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Helping Pilots Better Anticipate: a User-Centered HMI Concept for Flight Displays

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Abstract

Anticipating and planning are two major components of the human ability to manage one's own cognitive load. Helping pilots enhance their anticipation potential in the cockpit environment becomes an important challenge to address. From an in-situ task analysis and a cognitive model of the anticipation we conceptualized an HMI aiming at supporting the anticipation and planning ability of pilots.

1. Introduction

Anticipation and planning are two major components of the human ability to manage one's own cognitive load. Helping pilots enhance their anticipation potential in the cockpit environment becomes an important challenge to address. Implementing a user-centered methodology for designing such a tool makes sense. It is then mandatory to understand the anticipation cognitive process. In the first part we will present a model of the anticipation from the cognitive psychology literature. We establish that one way to help pilots better anticipate can consist into presenting in advance the tasks they will have to perform. In order to do so, we implemented a knowledge management methodology to accurately define the task flow. This will be presented in the second part. At last we present the concept HMI resulting from our preliminary work.

2. Anticipation Model

The cognitive psychology field has been addressing the question of anticipation, mostly in static situations. A cockpit is a dynamic environment [1] which is highly demanding in a cognitive way. The area of application of our study is civil aviation. In this environment, we talk about long-term symbolic anticipation [2]. In [3], we underlined the fact that anticipation can truly be considered as a metacognitive process lying on cognitive resources management, situation awareness. From a set of sensory cues, the subject makes an assumption about the evolution of the situation and its cognitive demand and time management, using abstract representation.

Situation awareness process operates in three steps [4]: perception of sensory cues of the environment, comprehension of the situation, projection of its evolution. Rasmussen's SRK model [5] defines three levels of control of the situation: skills, rules, knowledge can alternately be used to deal with a problem, depending on both the available time and the subject's expertise, knowledge being highly resources demanding. In cognitive psychology, time is considered a high level process. This means that there are cognitive tools to manage it. Valax in [6] established what these tools are: pivotal tasks, time-based goals, tasks' built-in flexibility and open tasks, i.e. tasks that are not temporally constrained. All of these tools require an assessment of the kind of task the subject deals with.

This theoretical background allowed us to distinguish two kinds of anticipation [3]: preparing a solution in advance, Figure 1, and acting in advance. At that level of development of our concept we will keep to the former, which does not necessitate any kind of automation.

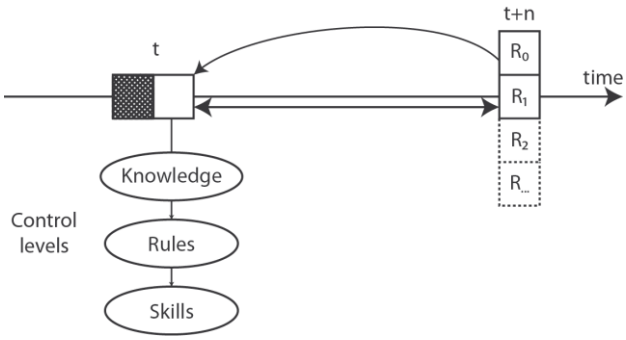

Figure 1: Anticipation: preparing a solution in advance

Situation awareness makes the subject perceive, understand and project the situation. Time management allows him to assess the temporal constraints of the problem. In this case, it is a time-based goal, which cannot be performed before the due date. Cognitive resources management allows him to assess the cognitive demand. It consequently allows him to climb into his control levels -depending on his expertise- and use his knowledge - or less if not necessary - to create a ready-to-use solution.

Figure 2 explains more deeply how anticipation operates: it activates a mental representation of the situation -a schema- from a set of environmental sensory cues. This abstract representation is incomplete and the subject will tend to fill the gaps. While doing so, this representation is compared to the reality. At the end of the loop, a decision is made: if the difference is small, the subject can go on; otherwise, he has to challenge anticipation and find another solution to his problem.

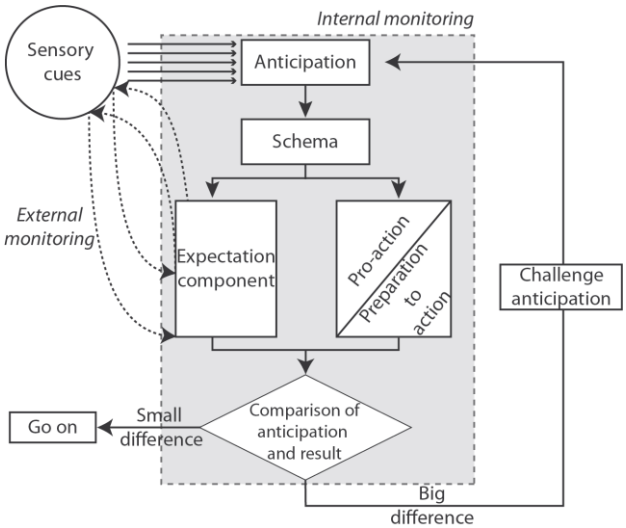

Figure 2: Anticipation model from [7] and [8]

Therefore an anticipation support should allow the subject to choose an appropriate representation, refining this representation and projecting the evolution of the situation. It should also be able to make the subject aware of a wrong choice of schema and make challenging it easier.

3. Task Analysis

Helping pilots better anticipate can consist in presenting the whole set of tasks they will have to perform. Modeling in the knowledge management field permits to get a simple representation of a complex system in order to better understand the activity of an expert.

Using the MASK knowledge management methodology [9] we made a task analysis aiming at building a knowledge base. The tasks diagram, Figure 3, is one of the models contained in the MASK methodology.

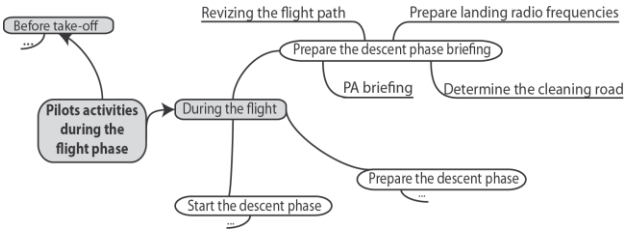

Figure 3 : Tasks diagram

At first, we capitalized the knowledge of an expert pilot on a defined flight phase: the descent and approach phases of a commercial flight are known to be representative of the troubles pilots have to face. This capitalization consists in a recorded semi-directed interview where the subject is asked to describe as accurately as possible his tasks and activity. Questions are asked from time to time to disambiguate grey areas. A camera video recording of the cockpit was also made during an actual flight phase with the expert.

These two sources of information form the material we have been using for building the task diagram. We stressed the inputs and outputs of every single task and their links to anticipation. This permits to build a representation of the progress of the pilots' activity over time. A second model, the activity diagram, gives a higher level of details about it: processes and used resources are detailed. We interviewed a second expert to double check the modeling.

At the end of this phase we get a knowledge base about the activity of pilots in a commercial flight during the descent and approach phases

4. HMI Concept

We use the previous analysis to fuel our HMI with data. One main idea is to present a task flow. This only makes sense with regard to an adequate time representation. We chose to mix distance with time information: pilots work with both and they mainly need time to distance information.

Absolute time is not relevant for them because the main information for projecting the status of the plane is its speed. Before taking-off pilots well know the three dimensional trajectory they will be following. Using the flight management system, it is possible to assess the speed at any moment of the flight. It is then possible to match time and distance: depending

on the speed, the graphical representation of time will be either expanded or contracted.

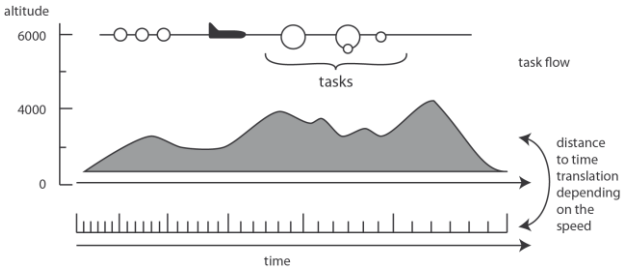

Figure 4: HMI Concept

According to the anticipation model, the task flow allows the subject to perceive and comprehend the situation: tasks are presented in advance and makes the subject able to refresh his representation at any time. Links between tasks are shown and help him better understand the evolution of the situation.

The time to distance representation makes easier for him to project the status of the situation and allows him to save resources from mentally representing the time to distance relationship. The time management process is made easier and the subject is made able to assess the temporal constraints for each task and the cognitive investment needed to deal with each phases. This way, he is able to prepare himself to the problems he might have to face.

A step forward is to deal with the second kind of anticipation: acting in advance. Further works are undertaken to offer the user the ability to automatize tasks. The challenge to be addressed here is to maintain him at the center of the decision loop in order not to decrease his situation awareness. This question will be the subject of future publications.

5. Acknowledgement

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