Analyzing the Collective Activity of Firefighters During Urban Fire Simulation

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ANALYZING THE COLLECTIVE ACTIVITY OF FIREFIGHTERS DURING URBAN FIRE SIMULATION

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Abstract
This chapter proposes the study of the collective activity of a team of firemen in a simulation situation. In reference to the Data/Frame theoretical model, this study analyzed team sense-making through the articulation of individual activities. The methodology was inspired by the principles of *in situ* analysis developed within the NDM framework. Observation and communication data were recorded from 11 firefighters in training situations and completed by verbalization data collected during subjective re-situ interviews. Data analysis was based on the use of multi-score format. The results highlight the (im)possibilities of inter-individual interaction that are created throughout a training situation. The "Sensemaking Articulation of Global Activity" (SAGA) mode of representation makes the articulation of individual sense-making visible. This study highlights the influence of the functional (mission of each agent) and spatial (position of each agent) configurations of the team on team sense-making during a maneuver. Within the team, two levels of understanding of the situation (macroscopic and microscopic) coexist with local and typical forms of coordination involving all or part of the team. As a result, the team sense-making appears as an enchainment of cycles of local sense-making in which the team leader is the coordinator. All of these results allow us to suggest ways to improve the design of simulations for firefighting team training.

Key-words : Team sense-making, semi-open space, simulation, firefigthers,

1. INTRODUCTION

This chapter presents an analysis of the activity of firefighters' teams in practical training situations designed for firefighters. More specifically, the objective is to analyze the team sense-making during a simulation in order to propose ways to improve it.

1.1. Simulation for training purposes

The use of simulation in a pedagogical perspective is a practice particularly exploited in domains considered as risky such as the military domain (Grau et al., 1998; Jensen, 2009); aviation (Rankin et al., 2016) or virtual teams (Rafaeli et al., 2009). The main interest lies in the fact that simulation allows, without risk for the learner, to promote the acquisition of skills when performing specific tasks that are difficult to reproduce in reality. Its use allows the manipulation of problematic variables, such as the consequences of actions in risky situations, the complexity of technical and organizational systems or the temporality of the processes involved (Samurçay and Rogalski, 1998).

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Within this framework, the simulator is defined as an "artifact that simulates (partially or totally) the functioning or behavior of a technical system, an installation, or a natural phenomenon" (Vidal-Gomel et al., 2011, p. 117). The latter is generally the result of modeling work on the real activity. It can be material (with interfaces for the trainees and possibly for the trainers) or purely symbolic (and not be a technological object per se). In the case of the training of firefighters that we have studied, the simulator is not a specific technological object but a global operational device defining the status and roles of each member of the team within a figurative environment (Béguin and Pastré, 2002).

Although the studies carried out on work situations in the field of ergonomics psychology have largely studied the individual dimension, they point to the need to analyze collective activity (Leplat, 1991; Hoc, 2003). At the same time, it appeared important for researchers (as well as for managers) to understand processes inherent to these situations leading, or not, to the passage of the skills of each individual to a collectively efficient team. This concern for the collective dimension was therefore logically integrated into the design of the training systems. The firefighting profession is characterized by the fact that it is not practiced in isolation but almost exclusively within a team based on a precise and perfectly established organizational system (Lipshitz et al., 2007). Collaboration between members of the firefighting team is essential in view of the plurality of risks, the evolving and uncontrollable nature of situations and the time pressure (Samurçay and Rogalski, 1993; Klein et al. 2010). In order for there to be collective efficiency in the field of work, the necessity for individuals is that they be able to share the same task, i.e. the same goal and the same working conditions (Leplat, 1993). In the case of the firefighting teams we studied, this common goal is to stop an incident and rescue victims.

1.2.The team sense-making model (Klein et al., 2010)

In order to understand how a team functions, valuing sense-making by a collective in a situation remains an avenue of research to explore. By adapting their individual Data/Frame model to the collective, Klein et al. (2010) attempt an approach aimed at specifically understanding *"the process by which a team manages and coordinates its efforts to explain the current situation and anticipate future situations, particularly under uncertain and ambiguous conditions ».* In this perspective, the authors take up the different activities that make up the original cyclical model and elevate them to their collective dimension (Figure 1).

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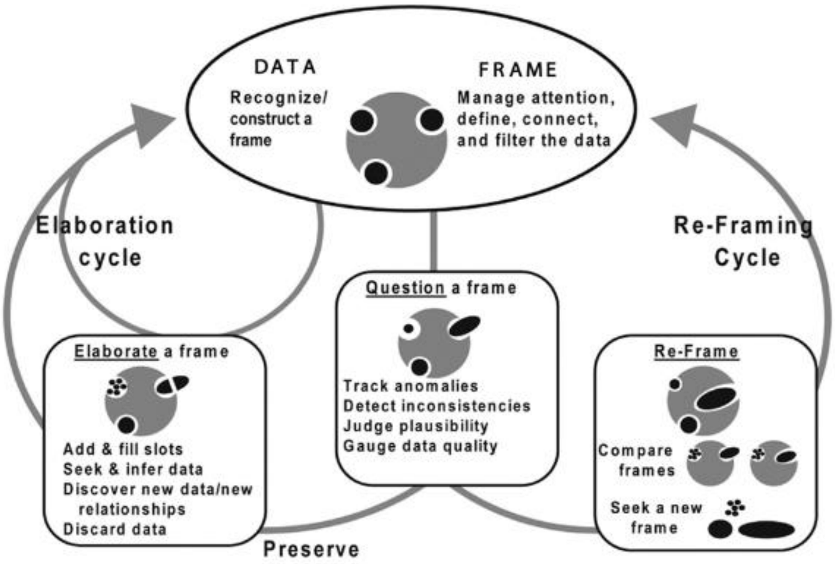

Figure 1. Expanded data/frame diagram to team sense-making taken from Klein *et al.* (2010).

Klein et al (2010) extract from this team sense-making model various strategies that contribute to the collective construction of a cognitive framework appropriate to the relevant data of the situation. All these strategies are listed and detailed in Table 1.

Table 1. team sensemaking strategies adapted from Klein *et al.* (2010)

Team sense-making	Emerging strategies
Recognize a frame	The team formulates criteria or rules used to identify the frame A team member announces what the frame is The team collaborates to identify the frame
Question a frame	Designate a team member to play the role of "devil's advocate" and raise doubts about the relevance of a frame The team creates rules or identifies triggers to alert that the frame may be irrelevant Team members speak up and discuss what could go wrong with using the frame
Re-frame (compare)	The team compares the frame and votes for one of them Team builds consensus on the most appropriate frame Leader announces which frame is most appropriate
Re-frame (seek)	The individual suggests a frame that is adopted, modified, or rejected by the team after comparing frames Team speculates on data and suggests causal views: leader or team member combines views within a frame The team collaborates to synthesize competing frame
Elaborate a frame	The team discusses and dismisses anomalous data as transient or otherwise insignificant signals Data synthesizing team members lead data "collector" activities to seek new data to verify the frame Synthesizing and collecting team members collaborate to discover new relationships that preserve or extend the frame

To the best of our knowledge this theoretical model has only been applied within a study on air traffic control (Malakis and Kontogiannis, 2014). The authors specifically studied team sense-making processes performed by the air traffic management collective in very low visibility conditions. These collectives involve controllers located in the control tower and on the tarmac as well as possibly a team leader. An interesting point lies in the modulable character (in numerical terms and consequently of attribution of functions) of the collective according to the density of the traffic which, independently of the conditions inherent to the studied situations, implies a fortiori different coordination processes according to the moments when these situations take place. Using the critical decision analysis method, Malakis and Kontogiannis (2014) verified the operability of the model in the real conditions of a risky activity. In this way, they highlighted the sense-making processes developed collaboratively within these collectives as well as the strategies put in place specifically for the domain. These results allowed the development of efficient technological devices adapted to the real activity of air traffic controllers in difficult conditions (e.g. in low visibility situations).

This study is of real interest in the context of our work insofar as the group studied, although in continuous audio contact, is highly spatially dispersed. As a result, the accessibility to information is not the same for all the team members (especially in terms of visual information) and requires them to communicate more in order to share the same information. This element is also underlined by the authors, in the perspective of designing technological management devices, by taking into account the aircraft's piloting team. Although pilots were not interviewed in the study, Malakis and Kontogiannis (2014) point out the lack of shared situational awareness between them and the control team in that the weather information specifically provided to them is not entirely identical. As a result, this informational gap can lead to certain dysfunctions in the collective construction of meaning of a situation, especially if it takes place under difficult conditions.

2. OBJECTIVE AND THEORETICAL RATIONALE

(1) The main objective of this chapter is to report on the collective activity of the firefighting team in a practical training situation. To this end, we conducted an empirical study based on two assumptions. The fire department teams, in our case in an urban environment, are led to evolve in compartmentalized spaces partially preventing communication (verbal or visual) between the members. In order to determine the processes of team sense-making in a "fragmented" team (Grosjean and Lacoste, 1999), we start from the presupposition that this object can be understood from the articulation of individual sense-making.

(2) Taking into account the subjective and individual character of the agent in a collective requires an understanding of the experience of each member during the action and of their articulation. Therefore, our work is part of a naturalistic approach intended to account for the meanings that the team members construct through their permanent interaction with the simulation situation. We postulate the coexistence within the collective of different levels of understanding of the situation. This plurality of forms of understanding would be both the result of the different functions allocated to each member and of the (im)possibilities of interaction brought about by the context. The understanding of the situation could be organized according to a relation to a "framework" of sense-making at the individual level and possibly shared at a collective level (Team sense-making model; Klein et al., 2010)

3. METHODOLOGY

The presuppositions presented above require the development of a specific methodology capable of accounting for the collective's agency in relation to environmental constraints. Thus, the method of multi-score transcription seems suitable in that it is a prerequisite for identifying the dynamics of team sense-making (Guibourdenche et al., 2017). We bet that this method could allow: to highlight (im)possibilities of interaction constrained by the environment and to associate the latter with team sense-making.

3.1.Context and participants

The study was carried out in the context of training sessions on urban fire management for fire managers organized by a French departmental fire service. The training sessions take the form of a full-scale simulation on a technical platform. During an emergency, the fire chief is the first officer to arrive on the scene with his team. His responsibility is to quickly take charge of the first emergency measures. The team leader is in charge of a response truck with five team members: the driver, the supply pair (BAL) and the attack pair (BAT). The driver's role is to drive the truck to the scene of the incident and possibly manage the water supply to the fire hoses for the team members attacking the fire. The BAL is in charge of supplying water to the fire hoses and possibly supporting the team members attacking the fire. The BAT's mission is to explore the scene of the incident and to attack the fire with the hoses. These functions, although perfectly defined, are likely to be modified during a maneuver according to the real needs of the field.

The study was conducted in collaboration with 11 volunteer firefighters participating in the fire chief training organized by a departmental fire service in France. At the time of data collection, their average age was 36 years (standard deviation: 7.62). At the time of the study, their experience as a firefighter was 12 years on average (SD 3.58). Participants were named using a code corresponding to the maneuver (between 1 and 3) followed by their position name (Chief, BAL-1, BAL-2, BAT-1, BAT-2): for example, code 3 BAT-1 corresponds to the leader of the attack pair (BAT) in maneuver 3.

3.2.Data collection

In this work, we were interested in three maneuvers performed during the training in full-scale simulation on a technical platform. These maneuvers will be numbered from 1 to 3 according to their chronological order during the training. Maneuver 1 corresponds to a fire response in a city's technical services. Maneuver 2 involves a fire in an apartment adjacent to a home for the elderly and involving a victim. Maneuver 3 involved a fire in a street with a heavy truck (with one victim). These maneuvers had a duration of 12'43", 18'10" and 10'17" respectively.

During these three maneuvers, the data collection procedure was applied each time to the entire intervention team except for the driver (played by a professional not involved in the training process). In this way, on each intervention, five trainees were involved, playing the roles of squad leader, BAT leader, BAT team member, BAL leader, BAL team member respectively.

The data collection procedure was based on in situ analysis methods. Three types of data were collected:

- Observational data on the activity of the trainees during the scenarios. These observational data were collected through the audiovisual recording of the behaviors during the maneuver. The situations were filmed from two points of view, both providing extrinsic data, using two types of digital video cameras. On the one hand, the use of a shoulder-mounted camera made it possible to record the team's activity from an external point of view (movement in space, gestures, postures). On the other hand, the use of an head-mounted camera on the helmet of each trainee (see Figure 2) made it possible to report on their activity from the actor's own field of vision (participant's point of view in the course of the action).

- Communication data involving the trainees during the simulations. These data are mainly recovered from the recording of the head-mounted camera.
- Verbalizations obtained during individual interviews in subjective re-situ (Rix and Biache, 2004; Rix-Lièvre, 2010) directly following the execution of the maneuver on site. This form of interview, which gives access to intrinsic data, consists of confronting an actor with audiovisual traces of a period of his activity taken from his own point of view (in our case, via the cameras mounted on the helmets).

3.3. Data analysis

The analysis consisted in reconstructing the chronicle of the situations (temporal unfolding) by synchronizing the extrinsic data (behaviors and communications) and the intrinsic data (verbatim) collected for each participant. To do this, the analysis was based on the following 6 steps: (1) multi-score transcription; (2) sequencing of the maneuvers; (3) identification of individual sense-making; (4) categorization of the level of individual sense-making; (5) representation of the team sense-making; (6) validity of the analysis.

Initially, this work exploited the MUltI-SCOre Format (MUSICOF), which allows the analysis of collective activity in semi-open space (Guibourdenche et al., 2017). We performed a multi-score transcription using the video films, from all the cameras used simultaneously during the study situations. All of the participants' behaviors were reported and were supplemented with verbalizations from individual interviews with each participant. All these data were gattered together using MUSICOF for each maneuver. These tables are constructed along two axes: a horizontal axis to respect the temporal course of the situation; a vertical axis to respect the spatial configuration of the intervention sites. Figure 2 shows an example of the MUSICOF format used in this study.

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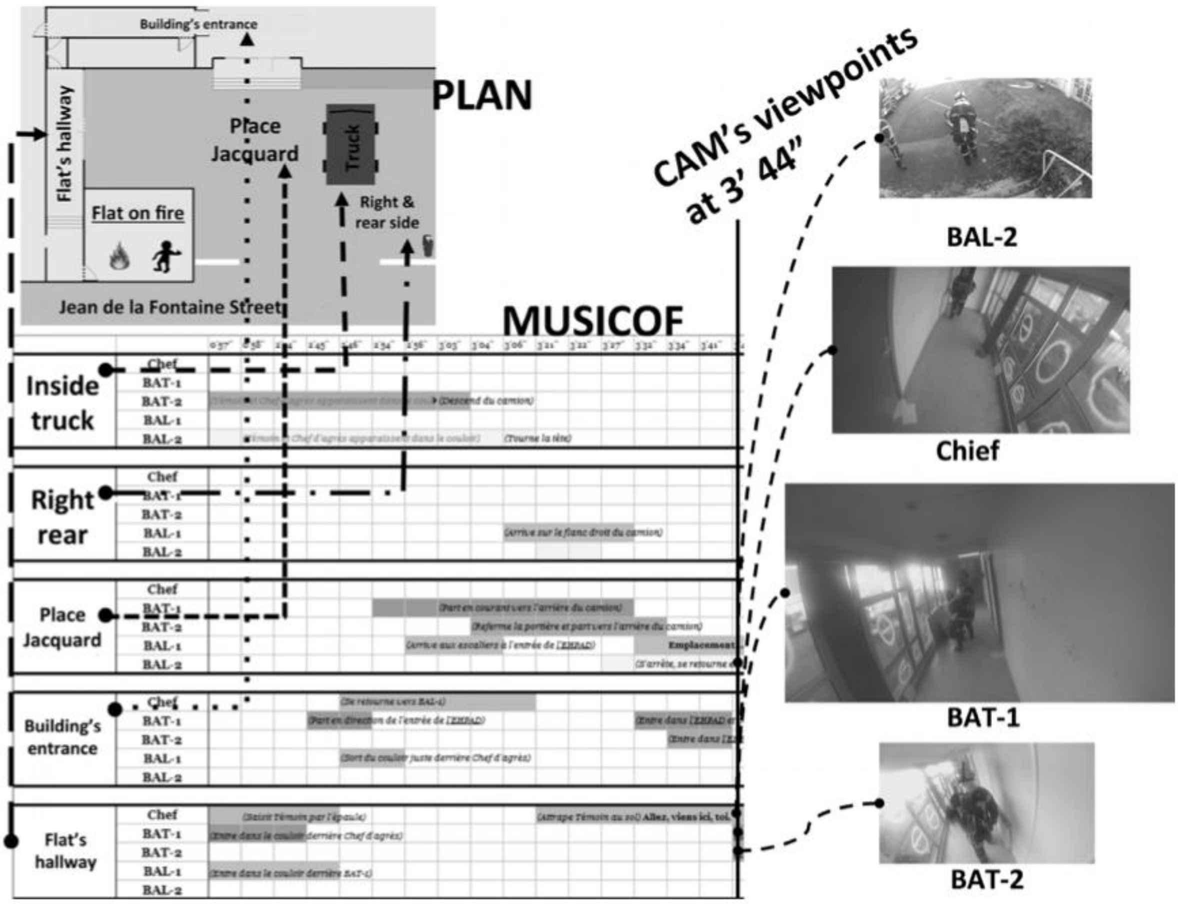

Figure 2. Relationships between the reference spaces (represented by the floor plan on the upper left and the photos on the right) and the MUSICOF transcription

For each maneuver, the overall intervention environment was divided into different spaces that could reflect the (im)possibilities of interaction for the collective. For each of these predefined spaces, each member of the team is represented in the multi-span chart by two lines: the upper line for his or her behaviors and communications; the lower line for placing opposite his or her corresponding verbalizations collected during the interview.

The second step consisted in sequencing the maneuvers by detecting "moments of rupture" within the collective activity (45 in total). These moments of rupture correspond to changes in the collective in terms of spatial configuration (separation and gathering of team members during the maneuver) or functional configuration (orders and missions given to each member by the team leader). These different configurations will be presented in the results section.

In the third step, we identified the individual sense-making activities corresponding to behavioral markers such as communications and behaviors noted during the situation and/or verbalizations collected during interviews.

The fourth step consisted in categorizing individual sense-making according to the level of individual understanding (377 individual activities in the whole study).

The fifth step is related to the graphical representation of the team sense-making. For this purpose, we designed a representation mode called "Sense-making Articulation of Global Activity" (SAGA) which consists in illustrating, for each sequence identified during the situation, the articulation of team members sense-making (according to the Data/Frame

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model) according to the spatial and functional configurations of the team. The figure 3 illustrates the spatial partitioning of a team in a semi-divided functional configuration of firemen with SAGA.

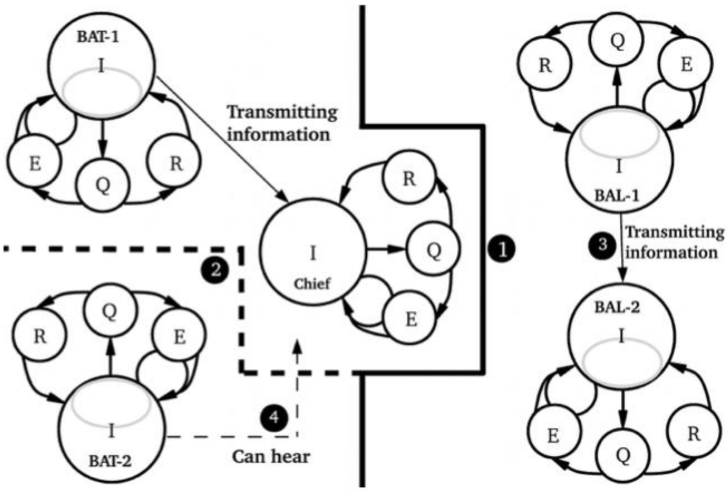

Figure 3. An illustration of the Sensemaking Articulation of Global Activity (SAGA).
Letter E elaborate a frame; Letter Q question a frame; Letter R reframe; Bold line radical impossibility for interaction; Discontinuous line limited possibility of interaction

Finally, we ensured the validity of the analysis by relying on the 3 principles of Corbin and Strauss (2008): completeness, exclusivity and fidelity (sequencing, coding, inter-coder agreement calculations).

4. RESULTS

4.1 Individual sense-making

The sequencing procedure extracted 45 sequences from the three maneuvers studied. Maneuver 1 has 15 sequences, Maneuver 2 has 19 sequences and Maneuver 3 has 11 sequences.
The step of identifying individual sense-making following the Data/Frame theoretical model allowed us to distinguish 377 individual sense-making over the whole study. The distribution of these individual sense-making for each member during the 3 maneuvers is summarized in Tables 2, 3, and 4.

Table 1. Distribution of individual sense-making of each member of firefighters team in maneuver 1.

Maneuver 1	Recognize a frame	Elaborate a frame	Question a frame	Re-frame (seek)	Re-frame (compare)
Chief	2	20	2	1	0
BAT-1	4	19	2	2	0
BAT-2	4	16	3	1	0
BAL-1	5	13	3	1	2
BAL-2	3	11	1	0	0

Table 2. Distribution of individual sense-making of each member of firefighters team in maneuver 2.

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Maneuver 2	Recognize a frame	Elaborate a frame	Question a frame	Re-frame (seek)	Re-frame (compare)
Chief	3	17	4	2	0
BAT-1	6	23	6	2	1
BAT-2	6	23	6	3	1
BAL-1	6	12	1	0	0
BAL-2	7	14	1	1	0

Table 3. Distribution of individual sense-making of each member of firefighters team in maneuver 3

Maneuver 3	Recognize a frame	Elaborate a frame	Question a frame	Re-frame (seek)	Re-frame (compare)
Chief	2	14	1	1	0
BAT-1	7	16	2	2	0
BAT-2	6	14	2	2	0
BAL-1	3	22	1	0	0
BAL-2	3	18	1	1	0

The number of occurrences of individual sense-making following the data/frame model (Klein et al., 2010) shows that two processes are particularly favored by firefighters. The recognition of the frame and the elaboration of the frame are the most mobilized by the firefighters whatever the role (leader/team member) or the maneuver involved.

From the 377 individual sense-making, a second analysis allowed us to distinguish two levels of individual sense-making: microscopic and macroscopic. The macroscopic level corresponds to the situation as a whole (type of incident, presence of victims, potential dangers, configuration of the site) and the type of maneuver applied to it (missions of each pair or partner, task planning). The microscopic level refers to the contextual elements (e.g. hydrant location, fire behavior, victim's health status, required equipment) and actions or procedures (e.g. fire attack, victim assistance, feeding) related to the execution of a specific mission. Over the course of the study, 182 individual sense-making were associated with a macroscopic level and 195 of these were associated with a microscopic level.

4.2. Highlighting of 6 typical structures of team sense-making

The 45 collective activity sequences identified from the 3 maneuvers were represented using SAGA for each of them. This step allowed the extraction of local structures of firefighting team sense-making. Specifically, these results highlight six typical structures of team sense-making: Alertness, Binomial development process, Negotiation, Team sense-making standby, Mission Reassignment, and Team sense-making adjustment.

4.2.1. Alertness

The first structure of team sense-making corresponds to the first sequence of each maneuver. This takes place in the truck when the fire chief receives the departure message from the call center. During this sequence, the team is in a "grouped configuration" in the truck, which gives all members the opportunity to interact. The departure message from the call center gives the fire chief the address where the team will have to intervene and can then be more or less detailed on the characteristics of the incident. The fire chief then passes on to his team members the information he has gathered from the call center concerning the situation. This is illustrated in figure 4. He also gives them all the safety rules relative to the type of incident to be managed as well as certain information concerning the application of the future maneuver

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(e.g. location of fire hydrants). To compensate for a possible lack of information, this moment can also be used by the fire chief to transmit to his team his possible assumptions about the situation (e.g. "*We don't have the notion of a victim but I imagine that the truck must have a driver*").

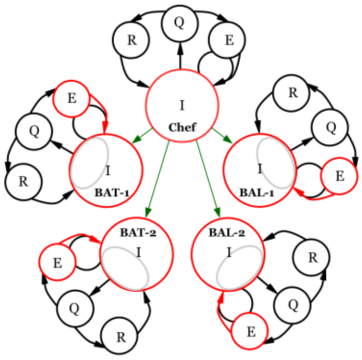

Figure 4. SAGA : Alertness

4.2.2. Binomial development process

The second structure concerns a binomial elaboration process (it appears six times in our data set). It corresponds to a transmission of information between the two members of the same binomial so that each of them can elaborate their respective microscopic framework. The transmission of information can be unidirectional in the case where only one of the two partners has access to the information and transmits it to the other. This case appears for example in maneuver 3, when the BAL attacks the fire. The BAL leader carries the lance but is unable to update his understanding of the situation because the headwind prevents him from seeing what is going on. It is the BAL team member behind him who shifts a little to see what is going on and gives him information as he goes along (e.g. *"Maybe put yourself a little stronger.", "We'll move. We're going to get closer.", "That's okay, fire out apparently. I'll pass it on."*).

This transmission of information can also be bidirectional in the case where each of the partners gives the other the information that it considers relevant. This is the case during maneuver 1 when the TAO enters a smoky room in order to cut the electric meter and to extinguish the fireplace. The two partners exchange information on what they respectively consider relevant in their situation. This exchange then allows both parties to elaborate and align their respective microscopic frameworks. The structure of this team sense-making can be illustrated in Figure 5.

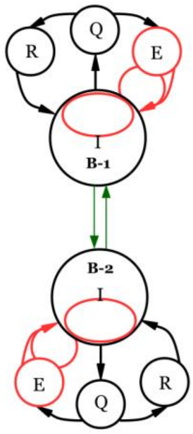

Figure 5. SAGA : Binomial development process

4.2.3. Negotiation

This structure (which appears 9 times) concerns moments of questioning by a member of the pair and presents three variants illustrated in figure 6.

Globally, a member of the pair, by initiating a questioning of his microscopic framework, informs his partner who will also proceed to a questioning of his microscopic framework. An exchange of information between partners follows, which can be compared to moments of negotiation, and leads to one or other of the variants presented. Thus, this process of questioning can have a symmetrical structure insofar as the two partners will conclude either by preserving their microscopic framework (variant a) or by reframing it (variant b). These cases appear, for example, during a situation where the BAT is lost in the apartment where they have to rescue a victim and regularly question their microscopic frameworks in order to know if they have taken the right path in relation to what the team leader is asking. This questioning leads either to the preservation of their respective frames (considering that they have taken the right path and that they are close to finding the victim) or to the search for a new frame (considering finally that they have taken the wrong path and that they must find another one).

This questioning can also present an asymmetrical structure (variant c) when, following a negotiation, one member of the pair preserves his microscopic frame while the other creates a new frame (re-framing). This situation arises, for example, during maneuver 1 when the BAL team member informs the BAL leader of his skepticism regarding the location of the supply division in relation to the location of the fire. The BAL Chief then reconsiders his action and moves the division in accordance with his teammate's remarks. The BAL leader therefore proceeds to refocus while the BAL team member preserves his initial microscopic frame.

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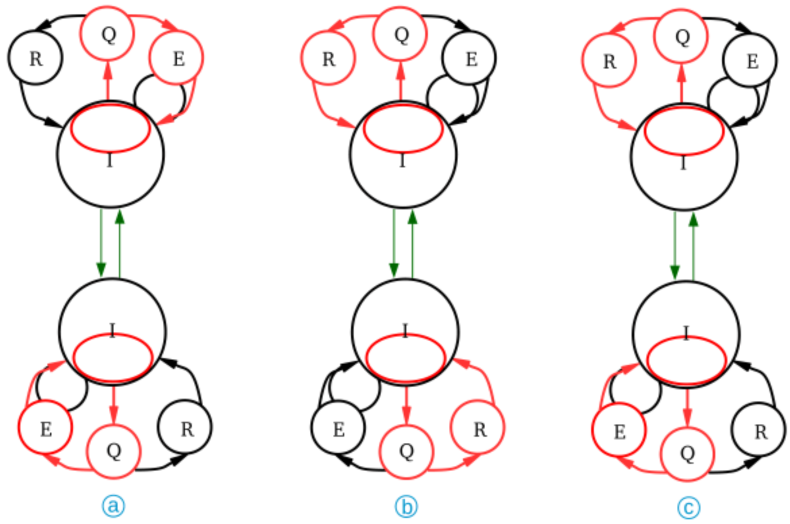

Figure 6. SAGA : Negotiation

4.2.4. Mission reassignment

The fourth structure of team sense-making relates to moments of transition where a pair reports the result of its mission and/or its availability to the team leader (Figure 7). The team leader takes advantage of these moments to elaborate his macroscopic framework by taking into account information on the state of progress of the maneuver that he is implementing. Following this process of updating, he further clarifies the mission to the teammate or transmits a new mission to him. This structure, illustrated by figure 7, appears six times in our data. For example, during maneuver 1, the fire chief finds the BAT when he leaves the smoke-filled building. The latter gives him an account of what they have done and also of the significant elements that they have noted. The fire chief then explains their mission, insisting on the ventilation of the building in order to evacuate the smoke.

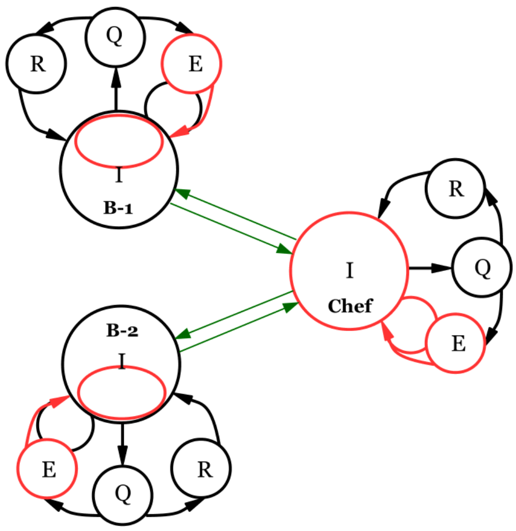

Figure 7. SAGA : Mission reassignment

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4.2.5. Team sense-making stand-by

This structure (present 12 times in the data) concerns moments of waiting for a pair (or a single agent) when the latter has finished his mission and is available. These moments without any specific function allow the agents to elaborate their macroscopic framework by taking into account the activity of the fire chief and/or the other team members in order to update their understanding of the situation. This sense-making is directly dependent on the spatial configuration of the team and the possibilities of interaction that it offers to the inactive agents. This is illustrated by maneuver 2, during which the BAL is left without an assigned mission for a long time. During the first four sequences, the two partners constituting the BAL proceed to an elaboration of their respective macroscopic framework by taking into account mainly information concerning the activity of the team leader to which they have regular access. However, this possibility of interaction is abruptly interrupted when the fire chief enters the truck to pass the ambient message. This interruption then prevents the BAL from any elaboration of its macroscopic framework. This process of elaboration on the part of the BAL resumes immediately the next sequence when the fireman gets out of the truck. This structure of team sense-making is illustrated by Figure 8.

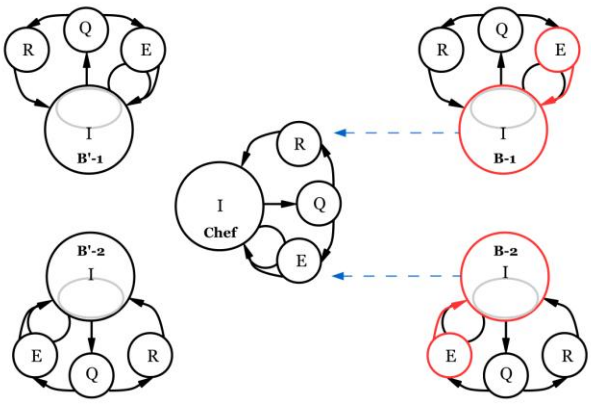

Figure 8. SAGA : Team sense-making stand-by

4.2.6. Team sense-making adjustment

The last structure of team sense-making (which appears only once) concerns a particular moment of questioning of the microscopic framework within a pair leading the partners to a process of reframing by comparing their microscopic and macroscopic frameworks (figure 9).

Although this structure cannot be considered as typical of fire fighters sense-making, it can constitute a significant element of the collective activity that can be directly linked to a risk of collective underperformance. Indeed, the assignment of a mission to a pair (or to a single agent) means that the latter will mainly focus on the construction of its microscopic framework related to its objective. However, during the execution of this mission, the detection of certain information relative to the global situation (thus entering into their macroscopic framework) is likely to no longer fit into their microscopic framework. This disturbance may provoke a questioning of the framework, leading to a reframing process by comparing the microscopic and macroscopic frameworks. This is what happens during maneuver 2 when the BAT returns with his equipment to the corridor leading to the apartment

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where the fire is located. At this point, the BAT's mission is to set up all the necessary equipment at the entrance to the apartment to attack the fire and rescue the victim inside. However, when he enters the corridor, he comes across the fire chief who is rescuing the witness who has been intoxicated by smoke. Taking into account this information, which is not related to their mission (microscopic) but to the situation as a whole (macroscopic), will create a disagreement in their understanding process. Indeed, the BAT leader and his teammate will stop all action (BAT teammate: "*So there, we see that the fire chief, he takes out the witness he had [...] Now we ask ourselves, should we give the fire chief a hand? Should we abandon our mission? So we didn't really know what was going on. That's why we're watching a little bit."*). The BAT will only resume its activity after the intervention of the trainers who will consider, within the framework of the simulation, that the witness has been rescued and that the fire chief can consequently give the executory mission to the BAT.

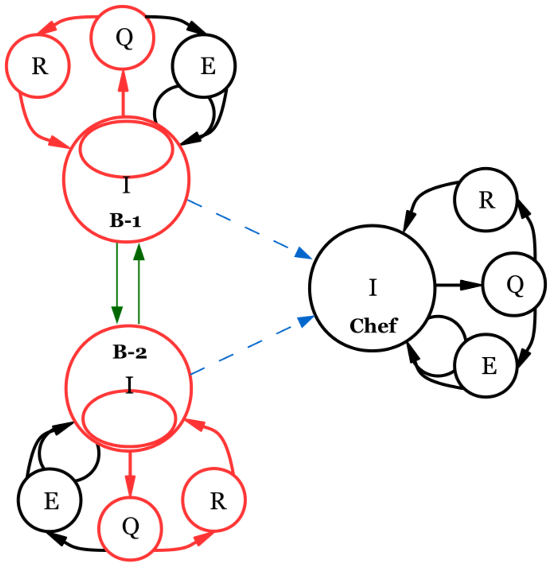

Figure 9. SAGA: Team sense-making adjustment

5. Discussion

The main objective of this study was to report on the collective activity of the firefighting team in a practical training situation. This analysis was concretized by the implementation of a representation mode (SAGA) intended to put in visibility the articulation of the individual activities according to the functional and spatial configurations of the collective. The results of our study will be discussed according to 3 axes: 1) The articulation of the two levels of comprehension of the situation to be trained; 2) Change of role and function to enrich sense-making at individual and team levels; and 3) Typical structures of team sense-making to be taken into account to design new simulations.

5.1The articulation of the two levels of comprehension of the situation to be trained

The functional diversity that characterizes the team results in each member understanding the situation according to his or her own objective, his or her own point of view. Indeed, by looking at the way in which each individual understands the situation and develops sense-making, we were able to highlight the coexistence of two levels of understanding within the collective: macroscopic and microscopic. Our results show that the team leader focuses exclusively on a macroscopic understanding of the situation. This aspect corresponds to his function, insofar as it requires him to understand the problem he is dealing with (recognition of the situation) and to deduce from it the missions he must entrust to his team members. In this way, from a personal point of view, he is rarely led to act directly on the situation, except on an ad hoc basis. Thus, his analytical work remains global with respect to the situation (type of incident, presence of victims, potential dangers, spatial context) and does not require an extremely "fine" understanding of the situation. Even if the specific and precise understanding of the elements of the situation characterizes more the activity of the crew members (BAT and BAL), our results show that all of them adopt both levels of understanding during a maneuver (macro and micro). The team members adopt a macroscopic level of meaning-making with respect to the situation until the team leader assigns them a specific mission. From then on, they turn to a microscopic meaning-making process specific to the situation (e.g., rescuing a victim, extinguishing a fire) and partial understanding of the overall situation. It seems relevant to support the team leaders in their ability to orient the activity of each team member according to their function and the level of understanding that this function requires (macroscopic or microscopic). For example, a trainer could guide the activity of the officer in charge of entering an apartment with the lance in order to find a victim. In the case of such a mission, the agent enters into a microscopic sense-making process related to a specific objective to be reached. This help could thus concern precise elements such as the safety measures to be put in place before entering a closed room and then the clues to be taken into account in the smoky environment in order to understand the configuration of the place. Simulation has a particular interest here again by proposing realistic and credible situations, training the agents to identify and share significant information specific to the situation in order to build a macroscopic understanding when it is necessary for the team. Thus, in firefighting teams, the sense-making of the situation is done in action, mixing an individual activity focused on the mission to be achieved and a social activity focused on the understanding of the situation from the team's point of view. Finally, the training could be improved by asking the trainers to insist on the back and forth between these two levels of understanding of the situation for each member of the team. The training would then allow for modulated learning alternating between personalization and homogenization.

5.2 Change of role and function to enrich sense-making at individual and team levels

The consideration of team sense-making as an articulation of individual sense-making allowed us to note its heterogeneous character. Our results show a disparity of individual sense-making within the firefighting team as well as levels of understanding of the situation. This heterogeneity results from the influence of individual functions because a firefighting team is characterized by the diversity of roles allocated to each of its members. Although these roles have a strong influence, they do not entirely substitute for the functions actually performed in the field. The case of the fire chief is different because role and function overlap insofar as his responsibility is to direct his team members in order to resolve the incident in progress, which is relatively generic to be transposable from one situation to another. However, as far as his team members are concerned, the function of each one depends on the mission entrusted to him by the fire chief. It is not uncommon, for example, for the BAT, theoretically intended to extinguish the fire, to be called upon to manage the water supply instead of the BAL (example in maneuver 3 of our present study). In this way, depending on the missions dictated by the fire chief, the intervention team can take on different functional configurations during a maneuver, thus influencing the understanding of the situation of each individual. This opens up an opportunity for training firefighting teams, since it is not only a matter of training them to take on the role specific to their function, but also of teaching them to change roles during an intervention according to the needs of the situation. The representations SAGA show here all their relevance because they help to build

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pedagogical scenarios in which the actors can train these adaptability skills through team sensemaking. Simulations offer interesting possibilities thanks to replay, individual and/or collective viewing (with the possibility of changing the point of view) to build a shared frame during debriefing sessions. Simulation allows learning by doing, being part of active pedagogies, where different relationships to the frame can be deployed. Thus, from a pedagogical point of view, it seems important that the trainers accompany the trainee fireman to pilot and manage the activity of his team throughout the situation. This aspect is already the object of interest in the training but in an informal way and always after the simulation activity (during the debriefing). Our study shows the importance of this team sensemaking skill, which allows us to recommend to simulation designers to fully integrate it into the scenarios and to make it a pedagogical activity in its own right.

5.3 Typical structures of team sense-making to be taken into account to design new simulations.

The heterogeneous nature of the collective construction of meaning also lies in the (im)possibilities of interaction in the environment. Alterations in the possibilities of communication (verbal or visual) constrain the members of the team because of the compartmentalized environments in which the teams have to evolve. According to the movements of each one during the maneuver, the team is led to present varied spatial configurations acting on the mechanisms of collective construction of meaning. It appears from then on "local" and "typical" structures of team sense-making. The configuration of the places, associated with the absence of remote communication devices (e.g. microphones), leads the members of the team to be able to communicate only with the people in the vicinity. We then observe "very localized" structures of team sense-making which take different forms according to the movements and the activity of each one. This phenomenon can be observed at different levels of the collective, either on a part of the team (e.g. a pair readjusting its understanding during its mission) or on its totality (the team leader who transmits information to the rest of the team gathered in the truck). Our results show regularities in the modes of coordination between team members leading us to identify 6 typical structures of team sense-making.

The team sense-making take a multitude of forms in the course of the missions entrusted to each pair (or team member) and of their movements within the environment continuously modifying the (im)possibilities of interaction between each individual. The set of typical structures of team sense-making that could be extracted contributes to constitute cycles of local coordination corresponding mainly to the activity of the two pairs and intermingling to constitute the global activity of the team during a maneuver.

From a pedagogical point of view and in the perspective of progressive learning, these environmental constraints could be overcome by equipping the team members with microphones. This would allow them to exchange important information at any time, overcoming the need to be in close proximity to communicate. This system would facilitate the collective activity of the team and could be a step before training situations without the possibility of exchanges other than in immediate proximity. From there, a certain progressiveness could be established by leaving all communications between the trainee team leader and his team members free, then by reducing them as the training progresses (e.g. limiting the number of communications during a situation or only authorizing calls initiated by the trainee team leader and prohibiting calls from team members). These pedagogical situations would allow to train team sense-making, an "embedded" phenomenon where the agents need to share very precise and specific information about the situation (e.g. "headwind" in the results). Locating this relevant information in the situation, which is similar to affordances, requires specific training that must be taken care of by the training of teams.

In conclusion, the model of team sense-making used in this work appears useful for describing and understanding the back and forth between action, its effects and the frame for acting in a dynamic situation. The consequences for training are interesting because it implies to favor an intuitive functioning in simulation enriched with affordances and a reflexive or rational functioning in the case of debriefing by exploiting the changes of point of view or the replay for example.

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