A Study of Knowledge Exchange for Airborne Delegation in C-SAR Mission

T. Pagliardini-Leduc[1][a], T. Letouze[2][b], M. Poret[2][c], B. Le Blanc[2][d], D. Marion[3][e], J. Diaz-Pineda[1][f], M. Gatti[1][g], B. Claverie[2][h] and J-M Andre[2][i]

[1]*Thales AVS, Bordeaux, France*

[2]*Bordeaux INP-ENSC, IMS UMR 5218, Université de Bordeaux, CNRS Talence, Bordeaux, France*

[3]*Thales LAS France, Bordeaux, France*

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Abstract: Leadership delegation is a critical process stemming from the Command and Control (C2) centre, overseeing various operational activities. Its primary objective is to assign strategic authority from C2 Air operators to operational units. The initial step involves transferring comprehensive knowledge frameworks to local entities. Implementing Common Relevant Operational Picture (CROP) concept enhances delegation capabilities across diverse operational setups. CROP facilitates sharing necessary and relevant knowledge (and information) among small collaborative teams, aligning with distributed situational awareness principles. This study presents a new method to evaluate the significance of exchanged information to improve collaboration between fighter pilots and military air traffic controllers in complex Combat-Search and Rescue (C-SAR) scenarios. It focuses on identifying Necessary Shared Knowledge Elements (NSKE) crucial for mission success. A collective self-confrontation method involving pilots and controllers acting out simulated scenarios demonstrates effectiveness in determining NSKE. A demonstrator methodology and graphical interface are suggested to aid operators during knowledge transfer in complex situations, supporting them visually through the CROP. This approach allows supporting different actors in operation for the design of appropriate representations associated with recommendations for future enhancements.

1 INTRODUCTION

Leadership delegation is a process originating from the Command and Control Centre (C2) (Claverie & Desclaux, 2016), a centre responsible for the overall supervision of all types of operations carried out by units in the field, which aims to transfer strategic authority (the decisions of a C2 Air operator) to an operational unit. One of the first stages of the delegation of control is the transfer of the global knowledge framework to a local entity.

Our study is focusing on how to evaluate the optimal knowledge transfer in a collaborative work. To be more precise, the study concerns the evaluation of a methodology based on the representation of a CROP (Common Relevant Operational Picture) instantiated in a use case - known as the HMI CROP.

The importance of situational awareness in decision-making and situation management is well established (Endsley, 2021), particularly in complex situations involving several agents with different knowledge and goals (Steen-Tveit & Erik Munkvold,

[a] https://orcid.org/0009-0008-6556-0750
[b] https://orcid.org/0000-0002-8670-0280
[c] https://orcid.org/0000-0002-2471-373X
[d] https://orcid.org/0000-0002-7131-1805
[e] https://orcid.org/0009-0002-6399-1051
[f] https://orcid.org/0009-0007-0591-7706
[g] https://orcid.org/0009-0000-5817-5063
[h] https://orcid.org/0000-0002-7131-1805
[i] https://orcid.org/0000-0001-9844-4694

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2021). A definition of situational awareness has been proposed by Endsley (1988, 1989, 2000). For this author, at the level of the individual, situational awareness (SA) is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future". In the case of a team, Demir et al. 2017 propose "the degree to which each team member possesses the situation awareness required for his or her responsibilities" (Endsley & Jones, 2001). According to Neville A. Stanton, SA for a team is also known as Distributed Situation Awareness (DSA) (Salmon, 2008). His definition is: "*activated knowledge for a specific task within a system .... [and] the use of appropriate knowledge (held by individuals, captured by devices, etc.) which relates to the state of the environment and the changes as the situation develops*". The team's situational awareness is maintained by information transactions. One agent can compensate for the degradation of another agent's SA. This follows the work of Wei's team (2017), who proposes that team members don't share all the information for a dedicated the environment with other members, but selected common elements to be shared, known as common SA requirements. This later definition relates to the Necessary Shared Knowledge Exchange that needs to be exchanged among the members of the team (Cain et al., 2016).

The Common Operational Picture (COP) is defined by the United States Army Combined Arms Center (2022) as "(Army) A display of relevant information within a commander's area of interest tailored to the user's requirements and based on common data and information shared by more than one command.". This definition is quite restrictive and is more a manifestation of the need to share a common representation of an activity rather than truly theorizing it.

Baber and collaborators (2013) highlight some of the limitations of Common Operational Picture (COP): "*Although COP can offer benefits in terms of information flow, it can create problems of information overload, irrelevant information or distraction for team members*." These authors also introduce another concept, the CrOP: "An alternative system, known as a CrOP (Common relevant Operational Picture), comprises a number of smaller shared systems linked to agents with the same situational awareness needs". This concept has been used, for example, in the study of SA in commercial aviation (Leduc et al., 2022).

1.1 Problematic and Hypotheses

In the context of collaborative work, what is the value of CROP and how relevant are its elements for sharing? By involving participants in a complex scenario in which sharing information between team members is essential to success, we hypothesise that the contribution of a technological tool supporting CROP can improve the sharing of mental representations within the team. We design an experimentation that offers a detailed and precise evaluation of CROP. It enables the identification of the specific elements of the activity that facilitate teamwork and sharing of representation. The process of identification is made possible by an interface annotation task, which is initiated in the event of an interruption to the scenario. In the course of this task, the subject is required to annotate the CROP support interface. It is hypothesised that the result of this annotation is representative of the essential element in the constitution of a common representation of the task.

2 METHODS

2.1 Participants

Six operators took part in the experiment (three pilots and three controllers) (mean of age: M=51.8 SD=3.4). Both pilots and controllers have been retired from the French armed forces for less than 6 years, but pilots are still providing training for the armed forces. They gave us their consent to participate before being brief for their role in the experiment. All the operators are former fighters or controllers. Many of them have experienced a Search and Rescue mission in their past experience.

2.2 Scenario Design

The evaluation process for this study consists of having a pilot and a controller sitting in two different rooms and playing out simulated C-SAR scenario while their behaviour is monitored. The C-SAR mission has been broken down into several phases to provide a robust assessment of the information relating to its activity.

This scenario was designed and implemented on a consumer simulation software. The software Digital Combat Simulator – DCS (*Digital Combat Simulator*, 2024) has been chosen among others (detailed in the simulation setup section) to instantiate our scenario.

The scenario is broken down into a set of five consecutive missions, each subdivided into two to four steps representing major phases of the progression of events, decisions and actions. The scenario was designed iteratively according to discussions and pre-tests with experts: pilots and controllers (see the briefing on the map: Air Task Order (ATO), on Figure 1).

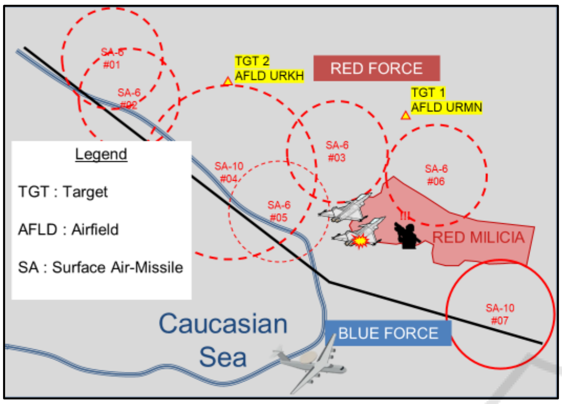

Figure 1: Organization of the required software for the C-SAR use case, within the stations.

The initial goal of the mission is to provide an Air interdiction on enemy bases. The scenario is located on the Caucasian theatre. Multiple tactical elements have been set to make the simulation more realistic and make the participant engaged in this environment (detailed in the legend of the Figure 1).

To achieve their goal in the scenario, the following assets are engaged:

- Uzi1 is an air fighter patrol where the pilot participant plays the leader of the two fighters. They are set for Air/Ground capacities and tasked to engage the target TGT1. The wingman is AI controlled. The pilot participant can interact via the Radio with its wingman that is played by one of the experimentation accomplices.
- Cyrano is an AWACS (Airborne Warning and Control System) with the task of control over all the assets engaged. This role is played by the controller participant.
- And other several assets that are piloted by an AI system (blue and red forces) such as a blue tanker, blue fighters, red fighters, ground vehicles.

The scenario emphasizes collaborative working to support the delegation, as at one point the wingman is hit behind enemy lines. All the assets involved in the surveillance and safety of the wingman on land then have to be reorganized.

2.3 Simulation Setup

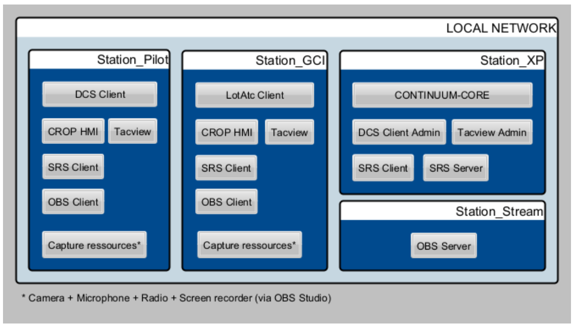

Figure 2: Simulation setup with their software to support the use case scenario.

The experimental setup is made up of four workstations named "Pilot" "AWACS", "XP" and "Stream". The first two are used by the test participants who play as the pilot and controller, and the latter two are for the operators handling the experiment (Figure 2). Each workstation is equipped with a pair of headphones, microphones, and camera video over the same network for monitoring purposes. The participants can communicate via the open-source software DCS Simple Radio Standalone (Ciribob, 2024) through their headphones.

Figure 3: Pilot's workstation including the cockpit, the static HMI CROP and the geospatial HMI CROP.

Each participant has at their disposal three screens (Figure 3, Figure 5). The first one is their workstation: the fighter cockpit for the pilot provided by the DCS Client; the display of what an AWACS operator can see rendered by the LotAtc software (DArt, 2024) connected to DCS. The second is the instantiated CROP interface is presented as a series of static images. Each one of the images displays the relevant information upon each step of the scenario. Those images are shown to the participants via a web interface opened on dedicated screens of the “Pilot” and “AWACS” stations. An operator at the “XP” station is tasked with changing the images being displayed as the scenario progresses. For each change, a brief audio notification plays in order to direct the participants’ attention to the new information being provided.

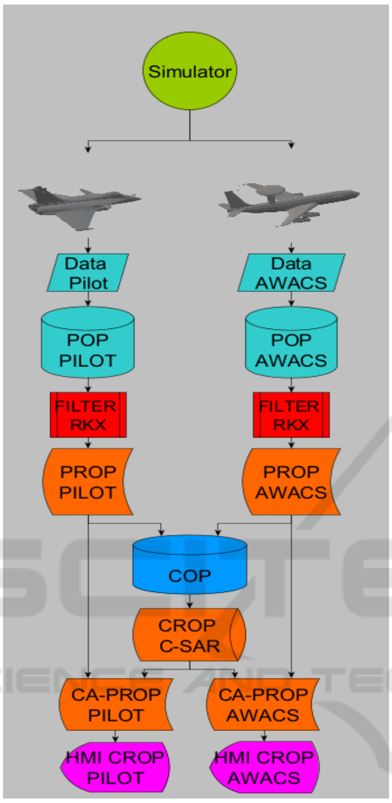

Figure 4: Data flow of simulators within CONTINUUM-Core.

Legend: POP – Personal Operational Picture, RKX - Relevant Knowledge Exchange, PROP – Personal Relevant Operational Picture, COP – Common Operational Picture, CROP – Common Relevant Operational Picture, CA-PROP – Collective Augmented Personal Relevant Operational Picture

The last screen available is the spatially informed part of the CROP information. This visualization is provided in the consumer software Tacview (Raia, 2024) as a dynamic cartographic display. This display uses data which are gathered from the pilot’s and controller’s points of view, then aggregated and filtered for relevance using a custom-made program called CONTINUUM-Core (Figure 3).

In other words, all the tactical data related to the simulation software is gathered to the CONTINUUM-Core, while the data related to analysing the behaviour of the participants are saved to the “Stream” station. More precisely, the “Stream” station runs the consumer software OBS Studio (Lain, 2024) specialized in capturing and synchronizing all of the aforementioned video and audio streams, including radio, into a single video for later commentary and analysis.

2.4 Procedure

By splitting the experiment into separate missions, we were able to pause in between phases in order to gather spontaneous feedback from the participants immediately after their experiences with the interface. Each participant was introduced to the CROP HMI to be used in the upcoming chapter before it starts. Then they can react to the CROP HMI that were shown over the past chapter by writing down their remarks over printed versions of the interface.

Figure 5: Controller's workstation including the cockpit, the static HMI CROP and the geospatial HMI CROP

In addition to the elements mentioned above, each participant returned an annotation of the static CROP images. Participants were asked to assess the information value of each graphic element in terms of relevance. Information is categorized according to the criteria described in the result section. Afterwards, participants took part in a self-confrontation (Theureau, 2010). The collective self-confrontation interviews were carried out in order to capture the different points of view on the activity. To be more precise, this interview allows us to get deeper in the understanding of the operator’s activity and the analysis of the annotations of the CROP HMI. Those sessions were recorded for future analysis.

3 RESULTS AND DISCUSSION

In order to answer our hypothesis, during the experiment the participants shared their impressions of the different HMI CROP mock-ups linked to the different phases of the scenario. The components of each model were evaluated according to four relevance criteria:

- Relevant information, which allows me to carry out my task or understand the situation;
- Irrelevant information that can disturb me in my task, mislead me or distract me;
- Useful but not essential information, which does not disturb my task;
- Missing relevant information to add to the component;

In addition, to analyse the comments about the interface from the self-confrontation interviews, these were recorded and then transcribed using an algorithm.

A synthesis was then produced from the handwritten comments on the interfaces and the comments from the self-confrontation interviews.

A quantitative analysis of the results was carried out, counting the number of comments made by all the participants for each component of each interface, with reference to the four relevance criteria mentioned above.

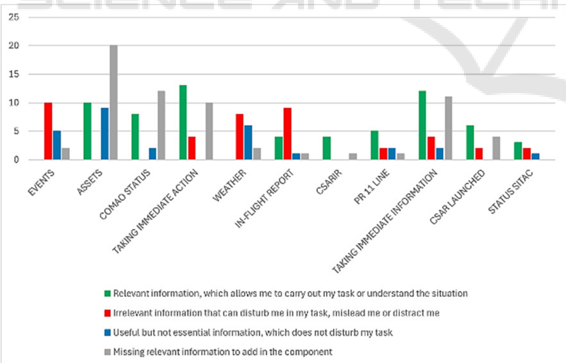

Figure 6: Quantitative analysis of HMI CROP components.

From Figure 6, we see that certain meteorological and event information, as well as information related to the in-flight report, are mainly considered as irrelevant or even disturbing information.

However, the information relating to the state of the tactical situation remains variable, while the direction indication data is mainly relevant.

Moreover, regarding the operators involved in the operation, this information is useful to them and should contain additional information for each asset (such as their altitude block or their task).

Furthermore, the PR-11-LINE and CSARIR components (checklist) allowing them to identify and transmit the various information relating to the ejected ally are mainly relevant for pilots and controllers.

The C-SAR (Combat Search and Rescue) package launch information is also mostly relevant and useful, but needs additional information (such as the package arrival time).

As far as immediate action is concerned, i.e. the recommendations made by the interface to the participants, these results essentially show that this information is relevant, even if some participants indicated that it was irrelevant or even disturbing. This can firstly be explained by the fact that some participants had not understood that this component presented recommendations that they could either accept or reject. In addition, others explained that for them to be able to make these decisions, it would have to be assigned to a specific role (such as ACE - Airspace Control Element, or TEA - Terminal Engagement Authority).

Lastly, the information highlighted in the interface receives a large number of comments. This information is mainly relevant and enables them to carry out the task and understand the situation, even if some of it remains irrelevant. This component of the interface is highly contextual and can therefore contain very different information from one moment to the next. The different opinions thus depend on the context.

4 CONCLUSIONS

The methodology we implemented enabled us to demonstrate that the relevance of information is contextual, but also that the need to access this information strongly depends on the type of task being performed. Indeed, whether the task consists of taking information or making decisions, the need for relevant information, and in particular access to it, will vary. What's more, in our military context, the acceptance of the task delegation is closely linked to the delegation of the associated role. Thus, the results presented suggest that interaction with the recommendations made by the system is essential in order to pursue the relevance analysis and thus assess the acceptance of delegation and its use in operation. Finally, we have highlighted the interest of CROP and shown that it seems to be the preferred and indispensable support for the acceptance and quality of delegation. The step forward is to evaluate the following question: does the CROP support the mechanism of delegation for future collaborative avionics?

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