Analysis of the flight task around different types of aircraft

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ABSTRACT

This paper deals with the first results of a research project on designing the Flight Management System (FMS). These automated systems are complex and may imply wrong comprehension of the situation by the pilots [2, 9, 11, 12]. Interviews of seven pilots were carried out to analyze the main tasks belonging to flight activity and their workload demands. The results are consistent with previous studies, particularly regarding the four meta-tasks (aviate, navigate, communicate and monitor system) and the workload in relation to flight phases (in particular take-off and landing). Implications on the design of the FMS and further analyses and studies are discussed.

Keywords

Automation, FMS, flight task, workload.

INTRODUCTION

At the beginning of aviation, piloting was based on pilot's sensory judgment. On-board instruments progressively appeared (such as altimeter, airspeed indicator, compass, artificial horizon, etc.) and the flight deck evolved. Automated systems were introduced in the 70's [1], for instance, the Flight Management System (FMS). These automated systems allowed increased safety [5, 10], precision and efficiency [11].However, the automation induced also a reduction in the number of operators in the flight deck (now, two pilots), and thereby changed the pilots' tasks. The pilots have had to carry out new tasks, like flight planning, navigation, performance management, and flight-progress monitoring [12]. In a short amount of time, the pilots' tasks became more passive and mainly devoted to monitoring [7, 9, 10].

The automation radically changes the pilot activity, so that, when the pilot is novice, he spends a lot of time to learn to use the FMS. When he has become expert, he spends more time to use the FMS rather than directly drive. We know the "user paradox" effects [3] (e.g. with the QWERTY keyboard) which are linked to a systematic use of a system for carry out a task: an inefficient but so integrated system that it become almost impossible to improve. In others words, it becomes hard to think the ergonomics of a such system (i.e. assessing and improving its design) as it is so much part of the situation, and it has changed the tasks so much.

In brief, it has become harder to characterise the flying task and, by way of consequence, to design a system which helps efficiently the pilot, without considering the FMS. However, this paper (which is a part of a PHD project) attempts to take up this challenge by analysing the activity of several types of pilots (fighter, airliner and light plane pilots) on different aircraft types (starfighter, Mirage 3, Concorde, A330, DA42, TBM 850…) which are equipped or not of FMS.

The challenge is that such an analysis of different categories of pilots will allow :

- to point out the invariants of the flight task,
- to identify the temporality of requirements during their task,
- to analyze the pilots' representations of the automated systems.

In the following parts, we will introduce empirical and theoretical studies about pilots' tasks when they use automated systems. The general flight characteristics are exposed to illustrate the global flight environment, the tasks performed by the pilots and the workload requirements.

Flight characteristics

The pilot evolves in three types of environment [2]:

- An organizational environment, i.e. a set of constraints that can be imposed by the airline, the government, or even the armed forces for the military aviation.
- An operational environment, i.e. a set of constraints that can be imposed by the controllers and the air traffic management.
- A physical environment in which the aircraft is flying (turbulence, precipitation, ground or in flight obstacle, etc.)

To evolve in these environments, the pilot has to perform four meta-tasks [2, 17, 19], which are [2]:

- Aviate: control the aircraft's flight path.

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[1].Enrique R. Laso* and Patrick Mazoyer*

- Navigate: direct the airplane from its origin to its destination.
- Communicate: provide data and request and receive instructions and information.
- Manage: manage the resources available (fuel, temperature, oil, etc.).

The tasks have not the same priority, the aviate and navigation tasks being considered as more priority than communicate and manage [17]. Moreover, according the flight phases, some tasks are more present than other (take-off is mainly a task of aviate). Generally, a flight plan is divided into nine flight phases: pre-flight, taxi-out, take-off, climb, cruise, descent, approach, landing and taxi-in.

The workload Informational needs according flight phases

The workload varies regarding the flight phases. Several studies [5, 6, 16] have shown that the most demanding flight phases are the pre-flight, the taxi, the take-off (at the beginning of the flight) and the descent, the approach and the landing (at the end of the flight). This can be explained by the fact that takeoff and landing are phases that occur near the ground resulting in greater risk in terms of safety. Moreover, during these phases, there are a lot of changes (e.g. aircraft configuration) and also a lot of communication with ATC. Thereby, the amount of information to process is highest for the pilot during these phases [13] also explaining this high workload.

Consequences of an important workload and time pressure may be a loss of the situation awareness (e.g. attentional tunneling) [5] and then produce incident or accident (e.g. crash of the Eastern Airlines L1011 into the Everglades [18]). That is to say, a lack of situation awareness may cause wrong decision-making.

Impact of automation

As we stated in the introduction, automation does have some advantages. However, it has also negative effects.

Automation is “any help for carrying out operations of selection, decision and action, in a sequential or parallel way with regards to the actions conducted by the operator” [1]. Consequently, automation has given the pilot a passive role, mostly consisting of monitoring tasks. This passivity can lead to a bad detection of information, and thus affects the level one of the situation awareness following Endlsey. Another point is the problem of complacency leading to a lack of vigilance in the monitoring [9]. A taxonomy of SA mistakes [8] shows that most errors occur at this level. Secondly, these automated systems are complex. The opacity of systems generates poor or wrong mental models [1, 11]. Moreover, the limited feedbacks, as well as the high degree of autonomy of the system, are not helping pilots in their interpretation of the state of the system [7, 11]. At last, automated systems has lead to a loss of manual skill for piloting. In particular, the pilots are slower to react when the automation fails [4, 16, 19].

The different studies presented in this part concern especially the airliner pilots. Indeed, to our knowledge, no existing empirical research has investigated piloting tasks according to diffent types of planes flown in the same study. Consequently, we have made an updated task analysis of piloting in relation to three categories of pilots (fighter, airliner, and light plane pilots). This analysis has to purpose to research the invariants according to the type of planes flown. We examined the representation of the piloting task and what parts of the task are commonly shared by pilots (four metatasks: aviate, navigate, communicate and manage). Another point concerns the temporality of requirements according to the flight phases. We investigated the workload temporality (mainly takeoff and landing) for all the pilots? Lastly, the interviews assessed the pilots’ representations of automation, in particular about the impact of automation on their activity.

METHOD

In order to formalize the flight tasks and the main associated cognitive requirements, seven pilots’ semi-directive interviews were carried out.

In a first phase, a hierarchic task analysis was carried out [14] from the recorded verbal protocols. To perform the analyses of the task we observed training sessions on a simulator in an Airbus training center, examined training manuals, and conducted seven semi-directive interviews with two light plane pilots in aero club and five pilots working on fighter (three of them have then been pilot of airliner). The objective of these interviews was to identify the main tasks performed by the pilots during a flight. Moreover, the diversity of their experiences allows us to see if there were invariants and/or specificities between types of plane driving.

Three topics were addressed during these interviews: the pilot’s tasks, the evolution of the automation and the impact of automation on the pilot’s activity. All the interviews have been recorded and transcribed. In order to analyze these interviews, a thematic research with the help of paper / pen has been made around three topics:

- Tasks and subtasks,
- Conditions having to be fulfilled so that the actions can be done,
- Actions.

In this analysis, there is an importance of words indicating a notion of time to understand the order between the tasks (sequential or parallel). Then, for each interview, we have performed a hierarchical tasks tree. This allowed us to compare the data of all pilots. Lastly, a terminology was decided to define (in a few words) the tasks and subtasks addressed by the pilots. From this terminology, and using the Description Analytic Method (MAD) [14], the fly task was formalized.

This first analysis has provided results regarding the piloting task, particularly the meta-tasks. Moreover, we have also obtained results about the subjective pilot analysis of the workload according the flight phases. Lastly, data about the point of view of the pilots are presented.

RESULTS

Tasks and subtasks

All the pilots (fighter, airliner and light plane pilots) addressed the four meta-tasks defined by previous researches (Figure 1). They define these tasks in the following way:

- Navigate: go from point A to point B knowing where they are on earth. There are two main subtasks: the flight preparation in preflight and then the data monitoring in flight.
- Aviate: fly and stabilize aircraft to follow one trajectory. This can be carried out manually or using the autopilot.
- Communicate: between pilots and ATC. Here, the pilot announces his/her intentions to the ATC and/or receives instructions.
- Monitoring system: it is especially monitoring of engine system. The pilot can correct some element.

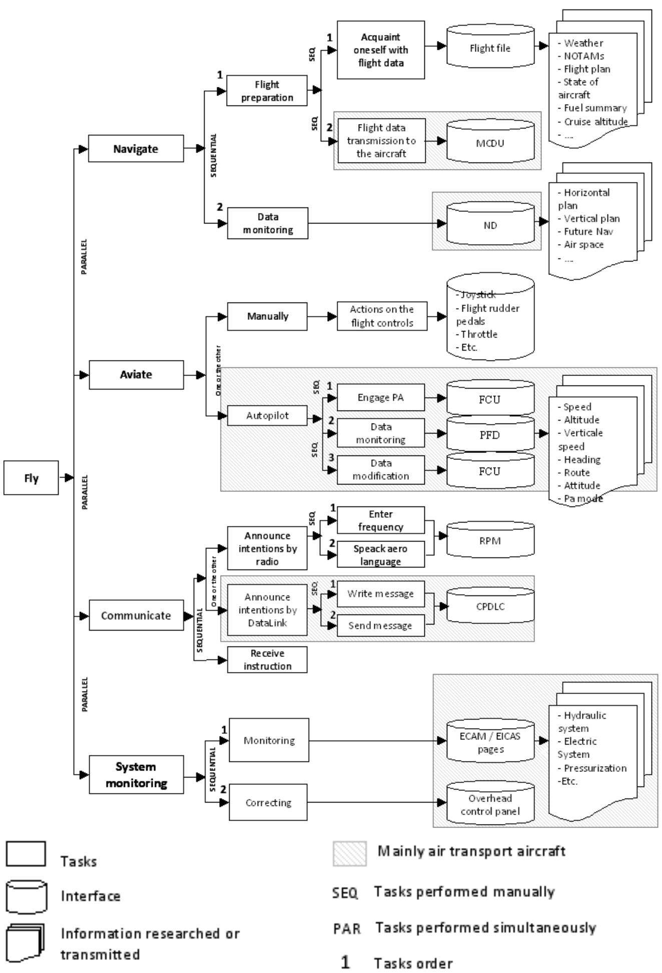

Figure 1: Hierarchic task analysis of fly task

According to the subtask, the main difference is between the pilot using or not the automated systems. On the automated systems, we can see that the main task is monitoring in flight (monitoring navigation data and monitoring data of the immediate flight path). This can reduced vigilance, espacially in long-haul [5]. Conversely, on the non automated systems, pilots have to carry out numerous checks, controls, calculations for the navigation. At the same time, the pilots have to control and stabilize the aircraft on the path. This allows to maintain a good level of vigilance. However, in the case of problem or failure, the workload can increase quickly.

An other difference is between the fighter pilots, light planes pilots and airliner pilots. The difference lies in the diversity of goals. For the fighter pilots, the goal is the military mission for the fighter. This implies an important time pressure, especially in the enemy's territory because conditions can vary rapidly. For the light plane pilots flying for leisure, the main goal is the pleasure of flying. Finally, for airliner pilot, the main goals are to bring passengers to destination safely and efficiently, all the while keeping in mind fuel consumption. The issue of fuel consumption is crucial for the airline and consequently for the pilots. Another main difference resides in automated systems especially very present in modern airliners. The difference lies on the fact that the pilots of airliner must give a lot of information to the aircraft about the flight data, in particular navigation data during cockpit preparation phase. Therefore, the workload is not the same regarding the type of operation.

Workload depending on flight phases

Consistent with previous studies [5, 6, 13, 16], the present study shows that take-off and landing are, for all the pilots met, the two phases which generate an important workload. Both phases imply an important time pressure and also require critical decisions to be made during these phases (e.g. V1 at take-off).

However, we can see a difference of workload for the cockpit preparation phase according to whether the aircraft is equipped with automated navigation systems or not. Indeed, the pilots flying with automated systems have to feed the aircraft with a lot of information concerning the navigation data (e.g. flight plan) to transfer at the aircraft, which requires attentional resources [5]. Another difference during this cockpit preparation phase between the airline pilots and the others regards task interruption task interruption (interactions with other operators: coordinator, catering, fueling, cabin crew…).

The point of view of airline pilots about automation and its impacts on pilot's activity

Automation has disadvantages but also advantages for pilots using automated systems. The advantages are, firstly, that automation has simplified task, in particular, because there is less calculation to perform, as shown by [2]. Nevertheless, the workload has not decreased. A second advantage is the safety improvement.

However, this second point is directly linked with a drawback, also addressed by pilots, which is the decrease of vigilance. The vigilance decreases because:

- First, the main task is monitoring.
- Second, the pilots trust the system too much [19].

Another disadvantage concerns the misunderstanding of the system, as noted previously [2, 11, 12]. A third problem for pilots is the loss of skill, particularly in manual piloting [16, 19]. They have a feelings to become “button pushers” [5].

CONCLUSION

To our knowledge, no study has investigated the three types of operations (military, airline, private) in the same research. We pointed out a few invariants in the flight task concerning these three types of pilots.

Our analyses showed that navigation task is important, in particular for the airliner pilots who have to interact with the FMS (as for example the communication of data to the aircraft in the cockpit preparation phase). Moreover, two flight phases are identified as demanding a highest workload for all the pilots: takeoff and landing.

However, some differences appear in their tasks regarding the goals pursued by the fighter pilots. The fighting missions are deeply different from airline fly. Indeed, the fighter flights take place in hostile environment leading to an important time pressure and rapidly changing conditions. In contrast, airline flights (in normal situation) have a flight plan established to follow. For them, the pressure is particularly related to the fuel consumption and the time of arrival at the destination airport.

Further analyses will consist in carrying out a hierarchic and cognitive analysis of navigation task. This will allow us to tap skills and knowledge that are required to perform navigation tasks efficiently. Moreover, we will analyse in depth the cognitive requirements according to the flight phases. Nineteen semi-directive interviews were achieved: thirteen with airline pilots using FMS and six with pilots not using FMS (ATR pilots, former airline pilots, and pilots of light plane). The interviews were elaborated around three topics: execution and requirements of the navigation task and the informational needs.

In addition, in-flight observations were carried out in an airliner (A320). All of these data have to be analyzed in order to obtain a formalism of the navigation task and put forward hypotheses about the difficulties for the pilots (high cognitive requirements, high workload, difficult access to the information, etc.). The results of this analysis will be presented during the conference on Human-Computer Interaction in Aerospace.

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