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EVALUATING ASAP (ANTICIPATION SUPPORT FOR AERONAUTICAL PLANNING): A USER-CENTERED CASE STUDY

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During ISAP 2011, we presented an early work about the theoretical background for the design of an anticipation support for civilian pilots. Two years later, the ASAP (Anticipation Support for Aeronautical Planning) project has grown and a preliminary version of our anticipation support has been implemented. Following a cognitive engineering approach, users were involved at each step of the design. An intermediate study allowed refining the information processing in order to better fit the actual need. On the basis of interviews and activity analysis, functionalities were implemented aiming at improving anticipation skills. In the context of a flight simulator and along two scenarios using the ASAP interface pilots are asked to act the way they are used to. In this paper evaluated functionalities as well as experimental protocol are detailed. Lessons learned are presented and discussed. Conclusions are drawn for future developments.

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Following a cognitive engineering approach, users were involved at each step of the design. An intermediate study allowed refining the information processing in order to better fit the actual need. On the basis of interviews and activity analysis, functionalities were implemented aiming at improving anticipation skills. Evaluating such an interface only made sense with actual users' expertise.

In the context of a flight simulator and along two scenarios using the ASAP interface pilots are asked to act the way they are used to. A cognitive and a functional evaluation are conducted at the same time. Hypotheses are the following: the ASAP HMI allows an improvement of situational awareness; it allows a decrease in cognitive workload as well as an improvement of overall performance.

Situation awareness is assessed using 3D-SART. Workload is assessed using physiological data (pupil diameter), real-time probe and subjective measures (NASA-TLX). A performance index is also analyzed.

In this paper evaluated functionalities as well as experimental protocol are detailed. Conclusions are drawn for future developments.

Introduction

Anticipation

Anticipation is often considered as level 3 of Endsley's situation awareness model (Endsley, 1995): the one in which environment information is projected in time in order to assess future states. Cellier (1996) gives the following definition about anticipation: an "*activity consisting of evaluating the future state of a dynamic process, determining the type and timing of actions to undertake on the basis of a representation of the process in the future, and, finally, mentally evaluating the possibilities of these actions. It is dependent on the overall goal assigned to an operator in a dynamic situation, which is to keep the process, physical or otherwise, within acceptable limits, and therefore avoid the propagation of disturbances. It is also governed by a logic aimed at reducing the complexity of a situation. Finally, it is a way of managing individual resources"*. This definition is close to the acceptation of an anticipatory system in computer sciences, which Rosen (1985) defines as following: "*a system containing a predictive model of itself and/or of its environment, which allows it to state at an instant in accord with the model's predictions pertaining to a later instant"*.

Hoc (1987) highlights the close link between abstraction ability and expertise: what distinguishes experts and naïve subjects is the capacity to abstract data from a problem and fit them into a generic frame it will specify. This result gives credit to the hypothesis according which anticipation is an ability that defines experts. In our context, it justifies the approach aiming at providing pilots, particularly less experienced ones, a means to compensate a potential lack of anticipation ability.

In the aeronautics field, pilots are taught to be "*in front of their plane*" and are encouraged to "*make permanent assumptions about the future situation in order to actively adapt to this situation and not wait for it to occur*" (Amalberti, 1996). Anticipation is a major skill that pilots are taught to develop all along their career.

Design process

Since the very beginning, we put the stress on putting actual end users (i.e. pilots) in the design loop. A first video recording was made in the cockpit during the descent and approach phases of an actual flight. The recording was analyzed and an activity analysis was performed. A semi-direct interview of this very pilot was conducted to validate our activity model. A second pilot was then involved to double check this modeling. This led to identifying anticipation material and the critical points linked to it.

During the process, two major approaches were identified to help better anticipate:

- managing tasks which need to be performed during the flight,
- considering a change of trajectory, during a divert for instance.

These two trends were presented to a set of pilots who approved them. It was then decided to implement:

- a task panel presenting an improved check/do list,
- a vertical display with augmented information about trajectory,

- a map display with augmented information about trajectory and divert planning options.

A hierarchical task analysis allowed defining the tasks graph and an algorithm was implemented to compute in real-time the feasibility margins for every single task with observation of the whole list of flight constraints (see Lini, Vallespir, Hourlier, Labat, & Favier, 2013). This algorithm allows the computation of a whole new trajectory in case of a diversion and the presentation of the matching check/do list with its feasibility margins.

Because of a non-disclosure agreement with Thales Avionics due to ongoing patents, it is not possible to show the ASAP HMI yet.

Objectives and hypotheses

As anticipation is assumed to be a major part of situation awareness and mental workload management, the objective of this work is to assess the impact of our anticipation support on both the situation awareness and the cognitive load of actual pilots. Two groups were compared: in the first one, our interface was available during the first scenario and not during the second. The second group was organized the other way around.

Experiment plan

As part of the ASAP (Anticipation Support for Aeronautical Planning) project, we chose to focus our experiment on the descent and approach phases when landing a civil aircraft. For this study, we chose to study a flight from Paris landing at Rio de Janeiro airport. The final approach is known to need anticipation, due to landscape.

Task description

The scenarios were played out in a civil aviation simulator (Figure 1). Pilots were asked to interact with the cockpit the way they are used to in their day-to-day cockpit environment. They were asked to follow the descent trajectory shown on the navigation display using only the automatic pilot (heading and vertical speed vector). During the final approach, they were allowed to use the ILS' localizer and glide.

This is not a very usual activity for them as they are more used to fly on a FMS driven basis and mainly monitor what is happening. We made the choice to ask them to "manually" follow the track in order to keep them in the perception/action loop.

Figure 1: Overview of the simulator: the pilot flying (participant) was seating on the right, while a pilot non-flying was seating next to him on the left. The experimenter was monitoring from the left side of the room. Cockpit information was shown on the front panel while ASAP HMI was shown on the central upper screen and the 3D-SART on the central downer screen.

The two scenarios were designed as follows:

- Scenario 1 was a nominal descent on Rio de Janeiro International airport, coming from Paris. The scenario started at the top of descent and ended when the plane had stopped on runway 10. Information about the aircraft position and the remaining petrol was given. Remaining petrol was calculated so as in case of a go-around it would only be possible to wait for 10 minutes.

- Scenario 2 presented the same initial conditions. The scenario started at the top of descent. 5 minutes after starting the descent, subjects got a message from the approach control telling them that runway 15 was closed and runway 10 was currently engaged. They were asked to prepare for a holding pattern. 5 minutes later, the information was confirmed and they were asked to wait for 10 minutes. The scenario ended when the pilot decided to divert.

Material and task description

The ASAP interface and the 3D-SART questionnaire were implemented in JAVA. The simulator used was based on the behaviour of X-Plane 9. All of the graphics for the simulator were generated using 8 PCs. The interface between the various software components on each of the PCs and X-Plane was implemented using an API developed in-house by Thales Avionics.

The ASAP interface and the 3D-SART questionnaire were projected on two 15.4-inch touch-screen placed to the subject's left, within reach. The adjustment buttons were provided on two modules: Saïtek Pro Flight Switch Panel and Saïtek Pro Flight Multi Panel, both located within reach to the subject's right. The outdoor view scrolls on a 3-m-diagonal screen placed 1 m from the subject. The cockpit was presented in a 15.4-inch screen.

Both this screen and ASAP's were captured in real-time using two synchronized AVerMedia HD cards. A GoPro Hero 2 was used as a scene camera and recorded at the same time on a third AVerMedia capture card.

36 pilots (Air France and business jet pilots) were recruited, 2 women and 34 men. The results for 3 subjects were excluded from analysis due to technical problems encountered during test runs. The first group was composed of 17 commercial pilots, aged between 28 and 52, accumulating between 3,000 and 16,000 flight hours ($M = 7{,}670$, $\sigma = 3{,}900$). The second group consisted of 16 commercial pilots, aged between 26 and 53, accumulating between 2,000 and 17,000 flight hours ($M = 7{,}610$, $\sigma = 4{,}100$).

Running test

After introduction of the system, subjects were trained for its use and allowed to familiarise themselves with it.

Situation awareness was measured using the 3D-SART questionnaire: throughout each scenario, the subject was asked to regularly answer a 3D-SART questionnaire. Every two minutes, the questionnaire was shown and a concomitant sound alert –phone ring- rang to warn the pilot.

Cognitive load was measured using three independent, crossed methods (Cegarra & Chevalier, 2008):

- Pupillometry: it is an indirect indicator of cognitive load (Beatty & Lucero-Wagoner, 2000). It is measured by continuously monitoring pupil dilation. To do so, subjects were fitted with a mobile eye tracker, Tobii's glasses, a head-mounted eye tracking system resembling a pair of glasses. The tracker is monocular (right eye only), sampling at 30 Hz with 56° × 40° recording visual angle. Tobii studio, the data processing software, allows dealing with mean pupil dilation, i.e. the percentage of dilation compared to the mean dilation measured during the calibration phase.
- Subjective measurements: at the end of each test mode, the subject was asked to subjectively assess his/her cognitive load using the French version of the NASA-TLX questionnaire (Cegarra, 2009).
- Real-time probe: the subject was asked to answer the 3D-SART as quickly as possible.

Scenario 1 and scenario 2 were played one after the other in that order. During scenario 2, the time taken to make a decision and divert will also be analysed. STARs and approach charts were given prior to the flights and pilots took time to prepare them. They were then asked to perform a descent briefing the way they are used to. As performance indexes, it was checked during the flight if constraints from the charts are satisfied. Time taken to divert during scenario 2 is also analysed.

All these results feed our dependent variables.

Lessons learnt and first conclusions

This five-month long simulation campaign led to several lessons learnt about our setup, the protocol and a few other things:

1. However unrepresentative of an actual airplane our simulator was, it has on the contrary proved to be an asset for our study: the pilots who came were flying Airbus' planes or Boeing's (and a few others). All of them had to deal with the system the same way.

2. The use of a head-mounted eye-tracker proved to be much more complicated than expected. People suffering from presbyopia and used to wearing glasses are troublesome from this viewpoint: they are used to correct their vision on the short range and not on the long range. Thus, they are used to looking out of their glasses half of the time and therefor they tend to do so with the head-mounted eye-tracker.

3. The third conclusion is about the interest shown by the pilots' community towards both the study and the ASAP HMI: 36 commercial pilots came, sometimes from hundred kilometers to spend half-a-day on a voluntary basis just to share their expertise in order to improve their work environment.

4. The use of 3D-SART regularly shown throughout scenarii can be used to draw global trends about how pilots evaluate the situation complexity along time.

These lessons learnt will be used for further investigation about how to improve pilots' world of work.

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