A DYNAMIC SYSTEM SIMULATION DEVICE TO DEFINE HUMAN-SYSTEM INTERFACE REQUIREMENTS FOR THE DASSAULT RAFALE

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Our study aimed to collect enhancement proposals of Rafale fighter aircraft human-system interface. Proposals had to be innovative and complied with the needs of information for pilots regarding Rafale future capabilities. We developed a methodology based on a device enabling the simulation of a dynamic system activity that is the Rafale integrated in its war environment. Creativity of front line pilots participating in this experimentation has been stimulated but constraint by the necessity of a useful production due to the risks associated to the modification of a fighter aircraft already operating since 2006. Each proposal has been analyzed and synthetized through the abstraction hierarchy model of Rasmussen (1986). Results showed that for prospective and retrospective fields, a specific tactical support built with models favored the expression of functional objective and that a board as a basic human-system interface favored the expression of physical functions. In the discussion, we supported the relevance of our methodology for the definition of human-system interface requirements in various dynamic systems.

Our study is part of an ergonomic intervention led for the French Navy and the French Air Force. We were tasked to define human system interface (HSI) specifications focused on the weapon delivery arena needed for the development of the future Dassault Rafale NG. In the field of HSI conception, we had to face a technological drift due to the multiple opportunities brought by the glasscockpit technology. We observed the well-known trend to orient conception of new HSI according to the offered technical capabilities more than by the user's needs. By example, more and more tactical screens are spreading up in cockpits whereas one of the essential needs for a fighter pilot is to keep his hands on the throttle and sticks (HOTAS). In the conception process, thinking might not be guided by the identification of the possible uses with a new technology which lead designers to provide the maximum of available information and create clutter, but by the search of the best technology responding to the user's operational need, in the field of action. The fact is that the observation of the fighter pilot activity is almost impossible because of the isolated location of the pilot in a supersonic single seat aircraft and the dynamic feature of a high-level risk environment.

Our approach aimed to place user's information needs as the ultimate objective of the ergonomic intervention (Hauret, Donnot & Van Belleghem, 2016). We decided to build a simulation device (Maline, 1994) with two objectives and one main constraint. Our device should permit to collect and/or create proposals in order to (1) simplify the current Rafale HSI, which takes place in the retrospective field of activity and in order to (2) integrate the new long-range air/air missile (i.e., METEOR), which is related to prospective field. We analyzed innovative proposals regarding the abstraction hierarchy (Rasmussen, 1986). We expected a higher level of abstraction in the prospective field because HSI designers need flexibility to develop technological solutions and a lower level of abstraction in the retrospective field when HSI designers intent to correct the current functions. The main constraint is to find a way to produce only useful proposals (Loup-Escande, Burkhardt & Richir, 2013) that are proposals matching a proved need.

Our approach consist in simulate the Rafale pilot activity to provoke the expression of needs to act. Thus, beyond the necessity of tangible supports (Barcellini, Van Belleghem & Daniellou, 2013) the request of fighter pilot as participants was unavoidable. However, fighter pilots are not HSI designers and need to be guided to produce proposals directly transposable in specifications.

Activity simulation on tangible support

The paradox of ergonomics in conception is to create before to use a product. How can we create a product if we do not know how we will use it and how will we use a product if we do not know what we can do with it ? (Theureau & Pinsky, 1984). We choose to simulate activity with tangible support based on models to avoid participants to call on prescribed uses. The tangible supports we created allow participants to be both actor and analyst. At each step of the simulation, the participant can either take on an allocentric view (in the mission environment) or an egocentric view (in the cockpit).

Building of the dynamic system simulation device

Preliminary analysis of fighter pilot activity

The prerequisite of the simulation of fighter pilots' activity is to collect sufficient data to know and understand tasks and skills of a Rafale pilot. During a week, we gathered knowledge by taking part in flight training briefing and debriefing in a Rafale squadron. By working with fighter pilots we understood that being creative is one of their core cognitive skills. This ability was a key feature for the success of our methodology.

Construction of Tactical support and HSI support

To reproduce a faithful environment of a Rafale mission we needed two main supports. Obviously a whiteboard (blank at start) was intended to reorganize the cockpit HSI but was not appropriated for simulating actions of the aircraft in a tactical environment. That is the reason why we built Rafale models destined to maneuver on a tactical map. These models lamp equipped and free to vary in altitude projected circles of light representative for each weapon domains. Our simulation device was composed by the combination of both supports for which one of the major points is to offer the opportunity of a static (step by step) simulation of a high risk dynamic system.

Simulation was guided by a three-part question. First, and at each step of the scenario, the pilot was asked to express his intent that is the aircraft status he wished to reach. Then, he described actions associated to this objective. Finally he listed required information by giving details about location, form and access of each mission and flight data.

Participants

Six French Air Force pilots and two French Navy pilots took part to the study. They got at least the pair leader qualification and claimed either an only Rafale flight experience or another combat aircraft proficiency.

Scenarios

Scenarios were created to be as closed as possible to real pilot activity and to integrate all the events related to the use of the new long-range missile. During an all-day session, first scenarios dedicated to handling and navigation were simple and became harder along the session with weapon management. Thus, the pilot progressively reconstructed his HSI and could focus on complex issues once the base of the HSI was redefined.

Procedure

The experimental setup was presented to the pilot. He was asked to realize specific mission just as he was in his real cockpit, which means we expected him to apply the same uses as he does in flight. Then, the mission was briefed by himself as a real mission. It was the time to reveal his own tactical schemas. The tactical support and the Rafale models were designed to permit him to realize the same aircraft actions than those required in the real environment (Figure 1). He was told to limit his highly trained ability to anticipate because he would progress step by step in the mission simulated on a static simulation device. Each step included decisions and actions realized during about one minute. The fact that simulation is static at each step favored a better understanding of the tactical situation and allowed him to deeply analyze and speak out his thoughts and actions to come. The main objective was to lead the pilot to identify the information needed in the HSI to act. Because the pilot is focused on his actions, available but not required current information should not be evoked and led us to a pure list of useful information.

Figure 1. The dynamic system simulation device with a pilot, an experimenter and an air traffic controller.

Data analyses

All the sessions were recorded with cameras. Two types of data were collected. Regarding both the retrospective and prospective fields, we recorded on one hand current necessary information displayed in the Rafale HSI and on the other hand, all the innovative proposals. Retrospective label was related to the evolution of existing functions in the aircraft. Prospective label concerned all the proposals related to the use of the METEOR or the use of a helmet mounted sight device.

These proposals were analyzed by a couple of experimenter and classified according to the Rasmussen’s abstraction hierarchy (Rasmussen, 1986). Thanks to this classification, proposals of all the participants have been compared, ordered and synthetized in a unique integrative proposal.

We adapted levels of abstraction as followed from the first (concrete) to the fifth (abstract):

1- Graphic/auditory solution (e.g., the weapon load is displayed in a rear view of the aircraft).
2- HSI function (e.g., be warned of an alternative weapon shoot opportunity)
3- Avionic (e.g., calculation of weapon flight time)
4- Rules (e.g., switch in autonomous mode of the missile, namely pitbull mode).
5- Goal (e.g., simultaneous management of *air to air* and *air to ground* weapons).

Collected proposals have been synthetized in three lists of specifications. The first list, related to information in the head-up display (HUD) is already the subject of a specific test in a dynamic flight simulator. The second list presents the specification of a helmet mounted sight device and the third list, still in development, the specifications of the tactical display in head-down.

Results

For several reasons included confidentiality agreements, results presented in this paper are only related to the list of HUD specifications. Proposals were ranked depending on the first level induced by the pilot. During the session, pilots suggested creative ideas starting at a specific level of the abstraction hierarchy but they were guided by the experimenter to explore higher or lower levels of abstraction. Levels presented in the following figures are the first levels spontaneously addressed by the participant.

For both retrospective and prospective field, our results showed that higher levels of abstraction, appreciated by designers, were reached with the tactical map whereas lower levels were get through the whiteboard support (Figure 2).

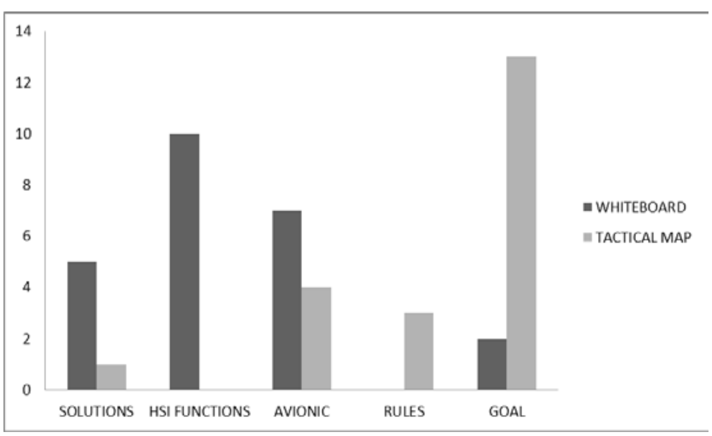
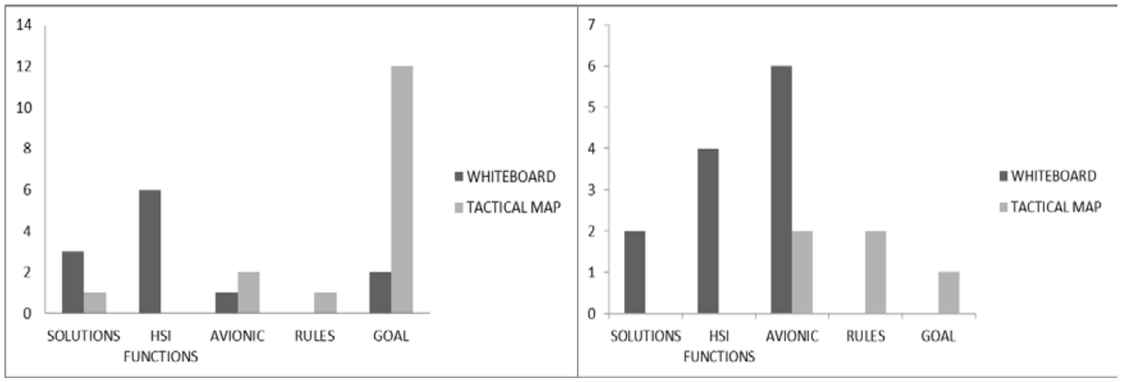


Figure 2. The whiteboard support favored production of concrete proposals whereas the tactical map support favored production of abstract proposals.

For the prospective field, our results confirmed the relevance of the tactical map to get abstract innovative proposals but it seemed interesting to underline that lower levels of abstraction are concerned by a few proposals with the whiteboard support (Figure 3a).



Prospective field ***Retrospective field***

Figure 3a and 3b. The tactical map support favored the production of prospective proposals at the highest level of abstraction. The whiteboard support favored production of retrospective proposals mainly at low levels of abstraction.

Concerning the retrospective field (Figure 3b), we confirmed that the whiteboard support brought more concrete proposals than the tactical map brought abstract proposals.

Discussion

We insist on the relevance of combining the two static supports to simulate the activity of a dynamic system. One of the strengths of our device is to allow the pilot to switch between the supports to be in the best conditions for revealing his needs of information. In this step by step approach, elaboration of the scenarios was crucial. An in-depth knowledge of fighter pilot activity is required preliminary to the simulation session because events occurring in scenarios will influence the pilot to be creative. The choice of front line pilots as participants improved the capacity of the simulation device to reveal useful needs which must not be confused with a user friendly feature. The resulting effect of soliciting representative front line pilots was to get a diversified sample of participants producing various innovative proposals. The use of abstraction hierarchy was justified and helpful to class, to regroup and to order all the proposals. Sometimes, two pilots suggested different proposals at a low level of abstraction but these same proposals were convergent at higher level of abstraction. Thus, we managed to produce integrative specifications. In fact, our lists of specifications, providing the identification of the appropriate level of abstraction, incorporated all the pilots' proposals.

In a near future, we will assess the relevance of our specifications for designing the future HSI in the Rafale program. We also consider reproducing our methodology and will apply it to other current functions of the aircraft such as the failure management or to prospective tactical concept such as handling remotely piloted aircrafts from a Rafale cockpit. In addition, we hope that the promotion of our methodology will create opportunities to investigate other complex jobs in aviation.

References

Barcellini, F., Van Belleghem, L. & Daniellou, F. Les projets de conception comme opportunité de développement des activités. In Falzon, P. (coord.) *Ergonomie constructive*. Presses Universitaires de France (2013), 191-206.

Daniellou, F. L’ergonomie dans la conduite de projets de conception de systèmes de travail. In P. Falzon (Ed.), *Ergonomie* Presses Universitaires de France (2004) (pp. 359-373).

Hauret, D., Donnot, J., & Van Belleghem, L. (2016). Intégration de la simulation de l’activité sur support tangible dans le processus de conception de l’interface homme-système du Rafale. Oral presentation, 15th conference Ergo’IA, Biarritz, France.

Loup-Escande, E., Burkhardt, J-.M., & Richir, S. (2013). Anticipating and Evaluating the usefulness of emerging technologies in ergonomic design : A review of usefulness in design. Le travail humain, *76*, 27-55.

Maline, J. Simuler le travail : une aide à la conduite de projet. Anact (1994).

Rasmussen, J. (1986). *Information processing and human-machine interaction*. New-York, NY : North Holland.

Theureau, J., & Pinsky, P. Paradoxe de l’ergonomie de conception et logiciel informatique. *Revue des Conditions de Travail* (1984), 9, 25-31.