope of the evolution of the species. When dealing with information that is not ecological, the organism may not interpret and react correctly. Of course, humans can learn to deal with technology, such as driving a car or flying an aircraft. However, when introducing new systems, one has to be aware that cognitive interpretation, acquired by learning and experience, may conflict with the more biologically based way of interpretation.

Information display solutions

In the previous paragraphs several solutions for displaying information were already discussed. In the literature and in dedicated studies and reports, a wealth of detailed recommendations is to be found on usability aspects of information display. For example, Mejdal et al. (2001) give guidelines on the design of multifunction displays. In this section three general approaches are described that address the display of complex and heterogeneous information: providing information in layers, contextualisation of information, and integrating and interpreting information. Examples are given from studies in the aviation domain, both flight operations and maintenance, performed at EURISCO International.

Layers

Providing information in different layers is a concept that helps to provide the adequate information related to the context of the operator. For example, the concept of having information in different layers was developed for pilots' documentation (Blomberg et al., 2000). Pilots do not need the same amount of information in all circumstances. For example, during a flight the pilot is usually only interested in what to do and how to perform a procedure. If there is more time, for example during a long cruise phase, or in debriefing, the pilot may be interested in the question of why a certain procedure should be performed. In training, in order to understand why the aircraft is behaving as it does, the pilot will want to know more about the workings of subsystems. Having different amounts of information is not only a matter of personal taste, but is closely related to the safe and efficient operation of a system. During operation, especially in a critical situation, only information should be given which is strictly necessary. For these reasons the concept of three information layers was developed:

- Layer 1: information related to the safe operation of the aircraft, providing concise information on what the pilot should do.
- Layer 2: information giving the rationale of the actions described at Layer 1, the philosophy of use, and additional information on operations not directly linked to safety critical issues.
- Layer 3: detailed information on the functioning of the aircraft.

The three layers ensure that the user is provided with information appropriate for his/her goal: during operation only Layer 1 information is needed, if the user wants to know the explanations for these actions and the reactions of the aircraft, Layer 2 information is needed, and if the user wants to understand the working of the aircraft, Layer 3 information is useful. For maintenance work these layers could be defined as:

- Layer 1: information needed to perform the task, such as the steps in a procedure.
- Layer 2: explanations of the reasons for a task, the way in which it has to be performed, and the precautions to be taken, as well as the relations to other tasks.
- Layer 3: explanations about the workings of the systems and all technical details.

A layered approach may present information of different status, certainty and level of detail on different layers. In situations where operators have to act quickly, only one layer may be presented. If they have more time, operators may engage in looking at other layers. In a layered approach, information remains connected, but is filtered out according to the current needs for a certain task.

Another option is to present information on graphically different layers in a 3D image (e.g. Wong et al., 2005). Layers may be transparent so that users can focus on information at a certain level while maintaining awareness of information at other levels. This kind of representations is becoming common in web-based applications dealing with large amounts of data, presented in a graphical 3D format, for example from data mining applications. Such representations might also present new options for aeronautic information.

Contextualisation

Information may be dynamically configured to match the actual situation. This is called contextualisation. In this case information is provided that can be used to characterise the situation of a person, place, or object that is considered relevant to the interaction between a user and its application, including the user and the application itself (Dey, 2001). The context acts as a set of constraints to limit the amount of information (Bazire & Brézillon, 2005).

In a project concerned with innovation of flight documentation (Ramu, 2008; Ramu et al., 2006; Ramu et al., 2004) a categorisation of the constraints was developed related to three direct questions an operator may ask him or herself when coping with a situation:

- What will I do? With this question, the operator wants to anticipate the operational tasks to perform in a given situation. For example: “what about performing a go-around?”
- What do I use? With this question, the operator seeks knowledge about systems and interfaces used in a given situation. For example: “what about the anti-skid system?”
- What if I have? With this question, the operator wants to analyse what will or can happen if a given situation is submitted to certain conditions. For example: “what about a hydraulic fault and low visibility at my arrival airport?”

In this project a demonstrator of pilot documentation in an EFB was developed, in which information is searched for and presented in a contextual way (Ramu et al., 2006; Ramu & Moal, 2006). Information input about the context may be from both the pilot and the aircraft systems. The context is agreed and refined in a dialogue between the pilot and the information system. By selecting environmental conditions, phases of flight, actions and operations, and systems, the pilot formulates a query to the information system. In this way the pilot is presented directly with all the information that is relevant for the current context. Not only information from the manual may be presented, but also other information, such as bulletins. This demonstrator was evaluated with pilots (Ramu, 2008). They found the information system easy to use and helpful. However, it is a different way of dealing with information, and pilots would need to get used to its different logic.

Also in the maintenance area a study was performed on contextualising manuals (Barnard et al., 2007b). Several demonstrators were developed trying out different ways of contextualisation. In this case contextualisation serves as a filter on the manual. The context may be set by the airline or maintenance organisation or by the technician him/herself. Also data from the aircraft systems may provide input for contextualisation, for example about the configuration and the history of the system. During evaluation maintenance technicians indicated to appreciate this approach, but they emphasised that it should at all times be transparent how the filtering was done, and they would want access to all other information if they should wish it. It is also important that safety critical information, such as warnings, should be visible at any time.

Providing an integrated picture

In current EFB’s, information is often presented in separate frames or windows. The operator has to select a section, such as information on the terrain or on the weather. Maintenance manuals also have separate sections for different issues.

There are several ways of integrating information. A simple way of doing so is to bring relevant information from different sources into one frame so that the user does not have to navigate from one (part of) a manual to another. In a demonstrator on maintenance manuals the technician was given the possibility to open links to other manuals in the same window as the procedure on which he/she was working (Barnard & Reiss, 2006). More advanced forms are integrating graphical, 3D and animations with textual descriptions. In a study on the use of 3D animations in maintenance manuals (Tapie et al., 2007), several forms of this kind of integration were tried out, such as textual descriptions next to animated images, and starting the animations from a step in the procedure, where the user could follow the animation step by step at his/her own pace. Although technicians were very much in favour of the use of animations and 3D images, they perceived a danger in being too much focussed on the images, and not paying attention to the text, thus running the risk of missing important details and warnings.

Images, and especially animated 3D ones, may grab a user's attention quite strongly. They may be easy to interpret and to use. However, the images are usually a simplification of the reality, or provide a synthesised picture, leaving out details.

Discussion and conclusions

Displaying information from different sources and about different issues, such as information in EFBs about weather, traffic and terrain, in an integrated picture is a solution for enhancing the support of operators in making decisions in potentially risky situations. If the most important information is extrapolated and displayed in a concise way, avoiding cluttered screens, this may bring many advantages to operators. It makes information easier to perceive, and operators are not presented with several different kinds of information at the same time and all competing for attention. As the complexity of information is reduced, operators need to make less effort in obtaining information from the system, and spend less time on interpretation. This means that the workload is reduced and operators can focus on the most important elements. In time-critical situations, decisions may be made faster, enhancing safety.

However, there are also some risks in integrating information. An important issue is trust. Operators may either trust the information too much, and become less critical, not searching for additional information when needed. Or they might not trust the information enough, because they do not understand how it was compiled. This may lead to superfluous search for additional information, for example to look at the details of the information or to inspect the constituting data from which the synthesised information was derived. If operators do not trust the system they might be inclined not to give the information its necessary weight in their decisions, and to use other criteria. Both concerns were expressed in interviews with maintenance technicians.

If the system provides integrated, easy-to-use information, operators may, on the other hand, come to feel too confident and comfortable about the correctness and adequacy of the information. They might be inclined to take more risks. For example, by being provided with hazard zones a pilot might be led to think that zones that are not indicated as dangerous are therefore risk-free. Presenting information relevant for the context in a focussed way, for example on a foreground level, may lead operators to neglect background information that is also relevant.

In order to reduce the risks of integrated information several measures may be taken. Make sure that the operators understand the system and the general way in which information is integrated. This requires training and a careful introduction and implementation of new information systems. Pilots and maintenance technicians are usually trained intensively in using manuals, instruments and other information systems. If they are required to use new systems that present information by using a different philosophy adaptation is needed. In interviews with both pilots and maintenance technicians, who interacted with demonstrators of innovative manuals, these concerns were formulated.

When information is presented on different levels, or is available in both integrated and non-integrated form, operators should have the possibility to switch easily. Transparency is needed on what information is available and may be accessed in order to avoid confusion. Shifting between different kinds of information should be made easy, avoiding confusion. By providing open, transparent information systems, trust will be enhanced.

This paper focuses on information from different sources and of different status in aviation. Other safety critical domains, such as the process industry and road transport, share similar problems. For example, in cars, information systems are becoming available that combine information from different sources. These include, among others, displays with combined traffic and weather information, cooperative systems providing information from intelligent traffic systems and other cars, giving warnings about accidents or traffic jams ahead of the vehicle. Such information may be combined with navigation information, for example advising to take another route. As cars are being equipped more and more with advanced driver assistant systems and nomadic devices providing all kinds of information, the challenge of combining information in such a way that drivers are not distracted from the driving task is pressing. Single information screens, combining information from different sources, are becoming available. As events in road traffic may develop very rapidly, it is of the utmost importance to prioritise information. Warnings, and indicating the behaviour that is immediately required (such as braking) should always have priority over giving information needed for more strategic purposes, such as finding the most efficient route. Some of the concepts presented in this paper may be of interest in other domains, but should then be tailored to the needs related to the specific users' tasks.

Acknowledgements

The work presented in this paper is partly based on projects performed at EURISCO International, Toulouse, France, in collaboration with J-P. Ramu, J. Tapie, M. Moal, and S. Prigent.

References

Barnard, Y.F., Boy, G., Tremaud, M, Payeur, F., & Fauré, X. (2002). Articulation of Operational and Training Materials. In S. Chatty, J. Hansman, and G. Boy (Eds.), Proceedings of the International Conference on Human-Computer Interaction in Aeronautics (pp.30-35). Menlo Park, California, USA: AAAI Press.

Barnard, Y., & Chandra, D. (Eds.) (2004). Proceedings of the Workshop Electronic Documentation: Towards the next generation, HCI-AERO 2004. Toulouse, France: EURISCO International.

Barnard, Y., Ramu, J-P., & Reiss, M. (2004). Future Use of Electronic Manuals in Aviation. In Y. Barnard, and D. Chandra (Eds). Proceedings of the HCI-Aero 2004 Workshop on Electronic Documentation: Towards the Next Generation (pp. 13-16). Toulouse, France: EURISCO International.

Barnard, Y., Reiss, M., & Mazoyer, P. (2006). Mental Models of Users of Aircraft Maintenance Documentation. In F. Reuzeau, K. Korker, K. and G. Boy (Eds.), Proceedings of the International Conference on Human-Computer Interaction in Aeronautics (pp. 232-239). Toulouse, France: Cépaduès-Editions.

Barnard, Y., & Reiss, M. (2006). User-centred innovation of electronic documentation for maintenance. In D. de Waard, K.A. Brookhuis, and A. Toffetti (Eds.), Developments in Human Factors in Transportation, Design and Evaluation (pp. 129-142). Maastricht, The Netherlands: Shaker Publishing.

Barnard, Y., Moal, M., Tapie, J., & Prigent, S. (2007a). Human Factors Study on Electronic Flightbags: State of the Art. (Report T-2007-192). Toulouse, France: EURISCO International.

Barnard, Y., Moal, M., Tapie, J., & Zahiharimalala, H. (2007b). Contextualisation of Technical Data. (Report T-2007-208). Toulouse, France: EURISCO International.

Bazire, M., & Brézillon, P. (2005). Understanding Context before Using It. In A. Dey, B. Kokinov, D. Leake, and R. Turner (Eds.), Modeling and Using Context, Proceedings of the 5th International and Interdisciplinary Conference (pp. 20-40). Berlin, Germany: Springer-Verlag,

Blomberg, R., Boy, G., & Speyer, J.-J. (2000). Information Needs for Flight Operations: Human-Centered Structuring of Flight Operations Knowledge. In K. Abbott, J-J. Speyer, and G. Boy (Eds.), Proceedings of the International Conference on Human-Computer Interaction in Aeronautics (pp. 45-50). Toulouse, France: Cépaduès-Editions.

Cellier, J.M., De Keyser, V., & Valot, C. (1996). La gestion du temps dans les environnements dynamiques. Paris, France: PUF, Collection Le Travail Humain.

Chandra, D.C., Yeh, M., Riley, V., & Mangold, S.J. (2003). Human factors considerations in the design and evaluation of Electronic Flight Bags (EFBs), Version 2. (Report DOT-VNTSC-FAA-03-07. Cambridge, MA, USA: USDOT Volpe Center.

Chandra, D.C., & Yeh, M. (2006). Evaluating Electronic Flight Bags in the Real World. In F. Reuzeau, K. Korker, K., and G. Boy (Eds.), Proceedings of the International Conference on Human-Computer Interaction in Aeronautics. Toulouse, France: Cépaduès-Editions.

Comerford, D. (2004). Recommendation for a Cockpit Display that Integrates Weather Information with Traffic Information. (Report NASA/TM-2004-212830). California, USA: National Aeronautics and Space Administration, Ames Research Center.

Dey, A. (2001). Understanding and Using Context. Personal and Ubiquitous Computing, 5 (1), 4-7.

Federal Aviation Administration (FAA) (2003). Guideline for the certification, airworthiness, and operational approval for electronic flight bag computing devices. (Report AC n°120-76A). USA: Federal Aviation Administration.

Forman, B.E., Wolfson, M.M., Hallowell, R.G., & Moore, M.P. (1999). Aviation user needs for convective weather forecasts. In Proceedings of the American Meteorological Society 79th Annual Conference, Dallas, TX, USA.

Lindholm, T.A. (1999). Weather Information Presentation. In D.J. Garland, J.A. Wise, and V.D. Hopkins (Eds.), Handbook of Aviation Human Factors (pp. 567-590). London, UK: Lawrence Erlbaum Associates.

Mejdal, S., McCauley, M.E., & Beringer, D.B. (2001). Human Factors Design Guidelines for Multifunction Displays (Report FAA/AM-01/17). Washington DC, USA: Office of Aerospace Medicine.

Novacek, P.F., Burgess, M.A., Heck, M.L., & Stokes, A.F. (2001). The Effect of Ownship Information and NexRad Resolution on Pilot Decision Making in the Use of a Cockpit Weather Information Display (Report NASA/CR-2001-210845). Hampton, VA, USA: NASA Langley Research Center.

Novick, D., & Ward, K. (2003). An interaction initiative model for documentation. In Proceedings of SIGDOC 2003, (pp. 80-85). San Francisco, CA, USA.

Ramu, J.-P., Barnard, Y., Payeur, F., & Larroque, P. (2004). Contextualised operational documentation in aviation. In D. de Waard, K.A. Brookhuis, and C.M. Weikert (Eds.), Human Factors in Design (pp. 257 - 269). Maastricht, The Netherlands: Shaker Publishing.

Ramu, J.-Ph., & Moal, M. (2006). Navigation Portal for Flight Operations. In F. Reuzeau, K. Korker, K., and G. Boy (Eds.), Proceedings of the International Conference on Human-Computer Interaction in Aeronautics (pp. 250-251). Toulouse, France: Cépaduès-Editions.

Ramu, J-P. (2008). *Efficience d'une Documentation Opérationnell*e Contextuelle sur la Performance des Pilotes de Transport Aériens. PhD thesis. Toulouse, France: Institut Supérieur de l'Aéronautique et de l'Espace.

Ramu, J.-Ph., Barnard, Y., Moal, M., & Boy, G. (2006b). CRIISTAL Final Synthesis Report. (Report T-2006-175). Toulouse, France: EURISCO International.

Schvaneveldt, R.W., Beringer, D.B., & Leard, T.M. (2004). Evaluating aviation information systems: The role of information priorities. USA: Federal Aviation Administration.

Shamo, M. (2000). What is an Electronic Flight Bag and What is it Doing in My Cockpit? In Proceedings of the International Conference on Human-Computer Interaction in Aeronautics. Toulouse, France.

Tapie, J., Barnard, Y., Mazoyer, P., Devun, J., & Moal, M. (2007). The use of three-dimensional animations in aircraft maintenance documentation. In D. de Waard, G.R.J. Hockey, P. Nickel, and K.A. Brookhuis (Eds.), Human Factors Issues in Complex System Performance (pp. 253-267). Maastricht, The Netherlands: Shaker Publishing.

Theunissen, E., Koeners, G.J.M., Roefs, F.D., Ahl, P., & Bleeker, O.F. (2005). Evaluation of an electronic flight bag with integrated routing and runway incursion detection functions**.** Proceedings of the 24th Digital Avionics Systems Conference, Volume 1 (pp. 4.E.1 - 41-11).

Vaa, T. (2005) Modelling driver behaviour on basis of emotions and feelings: Intelligent Transport Systems and behavioural adaptation. In L.Macchi, C.Re, and P.C.Cacciabue (Eds.), Proceedings of the International Workshop on Modelling Driver Behaviour in Automotive Environments. Luxembourg: Office for Official Publication of the European Communities.

Wong, B.L.W., Joyekurun, R., Mansour, H., Amaldi, P., Nees, A., & Villanueva, R. (2005). Depth, Layering and Transparency: Developing Design Techniques. In S. Balbo, and T. Bentley (Eds.), Proceedings of OzCHI 2005, the Annual Conference of the Australian Computer-Human Interaction Special Interest Group, Human Factors and Ergonomics Society of Australia. Canberra, Australia.

Yeh, M., & Chandra D.C. (2007). Electronic Flight Bag (EFB): 2007 Industry Review. (Report DOT-VNTSC-FAA-07-04). Cambridge, MA, USA: USDOT Volpe Center.