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# Transition between cooperative and collaborative interaction modes for human-AI teaming

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## Résumé

*Avec l'introduction de l'IA dans le pilotage des véhicules terrestres ou aériens, la répartition des rôles entre opérateur et système devra évoluer de manière dynamique. A travers une expérimentation en micro-monde sur la supervision d'un drone intelligent, nous étudions comment une telle transition entre modalités d'interaction coopératives et collaboratives peut affecter l'expérience et le choix de l'opérateur. Nous observons des variables comme le sentiment de responsabilité ou la confiance et constatons que les opérateurs ont faiblement conscience de l'influence de l'IA sur leur propre prise de décision.*

## Mots-clés

*Equipe homme-autonomie, automatisation adaptative, interactions homme-IA, coopération, collaboration*

## Abstract

*With the introduction of AI in the piloting of land or air vehicles, the distribution of roles between operator and system will have to evolve dynamically. Through a micro-world experiment on the supervision of an intelligent UAV, we study how such a transition between cooperative and collaborative interaction modes can affect the experience and the choice of the operator. We observe variables such as the feeling of responsibility or trust and find that operators have little awareness of the influence of AI on their own decision making.*

## Keywords

*Human-autonomy teaming, adaptive automation, human-AI interaction, cooperation, collaboration*

## 1 Introduction

Advances in Artificial Intelligence (AI) make it possible to envisage for the transportation industries the arrival of systems with a level of autonomy that evolves according to the needs of the user, from driver assistance to substitute driving. In October 2020, SNCF ran a BB 27000 freight locomotive for the first time in partial autonomy, under real operating conditions, with fully automated acceleration and braking functions [15]. Another first achievement in June 2020 concerned Airbus succeeding in making the taxiing, takeoff and landing of an A350 aircraft autonomous using on-board image recognition technology [1]. The increasing automation of aeronautical systems allows us to consider an improvement in safety while reducing the workload of pilots, and contributes to a progression towards cockpits that would be operable by a single pilot working as a team with AI. However, between two human operators, the division of labor and the way in which they team up can change depending on the situation. For example, during the flight for a go-around or for failure management, a change of flying pilot can be decided. An AI system replacing the second pilot would have to deploy adaptive automation to accommodate these changes in the distribution of roles that may occur, that is to say functions may have to be shared or exchanged between humans and machines in response to change in situation or human performance [7].

The evolution of the pilot towards the role of operator supervising operations requires the development of trusted AI to certify such frameworks, and will not be possible without a better understanding of the impact of adaptive automation on human behavior. Furthermore, what is true for aircraft pilots is also true for unmanned aerial vehicle (UAV) crews. It is even amplified by the physical distance between the human operator and a part of the system he or she is supervising, namely the airborne vector, because the ground station, if it includes AI, remains co-located with the operator. The central problem is decision making for choices that put the success or safety of the mission at stake, especially in the case of unexpected events or degraded situations, and that is why a human operator is left in the decision loop [4]. The aim is therefore to

define an interaction methodology that enables the human operator and the AI system to communicate their mutual points of view to achieve optimal decision-making in situations of uncertainty, and also encourages the critical judgment of the operator on the system's proposals. In this sense, we can consider the operator and the AI system as a team, a social entity composed of members who interact, synthesize and share information and expertise in order to achieve common goals.

## 2 Related works

Managerial and management sciences are interested, among other things, in how decisions are made within organizations. According to Roy and Bouyssou [13], "even if the ultimate responsibility for a decision rests with a clearly identified individual, it is often the result of interactions between multiple actors during a decision-making process". Thus, even if in an organization involving human operators and AI it may be agreed that the final decision remains the responsibility of human, this decision is still the result of the process of interaction between the different actors. Understanding the elements of these interactions and how they can shape the final decision making is an important issue to better develop systems based on a combination of human and AI. Turoff, White and Plotnick [16] highlight that in the literature the terms collaboration, cooperation, coordination are too often confused and they propose a scale that differentiates five increasing levels of communication in group decision-making: competitive: no trust in the information transmitted; informative: honest exchange of information about what each party is doing; coordination: mutual scheduling of what each party is doing and when; cooperation: mutual agreement on what tasks each party will perform; collaboration: mutual agreement to work together on the same tasks. In the context of decision making for important elements that could jeopardize the objectives or security of the mission, it is essentially the levels of cooperation and collaboration that can be at stake. We will therefore now detail what they cover.

**Cooperative teamwork.** For Dillenbourg [5], cooperation and collaboration do not differ in terms of whether the task is divided, but in the way it is divided. In cooperation, the task is hierarchically divided into independent subtasks, whereas in collaboration, cognitive processes can be heterogeneously divided into intertwined layers. Piquet [12] also defines cooperative work as a collective organization of work in which the task to be satisfied is fragmented into subtasks. Each of these subtasks is then assigned to an actor, either according to a perfectly horizontal distribution in which tasks and actors are equivalent, or according to a logic of assignment according to the skills of each one. This is a rationalized division of a task into actions that will be distributed among actors acting autonomously. Cooperative work is thus hierarchically organized and planned group work involving deadlines and task sharing according to precise coordination. Each member of the group knows what he or she must do from the beginning and communicates, exchanges or shares elements only to reach his or her individual goal [10]. At the end, everyone's work is brought together to create a single object of work. In

other words, it is the progressive and coordinated succession of each person's actions that makes it possible to achieve the final objective. The responsibility of each person is committed to the sole accomplishment of the tasks that are specific to them.

**Collaborative teamwork.** Collaborative work, on the other hand, does not involve an a priori distribution of roles, but a merging of individual contributions in action. Interpersonal interactions are permanent to ensure overall coherence, a necessary condition for the efficiency of the action and the achievement of the final objective. Collaboration within the framework of collective work is a modality that goes beyond individual action by explicitly implicating itself in a dynamic of collective activity. It is a question for each actor of a project to feed his individual contributions with those of the others. Collaborative work implies a mutual commitment of individuals in a coordinated effort to carry out the same task and solve the same problem together [2]. It requires team members to be more interactive and more motivation and interpersonal trust than other methods of work organization [14]. Nevertheless, human-AI teams are different in nature from the human-human teams that the concepts of cooperation and collaboration generally describe. There are important differences in the ways in which human and machine acquire and process information which could make trust much more difficult to build [8]. Klein [9] explains that one of the necessary conditions for the effectiveness of a group is interpretability, i.e. the ability to predict the actions of other parties with a reasonable degree of accuracy. Each member of the group should strive to make their actions sufficiently predictable to allow for effective linkage. However, user priorities may change over time, which may require the system to manage and adapt to changing constraints and preferences. If AI requires a precise definition to solve the problem mathematically, human actions are in fact of limited rationality and often informed by heuristics that are partly spurious [17]. There may be a mismatch between the precise mathematical objectives required by the AI and the potentially fuzzy specifications that can be provided and manipulated by humans. Heterogeneity in teams can be a source of difficulties in establishing a mental model of the other, but it is also a source of opportunities because team members can complement each other by providing skills they lack [11]. Thus, when AI systems need to interact with human users, it is not so much important to reason rationally as to emulate human-type reasoning [3]. An effective decision support system must not only provide quality information, but also consider the user's constraints in terms of available cognitive resources and personal preferences.

In this study, we define teamwork as cooperative when tasks are distributed among members, and collaborative when any member can contribute to any task.

## 3 Study hypothesis

It appears that the way of interacting between operators can be structured in a different way according to the chosen organization, the trust between the participants, the commitment

of each one in the collective process. Other factors such as the stakes, the time pressure, the nature of the activity to be carried out can also influence this interaction process, which is not necessarily fixed in time. In the case of collective decision-making, the organization of interactions but also their temporal evolution could be elements that directly influence the outcome of the decision-making process. To investigate how the way of teaming up with a decision support system will influence an operator's decision making, we have developed an experimental micro-world. This environment allows us to simulate a UAV flight replanning task that a participant performs with a mode of interaction with the AI system that can evolve between cooperation and collaboration. The aim of the study is to better understand, in an experimental way, how the modes of interaction between a human operator and an AI can impact the decision resulting from the interactive process and how this decision is considered and accepted by the human operator. Our hypotheses are:

H1: The evolution of the mode of interaction has an impact on the operator's feeling about the decision-making process.

H2: The interaction mode has an impact on the variability of the decisions made by the operator.

## 4 Experimental study

### 4.1 Task description

A group of 20 healthy PhD students and young engineers (40% female), with an average age of 26.1 years (SD = 2.7 years), participated in this study. All subjects volunteered to participate in the study and gave their full informed consent before taking part in the experiment. They embodied a military air operator responsible for supervising a UAV to carry out missions in enemy territory (Figure 1). The objective of the missions is to fly over several targets to photograph them

and then leave the enemy zone, while minimizing the risks taken and the fuel consumed. The missions take place on different territories but with a similar scenario: 1) the UAV heads towards the enemy zone with an initial flight plan, 2) enemy entities are suddenly detected, so the flight plan is no longer satisfactory, 3) the operator interacts with the system to define a new flight plan, 4) the operator validates a new flight plan, which completes the supervision task. The interaction phase occurs either in cooperative or collaborative condition, and has to be finished before entering the adverse territory.

**Cooperative condition.** In this operating mode, the roles between the operator and the assistance system are fixed: the operator defines the high-level tactical elements that force the modification of the plan (crossing points, objectives removed from the mission...) then the assistance system produces the optimized path taking these elements into account.

**Collaborative condition.** In this operation mode, the distribution of roles is not fixed and the assistance system will also propose tactical changes for the realization of the mission. The system will do this on its own initiative at the start of the replanning phase, and may then suggest other types of solutions (modification of crossing points, objectives retained or deleted...) at the operator's request. The system can also ask the operator to confirm the classification of an image for which the uncertainty would be high, and whose level of dangerousness if it were different could imply modifications to the plan (Figure 2). The tools present in cooperative mode are also present in this more advanced interaction mode, but the proposed solutions remain the same in both conditions, the constraint optimization algorithm being for its part unchanged.

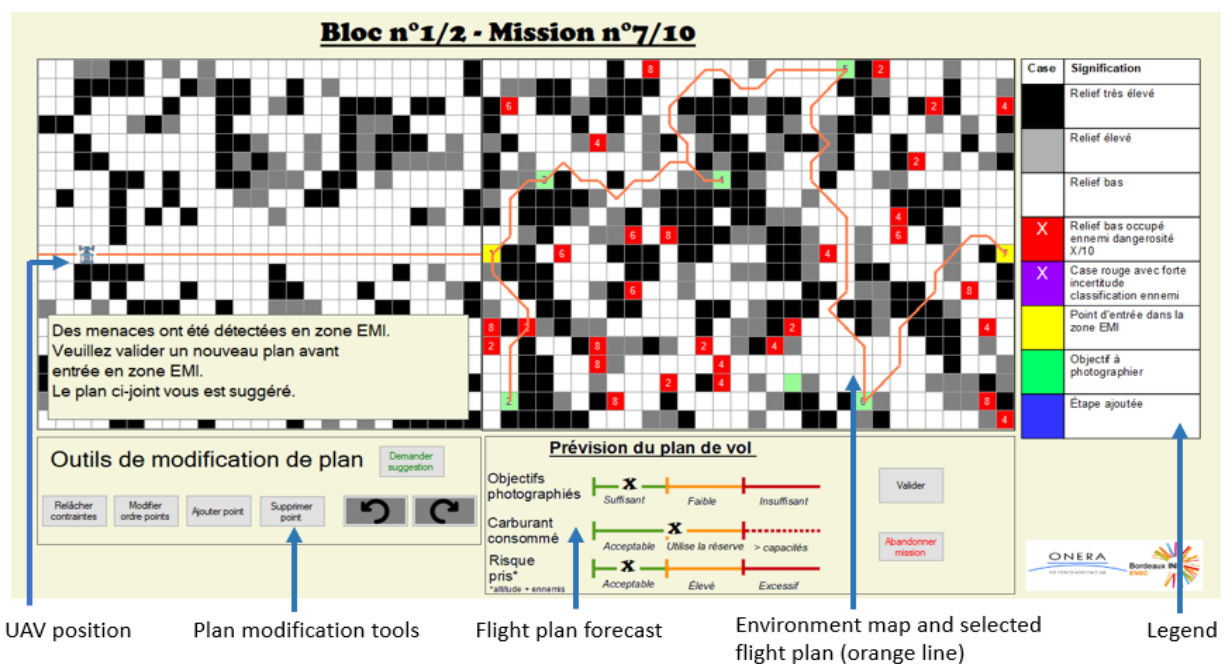


Fig. 1. HMI for replanning task in collaborative condition



**Fig. 2.** Tool for checking the classification of an enemy by the operator.

## 4.2 Metrics

All the participants completed 20 missions in the same order. Half of the participants carried out the first 10 in cooperative condition, and the last 10 in collaborative condition. The other half of the participants carried out the first 10 missions in collaborative condition, and the last 10 missions in cooperative condition. To study how the evolution of the teaming method influences the operator's final decision making, we defined two categories of metrics:

**Metrics of the operator's feelings about the chosen solution.** We use four metrics to evaluate the quality of teaming between the operator and the AI according to the level of teaming. After each completed mission, the participants answered three questions in the interface on 7-item Likert scales about their:

- Feeling of responsibility in the validated solution.
- Feeling of authorship of the validated solution, i.e. according to the operator who of him/her or of the system took the most part in its design.
- Confidence in the validated solution.

After completing all missions in an interaction mode, participants answered a NASA Task Load Index (NASA TLX) questionnaire to measure their perceived workload for the task [6].

**Metrics for variability of decision made.** To compare the dispersion of the solutions validated according to the interaction mode, we superimpose for each mission the plans validated in each of the two conditions (one plan for each participant). Then, we calculate for each mission the difference between the number of boxes that are never used in the cumulative plan of one condition and in the cumulative plan of the other condition. The sign of the dispersion index thus obtained gives us information on the condition for which the solutions are the most spread out on the map.

## 5 Results

Data from all 20 participants were included in the analysis. The metrics from the 10 completed missions were averaged for everyone for each condition. We set a threshold of 5% for

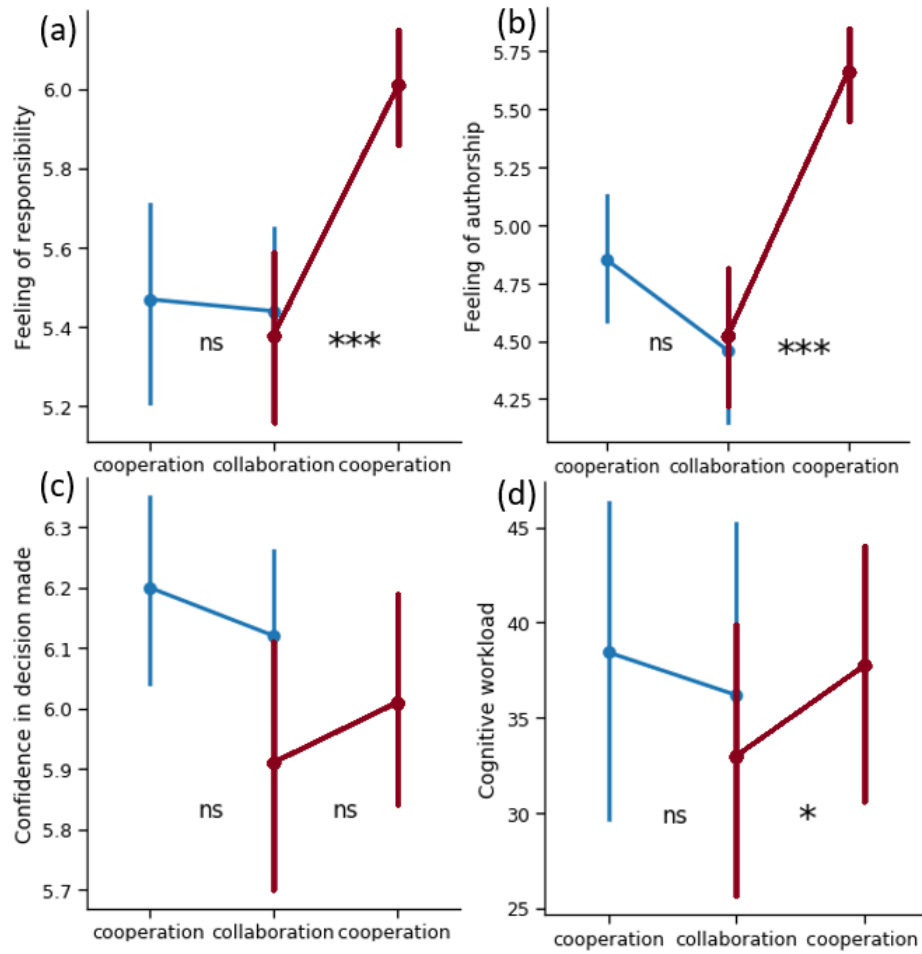
the significance of p-values.

**Impact of the evolution of the interaction mode on the operator's feeling.** To test H1, we conducted repeated measures analysis of variance (ANOVA) to compare the effect of the interaction mode evolution (*cooperation then collaboration*, or *collaboration then cooperation*) on metrics of the operator's feeling about the chosen solution (feeling of responsibility, feeling of authorship, confidence and cognitive workload). There was a significant effect of the interaction evolution *collaboration then cooperation* on feeling of responsibility ( $F(1,198) = 20.40$ ,  $p < 0.001$ ), on feeling of authorship ( $F(1,198) = 40.53$ ,  $p < 0.001$ ), and on cognitive workload ( $F(1,9) = 6.5$ ,  $p = .03$ ), but not on confidence ( $F(1,198) = 0.51$ ,  $p = 0.47$ ). On the other hand, we found no significant effect of the teaming evolution *cooperation then collaboration* on feeling of responsibility ( $F(1,198) = 0.03$ ,  $p = .86$ ), on feeling of authorship ( $F(1,198) = 3.84$ ,  $p = .05$ ), on cognitive workload ( $F(1,9) = 1.5$ ,  $p = .24$ ) and on confidence ( $F(1,198) = 0.54$ ,  $p = 0.46$ ). Some of these results are in line with our hypothesis as they show as expected that the transformation of task distribution with AI influences the operator's experience. However, when the transition is from cooperative to collaborative teaming, the reverse effect is not observed. This asymmetrical change (Figure 3) does not comply with our hypothesis.

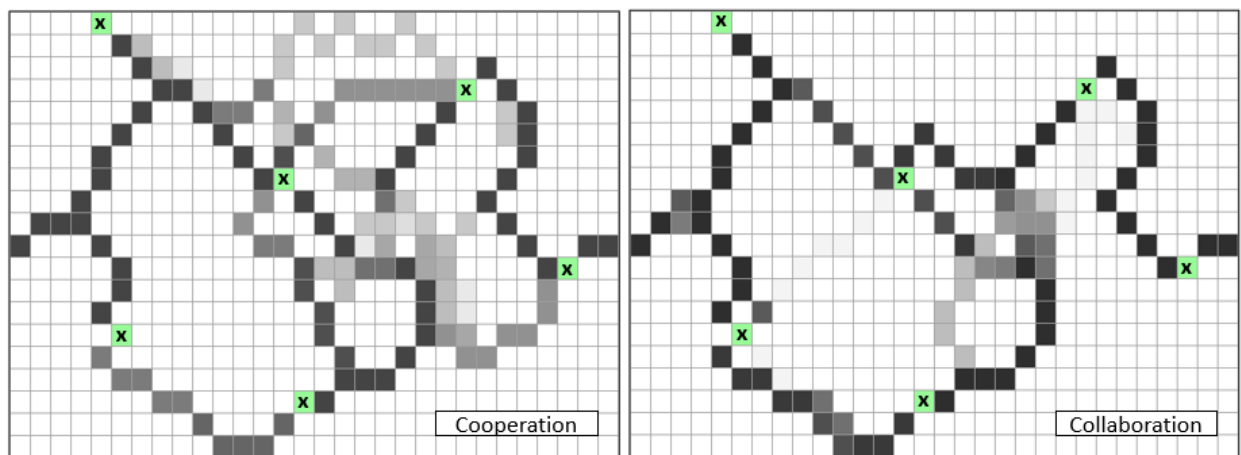
**Impact of the interaction mode on the operator's decision making.** To test H2, we performed a one-tailed t-test on the list of indices of dispersion of missions ( $t(19) = -3.08$ ,  $p = .003$ ). The average of the indices is significantly negative, which means that in collaborative teaming there are more boxes that are not covered by any validated plan than in cooperative teaming. In this sense, the variability of decisions made in collaboration is therefore lower than those made in cooperation with the AI system, which supports our hypothesis. A visual example of variability differences between teaming conditions can be visually observed for one mission in Figure 4.

## 6 Discussion

For the integration of Artificial Intelligence in vehicles, and especially aircrafts, cross-comprehension and trust between the decision support tools and the operator is a prerequisite to ensure the system's resilience. In this paper, we describe an experimental study where an operator performs a UAV flight replanning task assisted by a decision support system with varying levels of investment. The operator enters a process of co-constructing a flight plan in a complex environment requiring compromises between different constraints thanks to the assistance of the system. We seek to characterize the user's feeling and we hypothesize that it depends on the mode of interaction with the AI, but also on its evolution. We observe that as the operator-AI team moves from a collaborative to a cooperative teaming, where the system will progressively take less initiative in the action, the operator will feel more at the origin and responsible for the decisions taken. Withdrawing assistance to which the operator is accustomed creates a sense of loss. However, when AI will introduce plan suggestions



**Fig. 3.** Impact of the evolution of the interaction mode on the operator's feeling. (a) Sense of responsibility in the decision taken. (b) Sense of authorship in the decision taken. (c) Confidence in the decision made. (d) Felt cognitive workload for the task.



**Fig. 4.** Superimposition of the plans validated by the participants for one of the missions. The gray level associated to each box represents the proportion of plans validated for this level of teaming that passes through it (superimposition of 10 validated plans for each figure). The green crossed-out boxes represent the objectives to be photographed. (left) The mission is carried out in cooperative condition. (right) The mission is carried out in collaborative condition.

that were not previously present, the operator will not feel disinvested in his role. The help is accepted and does not disengage the operator. This asymmetry to change can be problematic insofar as we observe that the teaming method will nevertheless influence the decisions validated by the operator. The flight plans carried out with a cooperative organization are more varied than those carried out in a collaborative organization. When suggestions for plans are proposed by the system, the operator will tend to validate plans that are close to them, but without being conscious of this influence on his behavior. This work demonstrates that a system dedicated to assist a human operator in a decision-making task can insidiously modify the solution he or she validate. This is a critical issue when developing sophisticated support systems while the user is not aware of being influenced by the AI system. Such behavior is somewhat standardized by the AI suggestions and he or she is no longer challenging the potential solution in the same way. On the one hand, the reduction of human variability can be considered desirable because the predictability of the system can lead to a better overall reliability. On the other hand, the interest of keeping human operators lies precisely in their capacity to display a critical and subjective mind in the decision process. These first results suggest investigating if adding explanations about strengths and weaknesses of the proposed solutions, or highlighting underlying choices that lead to these solutions could reactivate the operator's alertness and avoid compliance to the AI suggestions. Moreover, the experiment shows that users combine the use of elementary and more sophisticated tools in both cooperative and collaborative modes. The next experiment should rely on a new interface, designed to enhance collaborative tools based for which human and AI initiatives could be more interdependent.

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