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# Analyzing the challenges of an assistive application' integration in a complex emergency interaction using a distributed cognition perspective.

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**Abstract:** Survival from on-street cardiac arrest is dependent on three factors: early recognition, CPR, and defibrillation. These three elements rely on a successful and complex interaction between a remote dispatcher and a bystander non-expert in on-site care. Digital applications have been developed to assist the bystander in performing the rescue procedures. This study focuses on the impact of introducing such an application on the already complex interactions between a bystander and a dispatcher. We performed cardiac arrests simulations and analyzed the results under the prism of distributed cognition. The results show that although the application helps the bystanders perform CPR, it disrupts an already complex interaction due to its characteristics; the distance and number of speakers can hinder the activity of the dispatcher while causing a feeling of loss of meaning and insecurity.

**Keywords:** OHCA, app, simulation, distributed cognition

## 1 Introduction

Approximately 55 out-of-hospital cardiac arrests (OHCA) occur for every 100,000 people worldwide each year [1]. Among these, only 7 to 10% survive [2,3]. The studies on the management of a cardiac arrest victim by a bystander<sup>1</sup> demonstrate that the earlier the cardiac arrest is recognized and thus the earlier the necessary rescue acts are performed (cardiac massage, defibrillation), the greater are the chances of survival [4,5]. These actions require prior recognition of the cardiac arrest by the dispatcher (operator of the emergency center) who is remote from the situation and has to acquire and identify the relevant information in a call with a non-expert person. Once cardiac arrest is identified, the dispatcher can engage the bystander to perform CPR as well as defibrillation, although the process is not seamless. Moreover, studies reveal that victims of cardiac arrest receive 10-40% of CPR and 1-18% of defibrillation by bystanders depending on the country [6,7]. This is why OHCA healthcare recommendations suggest using every available resource whether they be human and/or technological (apps) to improve these rates [5,8]. However, implementing an app in an already complex interaction may cause additional difficulties rather than providing actual help. In this paper, we investigate, through simulations of cardiac arrest management (on a training dummy) analyzed through the lens of Distributed Cognition theory, how information flows between the different actors, how they manage the imbalance of expertise and how an application impacts this information flow.

## 2 State of the art

### 2.1 Bystander assistance under the guidance of a dispatcher: a complex interaction

#### 2.1.1 Assessing the patient's condition

Research on emergency management situations highlights the difficulties healthcare professionals have in obtaining complete and adequate information [9–11]. The dispatchers dispose of a limited amount of time to carry out the assessment and to make a decision on the resources required as well as on the treatment to provide [12,13]. They frequently have to make a decision despite incomplete information, within a context of insufficient situation awareness. Individual situation awareness is defined as " 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 " [14]. Distributed situation awareness, when actors are separated "by distance, time or obstacles" is much more difficult to achieve since it requires an

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<sup>1</sup> A bystander is a person who witnesses an emergency and calls the emergency responders, but is not necessarily trained in emergency procedures.

understanding of roles, goals and an ability to determine what needs to be shared and how to prioritize information on both or more parts [15]. The collaboration between a dispatcher and a bystander is then particularly difficult, as the bystanders have neither a clear understanding of goals and procedures associated with OHCA nor any prior knowledge of the information to be shared [16–18].

### 2.1.2 Getting the bystander to perform CPR

As mentioned in the introduction, recognition of cardiac arrest is only one of the elements to increase a patient's chance of survival; the next step is to perform early CPR and early defibrillation. Once again, the dispatcher is the key element in initiating these actions [19]. However, few bystanders perform these procedures because they fear causing further injury to the victim [20–22]. To address the bystanders' lack of knowledge about CPR and consequently, the fear of hurting the patient, several digital applications provide the possibility for dispatchers to transmit videos of CPR demonstrations via the bystanders' smartphone [23]. A series of studies have been conducted and indicate positive effects on the number of CPR performed [24] and on its quality (rhythm, interruptions, position) [25,26]. While studies show a benefit on the bystander's side, this paper questions the addition of an extra application into the already complex activity of an OHCA regulation on the dispatcher side.

## 2.2 Distributed cognition framework

The paradigm of distributed cognition proposed by Hutchins [27-29] aims to explain the cognitive processes involved in the execution of tasks. He suggests that cognition is distributed between actors and artefacts, which together constitute a "unit of cognitive ecology". Based on the cognitive ethnography method, which includes an ethnographic field analysis (cultural dynamics) and an analysis of activity episodes, it allows the detailed description of distributed cognitive processes in terms of "information flows". Cognition is thus seen as a process of coordination of external and internal representations supporting an information processing system [30]. Hollan et al. [31] built further on this theory by suggesting that cognition could also be distributed across team members, multiple structures (internal and external), and within a given temporality. While this theory is widely recognized in the CSCW field, it is often criticized for its lack of operationality [32]. The DiCot model allows objectifying and analyzing a collaborative work situation according to the theory of distributed cognition. In 2005, in order to answer the criticism that this theory was not really applicable as an analysis method [33], the authors divided this theory into principles enabling the development of several situational models. Further details of the DiCot model are presented in the methodology section below. The distributed cognition gives access to a situational model in terms of "information flows" mainly based on the researchers' observation and on complementary interviews (and thus based on the individuals' behaviors). It permits to focus on a "unit of cognitive ecology" taking the global collective cognitive process as an object of study. It is possible to use a complementary approach to include the lived experience during interviews to deepen the understanding of the situation [34–36].

## 3 Methods

Healthcare experiments are recommended to be conducted in a semi-real context rather than in a real one since it might be dangerous for citizens and professionals as well as for the victim to experiment in a live setting [37]. Several authors recommend the use of simulations or scenarios to replicate emergency situations [38,39]. This paper focuses on testing an OHCA scenario involving all the real stakeholders (bystanders, first responders, dispatchers, paramedics).

### 3.1 Objectives and research questions

The objective of this study is to investigate the effects of the integration of an assistive application into an OHCA call. The aim is to understand if and how this technology articulates with the dispatcher's work in a semi-real context including the interaction's complexity factors: distance, stress for the bystander, time pressure for the dispatcher and multiple stakeholders. This paper proposes exploring three research questions embedded in a theoretical framework of distributed cognition:

- RQ1: How does information flow in an emergency call for a cardiac arrest?

The first stage is to identify the flow of information between the different participants (dispatcher, bystander, first responders, etc.) with various modalities; face-to-face, mediated Human/Human (telephone, radio, computer) and mediated Artefact/Human (application, defibrillator) to model the interaction situation in its ensemble. It is expected that the situation awareness might be poor and that the dispatcher might have to make decisions with incomplete information.

- RQ2: How does imbalanced expertise between bystander and health professionals affect communication?

To examine the actual effects of the application's integration in this complex interaction, other elements that might interfere in the interaction's progress also require analysis.

- RQ3: Does the application have any effect (positives or negatives) on the interaction and thereby on the treatment of OHCA?

Lastly, the analysis will focus on evaluating the impacts of using the application on several interactions. We propose to analyze significant elements from eliciting interview.

## 3.2 Protocol

### 3.2.1 Experimentation field and population

We collaborated with an Emergency Dispatch Center in Switzerland. The Center has been working with an application of first responders since three years (1500 volunteers). They are called in case of a life-threatening emergency such as cardiac arrest. The participants involved in this study were 2 dispatchers (noted D1 and D2); men, (50 years old), , 6 patient partner (noted B)<sup>2</sup>; 2 women and 4 men (45 to 75) 5 first responders (FR); men (30) and 6 paramedics (P), men (40).

### 3.2.2 Materiel

The application tested was developed in 2017. The application allows dispatchers to transmit to any bystander calling one video demonstrating the first-aid procedures: cardiopulmonary resuscitation (adult, child, infant) or Heimlich maneuver (airway obstruction in adults). In this study, we used the adult CPR video (Figure 1) consisting of a three-minute loop that provides help for the positioning for chest compressions, a sound for CPR pacing, visual support for performing cardiac massage and incentive messages.



Figure 1: CPR video

### 3.2.3 Methodology of the experiment

The 5 simulation workshops took place on 2 sites simultaneously: the dispatch center (dispatcher) and a park (bystander, first responders and paramedics). Bystanders were asked to take part on simulations using the application video with the following set point: “You find a 60-year-old man unconscious in a Park. You call 144<sup>3</sup> and follow the instructions the dispatcher gives you”. The bystander called the 144 center and the dispatcher assessed the victim’s state by audio. The patient turns out to be in cardiac arrest, therefore the dispatcher sends the video of CPR demonstration gestures. They then ask the participants to perform CPR on the training dummy until the paramedics arrive (8 minutes in the district of interest). first responders reach the participant at around the 6-minute mark. The simulations were followed by collective elicitation interviews with all participants per simulation (about 30 minutes). Elicitation interviews [40] are a particular interview technique that allows the interviewee to focus on their experiences and feelings during a particular event. The interviewer aims at deepening the lived experience and sensations while avoiding questions that lead to a rationalization of discourse [41,42]. This technique can be used with a single person or a group [43].

### 3.2.4 Data collection

All simulations and debriefing situations were audio recorded, filmed, and then transcribed.

## 3.3 Data analysis

Data was explored using Atlas, a software that allows for video, audio, and verbatim analysis. This was carried out in two stages: simulation films and audio as well as the verbatim from both the simulations and debriefings which were first coded in terms of the principles described by the DiCoT method (3.3.1). From this initial analysis, we selected key moments to be discussed in elicitation interviews (3.3.2).

### 3.3.1 Model Distributed Cognition for Teamwork (DiCoT)

DiCoT models allow researchers to analyze each element of a unit of cognitive ecology in terms of cognitive support (physical layout, information flow, artefacts and environments)[33]. These principles are described in Table 1.

Principle	Description
<b>Physical Layout</b>	
1: Space and Cognition	How information is presented in physical space
2: Perceptual Principle	The information is represented in a spatial environment or not (map)
3: Naturalness Principle	The representation of information matches its real form
4: Subtle Bodily Supports	Use of the body for cognitive support
5: Situation Awareness	Capacity to know the situation in real time.
6: Horizon of Observation	What the actor can see and hear in his direct field of view
7: Arrangement of Equipment	The layout of the equipment itself may change the individual’s perception
<b>Information Flow</b>	
8: Information Movement	Movement of information around the system
9: Information Transformation	Change of information (verbal/computerized/text)
10: Information Hubs	Grouping of diverse information to process them together
11: Buffering	Storage of certain information
12: Communication Bandwidth	Assessment of the communication media’s richness
13: Informal Communication	Importance of informal communication in completing the task
14: Behavioral Trigger Factors	Communication that is only intended to lead to action
<b>Artefacts</b>	
15: Mediating Artefacts	Artefacts used to collaborate
16: Creating Scaffolding	Artefacts created to support the activity

<sup>2</sup> “Partner patients” are former patients who have agreed to be contacted to participate in research protocols. They are not trained in first aid gestures.

<sup>3</sup> 144 is the Swiss Emergency number

17: Representation-Goal Parity	Artefact updating is status and representation along the evolution of the situation
18: Coordination of Resources	Resources (plans, goals, affordance, history, action-effect, current state) can be coordinated by the artefact to aid cognition

**Table 1: DiCoT principles (extracted from Blandford A, Furniss D, 2005)**

For this paper, the emphasis lies in analyzing the information flow with the addition of a new technological cognition tool. The first analysis (4.1) focuses on the description of the information flow principles and incorporates the physical layout and artifact principles in it. This primary analysis highlighted interest in conducting an in-depth analysis of the elements related to situation awareness (5), observation horizon (6), information movement (7) and communication bandwidth (8).

**3.3.2 Analysis of critical situations with explicitation interviews**

By combining our first analysis of the DiCoT and the verbatim of the debriefings, a selection was made in order to deepen significant moments in terms of cognitive and emotional processes from a subjective point of view. To perform the evaluation of the application's impact on the emergency call-taking activity, two categories were made: application related / non-related to the application.

**4 Results**

In this section, we will present a short description of the situation and analyze the information flow during the simulations. We will then analyze the effects of the interaction with a bystander on the handling of the victim of cardiac arrest and present the impacts of the use of the application on the process.

**4.1 A brief description of the situation**

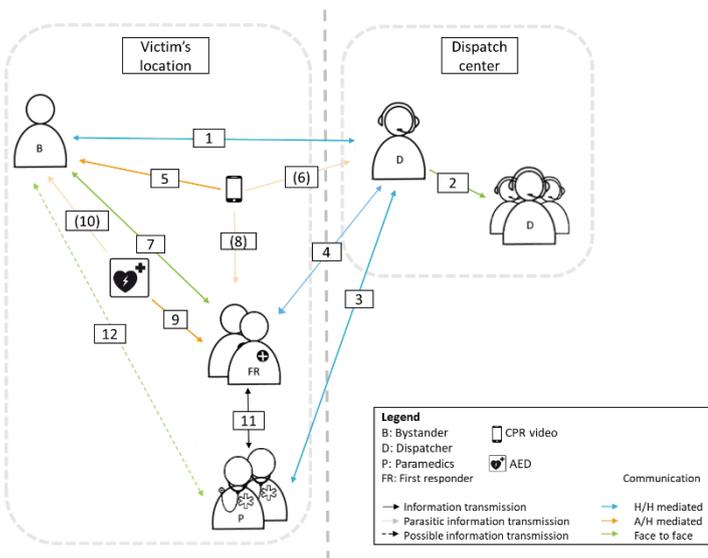
For all 5 situations, the process is as follows: the bystander(s) arrives and finds an inanimate training dummy and then calls 144. The dispatcher assesses the victim's condition by verbally guiding the bystander and then announces that it is cardiac arrest. The dispatcher calls an ambulance, the first responders, and sends the link for the application video. The bystander opens the video and begins cardiac massage; they are joined at around 5 minutes by the first responders who bring a defibrillator. The simulation ends when the paramedics have taken full control of the situation.

**4.2 Information flow (RQ1)**

**4.2.1 Descriptive Information Flow**

In the victim's location, the physical layout was similar to a cardiac arrest situation. As all interveners surround the victim and have both the ability to observe and hear anything happening in the area, principle 5 (situation awareness) and 6 (horizon of observation) are optimal. The different responders can also communicate directly verbally and non-verbally (through visual contact or gestures) allowing for subtle bodily support (principle 4). The dispatcher is at their dispatch center in another part of the city and can only communicate face-to-face with the others dispatchers. The interactions between the participants are described in Figure 2 and their number corresponds to the chronology of the interactions. The details of the content of these interactions are shown in Table 2.

**Figure 2: Information flow**



ID	Information movement description
1	Phone and computer interactions between the dispatcher and the bystander, assessment of the victim.
2	On site, face-to-face communication. The dispatcher informs the emergency center when cardiac arrest is identified.
3	Radio and computer communication between the dispatcher and one paramedics unit to ask them to go on the site.
4	Computer interaction between the dispatcher and first responders.
5	On site, CPR video instructions given to the bystander via the application.
6	The dispatcher overheard on the phone the instructions of the video.
7	Face to face, on-site, communication between first responder(s) and the bystander (about AED)
8	On site, first responder(s) overheard on the phone with the CPR video.
9	On site, audio instructions given by the defibrillator.
10	On site, the bystander overheard the AED instructions.
11	On site, face to face, paramedics exchange information with first responder(s).
12	On site, face to face, paramedics exchange information with the bystander.

**Table 2: Description of information paths**

Interactions and information flow are face-to-face between bystanders, first responders and paramedics (7, 8, 9, 10, 11, and 12). Interactions between the dispatcher and other participants is always mediated, by telephone, radio or computer (1, 3, and 4). The use of two technological artifacts brings additional mediated information that is sometimes necessary (5, 9) and sometimes disturbing (6, 8, 10). From an information bandwidth point of view (P12) indicating that information given face to face is richer than mediated interactions, only on-site participants are able to have such communication while the dispatcher, who acts as the information hub (P10), has the least bandwidth communication. As an information hub, they should be the one who has the maximum amount of information but it is dependent on the information transmitted by the bystander that may be inadequate or incomplete and on technologies (with varying degrees of reliability). On the other hand, the communication on victim's site is indeed direct and verbal between the participants, yet it is blurred by the amount of information arriving at the same time. As more people and artifacts are brought in, the amount of information is multiplied simultaneously, making it difficult to identify the most important information. The information in 7, 8, 9, and 10 is actually associated and non sequential. The most critical information comes from the defibrillator (9), which instructs participants to conduct a heart rhythm analysis and to perform a defibrillation if it is possible. It was found during the simulations that participants did not actually hear this instruction because there is no possibility of buffering (P11). This situation will be developed in the latter section.

#### 4.2.2 Information transformation

Only the dispatcher performs transformations of the information. They receive raw verbal information from the bystander, perform a filtration of the relevant elements (location, age, gender, condition of the patient) and then enter this information into the engagement aid system which indicates the next step to follow (assessment of the victim's condition, engagement of resources). Each processing of the information leads the dispatcher to request to perform an action, to trigger one behavior of the bystander (P14). The dispatcher is the one knowing the overall plan and must lead the bystander to carry out this plan systematically by analyzing, updating, and implementing the elements previously achieved.

### 4.3 The bystander as an informational source with varying degrees of reliability (RQ2)

Following the principles of physical layout outlined in Dicot, it would appear that the spatial layout and the way in which the information is represented allows the dispatcher to reach an important awareness situation while reducing the cognitive effort required to take in the information. Indeed, the system used by the dispatcher is conceived in order to optimize the principles 2 (perceptual principle), the information is displayed by order of priority and by color, 3 (natural principle), the ambulances are represented as an ambulance icon which moves on a map and 7 (arrangement of equipment), all the information is accessible directly in front of the dispatcher. Therefore, one could think that the situation awareness (principle 5) and the observation horizon (principle 6) are also optimal. However, while this is the case in terms of being aware of the activities occurring in the district, it is less so when monitoring the intervention. Only one screen (screen 1) is dedicated to the current intervention, the information available to the dispatcher is the location (with map) and the information provided by the interveners on site. The awareness situation relies entirely on the bystanders, first responders, or paramedics because the dispatcher's horizon of observation is very limited. They cannot see what is going on and may only be able to hear. In the intervention situations, the dispatcher is the lead with the bystander; he is the one who has the resources (computerized procedures, access to paramedics, etc.) and knowledge on how to act on the victim. However, he also has the least visibility on the situation.

#### 4.3.1 Incompatibility of "what to do next" representations

In order to assess the victim's status, dispatchers use the Swiss triage scale as a "*code that corresponds to a pathology, a degree of urgency and a destination*" (interview with dispatcher 1). This scale enables the assessment of the patient with the help of decision support schemes, "*you see the call in the form of answers and questions*" (D1). The answers to the questions allow the dispatcher to categorize the pathologies ("*cardiac arrest, chest pain, tachycardia, rhythm disorders, hypertension, hypotension*" D1) classified by systems (nervous, cardiovascular and respirator). This assessment procedure leads to the diagnosis of the patient's condition by asking different questions and different actions to be taken by the bystander:

- Are they conscious? Pinch them gently on the back of the hand
- Are they breathing? Place your hand on their belly and say "top" every time it rises.

At this point, the dispatcher and the bystander share the same final goal: to save the patient, but do not follow the same steps. The dispatcher follows a clear plan (displayed concretely on their screen and abstractly in their memory) which requires validating steps, meanwhile the bystander remains unaware of this procedure. Therefore, the bystander finds himself in a certain incomprehension caused by the lack of knowledge of this plan and leading to frustration as described by a bystander: "*I personally wanted to go faster because there are things that I know need to be done fairly quickly, but it is true that I could hear 144 asking me questions on the other end of the line and sometimes I got ahead of them a little bit*" (interview with Bystander 2 B2). It can also lead to inaction or error. The deficit of situational awareness is on both sides; the bystander does not have the mental representation of the plan that the dispatcher is following and the dispatcher has no visibility on the actions performed by the bystander. It may become a major obstacle in terms of treating the patient since it leads to a loss of time and quality of care for the victim.

### 4.3.2 Incomplete information transmission

The dispatcher needs to have the most accurate representation of the situation before making a decision. This picture is filled with information provided by the bystander. Yet, there are times when the bystander omits to report crucial information that influences the dispatcher's choices. In one situation, there were two bystanders; B3 calls 144 while B4 is already performing CPR on the training dummy. B3 doesn't say that the massage has already started and the video does not work. This poses two problems, the cardiac massage given is not very effective and the dispatcher does not have update on the situation. They will explain in the debriefing *"It was a little difficult for me to visualize the situation because I thought [B3] was all alone initially. I had no notion that there was already someone who was doing CPR. Above all I didn't know that the video didn't work, unfortunately, and I could have guided you instead of the video"*. The partial and false information affects the choices that the dispatcher makes (to not verbally guide CPR and not sending B3 to get an AED) since ha has a distorted representation of what's really happening. The loss of information is detrimental to the treatment of the patient who receives an unguided CPR of lower quality.

## 4.4 Effects of the application implementation in the process (RQ3)

### 4.4.1 Benefits for the bystanders

The goal of the application is to help bystanders perform CPR, but in concrete situations. However, its implementation leads to several difficulties. For the bystander, it is indeed *"good input"*, a *"help"*, a *"stimulation"*. Participants commented on how seeing the video made them correct their position and as a result press harder on the chest. Moreover, having a sound to indicate each compression and the seeing a person performing a massage helps participants to synchronize with the video and find the right rhythm; *"I heard the beep, that's when I saw that I had to go much faster"* (B4). Another noteworthy effect was the reassurance gained from the video's inclusion in a complex and stressful situation: *"I was happy to have a link, to be able to see it"* (B1), *"it added something comforting to us"* (B3), *"I felt well supported, even encouraged"* (B5).

### 4.4.2 Dispatcher uncertainty over whether CPR is performed or not

The implementation of the video provokes a deterioration of the dispatcher' awareness and horizon of observation. It may affect communication or the performance of CPR itself. When the video starts, it takes the lead over the dispatcher. This can be explained by the fact that the communication between the bystander and the application is richer, it is more direct and provides two indications; both visual and audio whereas the dispatcher is speaking over the same channel as the video, they have no visual feedback and the bystander does not see them. Interaction then shifts from 2 speakers to 3 speakers. However, the application is unable to monitor if the cardiac massage is performed or not and prevents the dispatcher from talking to the bystander who can be overwhelmed by the amount of information received. As can be seen in situation 3, the communication breakdown between them. The dispatcher tries to maintain the link, but the bystander cannot respond.

#### Situation 3

B5: I can't hear you

D3: Are you massaging?

**[B5 doesn't respond but is performing CPR]**

D3: Are you still with me, madam?

D3: Do you have people with you madam?

D3: Madam, I understand that there are two first responders with you, is that correct?

The communication was reestablished only when the first responders arrive and take the lead over the application, perform CPR and defibrillation. Only then, the bystander was able to take back the phone and answer the dispatcher. This absence provokes uncertainty for the dispatcher who expressed in the later debriefing *"I was not convinced that the massage was there, that it was going well. I didn't have the feedback at all. [...] it was total uncertainty."* (D4) He feels that *"this loss of communication was damaging for [the bystander] as well as for [him], and maybe for the patient too"* (D4). In this instance, the awareness situation appears to be null because the only source of information is unavailable. In situation 4, the dispatcher's awareness is distorted by the bystander' answers. The dispatcher thinks that the bystander is massaging while following the video, which would allow them to perform an effective massage because the bystander answers "yes". However, the bystander did not start the video and the dispatcher has no means of knowing this.

#### Situation 4

D4: Okay, you do exactly as in the video. You put the phone in front of you and you do exactly as in the video.

**[B6 doesn't press play on the video]**

D4: Do you see the video sir?

B4: Yes

D4: Okay, so arms straight out and decompress at least 5 cm.

D4: Follow the video; you do exactly as in the video.

**[B6 perform a weak cardiac massage but doesn't follow the video]**

D5: Are you doing CPR, sir?

B6: Yes

At this point, everything leads the dispatcher to believe that the cardiac massage is done well, especially since, as they will specify during the debriefing, the video is launched on their computer, leaving them to believe that it is running on the bystander' side. The dispatcher explains *"the problem is that, as not seeing what is happening on the ground, having audio feedback from the application, here, we think that the person on the spot performs 100% what is projected on the video"* (D5). The dispatcher then specifies that launching the video undermined their role while creating a false sense of reassurance: *"Ultimately, it completely misled me. I thought they were doing the massage, they have the video, they are going to do it by mimicry. That's not the case at all"*. The dispatcher's awareness situation is already non-ideal in a "normal" intervention since they are the only one who is not on the scene and cannot see what is going on, but the addition of a tool, that is not necessarily reliable, will further deteriorate this essential element.

**4.4.3 Information blurring**

Interveners (bystander and first responders) can be overwhelmed by the amount of information they receive, which may lead to an error. Figure 3 displays the various types of information transmitted during a period of 2 minutes and 15 seconds. This sequence took place 5'45 after the beginning of the simulation. Before that, the bystander (B) had started CPR while following the video and then switched over to the First responder (FR), which then arrived with the AED.

	5'45	6'	6'15	6'30	6'45	7'	7'15	7'30	7'45	8'	
B	Tries to apply the defibrillator patches									Success	Performs CPR
						"Here ?"			"Is that ok ?"		
FR	Performs CPR									Relay CPR	
	"you will put the patch right under my hand"	"Turn it over"	"On the other side, turn it"	"Great ! The other patch here"	"On the other side"	"The blue must be lowered a little more "	"The other way the other way"				
SARA	" Don't stop massaging"	" Press with the heel of the hand, as on the drawing"	« Arms outstretched, press as hard as you can".	"You are effective, release the chest completely"	" You are doing very well, rescue is on its way "	« Press hard on the chest".	" At the top change the masseur"	« Top change masseur"			
	C o n s t a n t m e t r o n o m e										
AED	"Adult patient, if the victim is a child, press the child button"	"Tear the clothing to expose the victim's bare chest."	"Tear the clothing to expose the victim's bare chest."	" Remove the packaging from the electrode "	« Apply defibrillation electrodes to the patient's chest"	« Apply defibrillation electrodes to the patient's chest"	« Apply defibrillation electrodes to the patient's chest"	« Do not touch the victim, analysis in progress".			

**Figure 3: Information blurring between participants and technologies**

Figure 3 shows that over a period of 2 minutes, the defibrillator and the application provide 8 verbal instructions each. The first responder gives 7 instructions and the bystander replies 2 times. Additionally, during the entire time, the video is paced with the CPR with a constant beeping sound. The first responder and the defibrillator give similar instructions, but the first responder is slightly ahead of the defibrillator, suggesting that he does not pay attention to the instructions given by the latter. Indeed, he was massaging exactly on the rhythm given by the video, which seems to suggest that his attention was at least partly focused on the application. The other part of his attention was on instructing and correcting the bystander attempting to place the defibrillator patches. The bystander who has to perform an unknown task in a stressful situation receives 23 instructions in 2 minutes, most of them simultaneously. The fact that she changes the patches according to the feedback from the first responder indicates that her attention is focused on him rather than on the technologies. Once she has successfully applied the patches, her attention is redirected to the application, which at that very moment indicates "At the top switch to another masseur". The first responder also seems to have heard this instruction because at 8', they switch. However, they both miss the most important instruction *"do not touch the victim, analysis in progress"*, which will prevent the release of the victim's electric shock. During the debriefing, the first responder explains what he found difficult: *"the confusion you can have between the defibrillator and the video. Because me, every time I massage, I try to count with the defibrillator and I was waiting for 'next analysis in ...' to stop and instead I would hear a voice saying 'keep massaging', I thought it was the defibrillator"* (FR2). Moreover, the sometimes contradictory instructions of the dispatcher, the video, and the defibrillator lead to a conflict for the interveners, especially novices: *"who do we let go now? Should we drop the video? Should we listen to the defibrillator? Without any training at all, I think we can be a bit lost."* (FR2) It appears there may be a conflict in the prioritization of information and resources, as tools should not be additive, but should rather replace each other. However, the application is managed remotely by the dispatcher who has poor awareness of the situation, not always allowing them to realize that the video should be stopped.

**5 Discussion**

As shown above, emergency-call-taking situations are particularly complex interactions because they include several stakeholders with different levels of expertise and are carried out in a very limited amount of time under stressful conditions. Dicot's model allows for capturing the complexity of this interaction by modeling the different flows of information.

However, using complementary explanatory interviews made it possible to document specific confusing and stressful moments experienced by the participants that would not have been detected otherwise.

## 5.1 Recommendations

This section will discuss the results of the study by reviewing the research questions in recommendation form.

### 5.1.1 Reducing the number of simultaneous information channels to improve information transmission (RQ1)

Our first research question concerned the flow of information in a cardiac arrest call, and we wanted to investigate the information flow between the different participants and modalities. We found that it was difficult to gather relevant information not only because the dispatcher is remote as suggested in the literature [9, 11] but also because of the number of interaction channels. The results show that in an 8-minute interaction, there are at least 4 people on site, 2 artefacts and 1 remote person (the dispatcher). Information flows through 12 different channels (live verbal, verbal on the phone, face-to-face, overheard, technological artefact to human) simultaneously and non-sequentially. As a result, the dispatcher who is the only one at a distance, but who acts as the lead, loses information and effectively makes decisions even when they do not have all the elements in hand and they are lacking of situation awareness [14, 15]. The first recommendation is to reduce the information channels to maximize the chances that the dispatcher and the responders can hear the relevant information. It would be beneficial to sequence the tools rather than adding them on top of each other. It could be integrating the communication channels so that the application is silent when the dispatcher is talking and that the sound of the application is muted when the defibrillator is on, as well as giving the dispatcher feedback on the sound of the defibrillator so that he can modulate his interventions.

### 5.1.2 Giving visual feedback for the dispatcher (RQ2)

Several situations revealed that the bystander did not know the procedures and therefore did not understand the correct action to take. Nevertheless, the dispatcher did not express any reluctance to rely on them, contrary to what is reported in the literature. Instead, the bystanders expressed frustration that they were not moving fast enough. In addition, their lack of knowledge of the procedures also leads to an omission of certain information such as the number of people present, which further deteriorates the visibility and awareness of the dispatcher. In order to improve upon this, it is possible to implement an application in the interaction that allows the dispatcher to have visual feedback on the situation. Several studies have shown that this significantly increases visibility and saves time in the care process [44,45].

### 5.1.3 Using the application only at the key moment of CPR if there is video feedback (RQ3)

The third research question hypothesized that the addition of explanatory interviews would provide insights into difficulties that could not be captured by the Dicot model. The findings indicate that the application helps the bystander perform CPR in consistency with other research findings [24] by helping them with their pace and position [25,26]. Nevertheless, we found out through the exploratory interviews that using SARA video has a negative effect on the dispatcher's experience as they no longer know if CPR is performed or not. The dispatcher feel substituted by an artefact and therefore suffers from a lack of control over the situation, which causes them to feel insecure. As the intention is not to replace the dispatcher by an artifact but rather to assist them in their activity, it appears that for the time being, the application drains the dispatcher's activity whereas the dispatcher has no confidence in it. This valuable element didn't appeared either in the analysis with the Dicot or in the literature. Therefore, it seems beneficial to use the two methods in a complementary way.

## 5.2 Limitations and perspectives

One of the limitations of this work is that it was a biased simulation where a new tool was added to a standard simulation to which neither the bystanders nor the dispatchers had been trained. Furthermore, the simulations were carried out in the context of Heart Day and the participants were sensitive to the cause. Therefore, it was impossible to confirm or deny the willingness of each participant to perform cardiac massage since they all agreed from the start. The small number of participants also constitutes a limitation. Consequently, our future work will focus on diversifying the situations to address this bias while adding a visual feedback tool for the dispatchers to improve upon their awareness. We will also focus on the links between information flow and the actor's behaviours (errors, regulations, efficiency of safety gestures, etc.).

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