6-18-2022

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THE IMPACT OF IT ON TEAM SITUATIONAL AWARENESS DURING IN-HOSPITAL CARDIAC ARREST INTERVENTIONS: IMPLICATIONS FOR TEAM COORDINATION

Research Paper

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Abstract

Effective team coordination during in-hospital cardiac arrest interventions is central to improving treatment outcomes. However, research highlights many obstacles to effective coordination during resuscitation attempts, including communication breakdowns and lack of information sharing. These factors are also associated with degradation in team situational awareness. Furthermore, resuscitation teams must interact with many IT to provide adequate treatment. While IT use supports the creation of task-oriented knowledge, the extent to which it enables shared knowledge and team situational awareness is not clear. Our study reveals that IT promotes team situational awareness in two ways: by providing shared access to information, and by aligning members' higher-level situational awareness. However, some team-oriented processes may be hindered by IT featuring high data density and detailed information displays. Our results contribute to IS literature on team coordination by revealing the role of IT in enabling team situational awareness and coordination in dynamic and complex environments.

Keywords: IT, situational awareness, resuscitation, team coordination.

1 Introduction

Despite significant advances in resuscitation science over the past decades (Husselbee, Davies, & Perkins, 2009), the prognoses for in-hospital cardiac arrest patients are poor, with survival rates of 15-20% (Kolte et al., 2015; Sandroni, Nolan, Cavallaro, & Antonelli, 2007). While the importance of high-quality cardiopulmonary resuscitation (CPR) for increasing survival chances is well-documented (Abella, Alvarado, Myklebust, & Al., 2005; Chan, Krumholz, Nichol, Nallamothu, & Investigators, 2008), evidence suggests that the quality of CPR interventions in clinical practice is often suboptimal (Leary & Abella, 2008; Ornato, Peberdy, Reid, Feeser, & Dhindsa, 2012). Studies have explored causes for substandard performance of cardiac arrest teams, leading to increased attention to the importance of team processes such as communication, leadership, planning and information sharing during CPR interventions (Andersen, Jensen, Lippert, & Østergaard, 2010; Chalwin & Flabouris, 2013; Ornato et al., 2012).

Effective team processes in healthcare are crucial to patient safety, since they enable health professionals to work together towards common goals (Boos, Kolbe, Kappeler, & Ellwart, 2011; Castelao, Russo, Riethmueller, & Boos, 2013). In the case of in-hospital CPR interventions, the main goals are diagnosing the cardiac arrest, oxygenating the brain, and restoring spontaneous blood circulation (Tschan *et al*., 2011). Consequently, resuscitation teams must manage a wide range of interdependent tasks through planning, team communication, task delegation, and information sharing, and maintain awareness of events as they unfold (Castelao et al., 2013). Furthermore, team members must acquire and use information a range of information technologies (IT) in order to comprehend the situation at hand and effectively coordinate interdependent tasks (Müller, Kristensen, Lauridsen, Zwanenburg, & Løfgren, 2021). The process by which teams acquire information (whether from IT or individual team members), make sense of its meaning, and use it to achieve a common situational perspective is referred to as team Situational Awareness (SA). Team SA can be of two types: (1) complementary SA where team members possess individual, non-overlapping SA, and (2) shared SA where they share the same knowledge and SA (Cooke, Stout, & Salas, 2017). Complementary SA is beneficial to team performance, since it allows team members to work more efficiently in situations characterized by high workload, while shared SA allows for coordinated action, which is particularly important in new and ad-hoc situations (Cain, Edwards, & Schuster, 2016).

Team SA is a critical factor in effective CPR, since it can impact team decision-making, CPR quality and ultimately, patient outcomes (Hunziker et al., 2011; Klein, 2000). However, resuscitation teams often struggle to achieve situational awareness necessary for effective teamwork. First, achieving a shared situation comprehension is challenging, since members of a resuscitation team often have little familiarity with each other (Patterson *et al*., 2015). Furthermore, resuscitation teams are cross-functional and cross-disciplinary, and vary in terms of size and composition (Lauridsen, Schmidt, Adelborg, & Lofgren, 2015). Research shows that the more heterogeneous teams are, the more likely members are to have different mental models and arrive at different situation comprehensions based on the same information (M. Wright & Endsley, 2008). Nevertheless, resuscitation teams also interact with many task-oriented IT and medical devices, e.g. vital sign monitors, defibrillators, electronic medical records (EMR), mobile computers smartphones, most of which are not designed to support team processes and the coordination of interdependent tasks. While such technologies may support task-oriented knowledge and enhance individual SA (Müller et al., 2021), whether or how IT use promotes the development of team-oriented knowledge and shared SA in CPR interventions is less clear. There is therefore a need to study the interplay between IT use, team SA and team coordination processes. Against this backdrop, we address the following research question:

How does IT use impact team situational awareness during cardiac arrest interventions, and what are the implications for team coordination?

To answer this question, we draw on an observational study of cardiac arrest interventions at a Danish hospital. Based on video data of in-hospital cardiac arrest events, we explore IT use patterns, information sharing behaviours and communication processes in order to reveal how IT use influences team SA and coordination processes during cardiac arrest interventions. For our aim, we conceptualize IT artifacts as non-human actors with information processing capabilities that are partial, provisional, and embedded in complex and dynamic social contexts (Orlikowski & Iacono, 2001). This conceptualization allows us to focus on the performative interactions among individuals, and between individuals and IT the artifacts in their environment, which reflect how team SA is built in practice. Our study reveals that while IT use generally enhances individual and complementary SA, IT use may hinder team processes necessary for shared SA and team coordination in dynamic and unpredictable environments.

2 Theoretical background

In this section, we first discuss literature on in-hospital CPR from a team coordination perspective. Thereafter, we review the concept of team SA, and discuss the role of IT in team SA and team coordination.

2.1 CPR as a teamwork process

In-hospital CPR is the practice of providing life support to hospitalized patients in case of sudden cardiac arrest. The procedure is initiated by ward personnel, who provide basic life support (BLS) to the patient while summoning the resuscitation team to take over advanced life support (ALS). Once arriving at the cardiac arrest location, the resuscitation team is required to adhere to a specific set of guidelines. The guidelines define best practices for CPR, including diagnosis, chest compressions, airway management, cardiac rhythm analysis, defibrillation, and drug administration following a standardized algorithm, where even small deviations may decrease survival chances (Laxmisan et al., 2007). Therefore, resuscitation teams must enact a wide range of time-critical, interdependent tasks based on imperfect information. Delivering quality CPR depends on both technical skills, i.e. the "adequacy of the actions taken from a medical and technical perspective", and on non-technical skills, or the "decision-making and team interaction processes used during the team's management of a situation" (Gaba *et al.*, 1998, p. 9).

Non-technical skills comprise a set of cognitive and interpersonal attributes that augment technical skills and contribute to care quality (Riem, Boet, Bould, Tavares, & Naik, 2012). During CPR interventions, desirable non-technical skills include communication, leadership and planning – all of which enable the team to maintain a clear overview of roles and unfolding situations (Chalwin & Flabouris, 2013; Fernandez Castelao, Russo, Riethmüller, & Boos, 2013). However, these skills are not only important in their own right. Rather, they are interrelated mechanisms that impact team SA (Hunziker et al., 2011), and influence the overall coordination of interdependent tasks (Fernandez Castelao et al., 2013). To that effect, leadership behaviour, communication and planning serve as vehicles for information sharing, clear task delegation and shared role overview – all of which enhance team SA and coordination. Effective coordination, in turn, facilitates seamless transition between interdependent tasks, which is the hallmark of effective CPR interventions (Fernandez Castelao et al., 2013).

Because team coordination and CPR quality are intricately linked, a promising way to improve CPR quality is to enhance health professionals' non-technical skills, focusing on human factors. Previous initiatives to improve CPR quality have included crisis management training (Fernandez Castelao et al., 2011, 2013) and adding a member to the cardiac arrest team dedicated to coaching chest compressions (Cheng et al., 2018). However, all CPR interventions are inevitably non-linear and unpredictable. Resuscitation teams are often faced with new situations and need to act decisively, often with imperfect information or large amounts of data from which it is difficult to extract relevant information. Yet, accurate, precise, and timely information sharing among team members and between team members and IT is essential to effectively coordinate interdependent tasks as part of resuscitation teamwork (Müller et al., 2021). While indispensable for retrieving task-oriented information and for the performance of specific CPR tasks, IT may impede certain team-oriented processes such as communication and cross-functional collaboration (Woods & Sarter, 2010). To begin addressing these issues, it is therefore important to better understand the interplay between IT and team SA. In particular, exploring the impact of IT on team SA should inform the development of IT that augment team cognition and facilitate dynamic decision-making in CPR interventions.

2.2 IT, SA and team coordination

Situational awareness (SA) has long been recognized as an important aspect of effective healthcare processes (Stubbings, Chaboyer, & McMurray, 2012; Melanie Clay Wright, Taekman, & Endsley, 2004), since it relates directly to cognitive and behavioral capabilities required by complex, dynamic environments (Lowe, Ireland, Ross, & Ker, 2016). SA, as defined by Endsley, is "the perception of elements on the environment within a volume of time and space, the comprehension of their meaning, and their projection of their status into the near future" (Endsley, 1995, p. 36). This definition suggests three interrelated levels of situational awareness. At the most basic level, SA is achieved when an individual perceives the elements in her or his environment. This commonly involves gathering data and information from multiple sources, including IT and other individuals. Acquiring a basic perception of one's environment is the precursor to comprehension, otherwise referred to as level 2 SA. Comprehension requires information synthesis, interpretation, and prioritization in order to create an understanding of the current situation (Rosenman et al., 2018). The highest SA level is achieved when the individual, based on the acquired information and comprehension, is able to project future states and scenarios. This involves predicting one or more possible trajectories to allow for contingency planning and anticipation (Rosenman et al., 2018). While the levels are interrelated, they are not necessarily sequential. Rather, the levels should be understood as ascending stages of situational awareness, where each level may underlie action (Endsley, 2015). Therefore, decision-making and action do not necessarily require that an individual possesses the highest SA level.

SA is indispensable in dynamic work environments characterized by high levels of uncertainty and situation variability (Rosenman *et al*., 2018), such as CPR interventions. Klein (2000) argues that SA is directly related to work performance, since the more information an individual possesses about the environment, the more adaptive he or she is when faced by new situations. Furthermore, SA is related to expertise, since attention to and comprehension of one's environment is key to handling a broad range of situations. Additionally, lack of information and its negative impact on SA is may lead to work-related errors.

However, research to date has predominantly focused on identifying SA characteristics related to individual cognitive and behavioral processes, and less to the team cognition and collaboration aspects of teamwork (Melanie C Wright & Endsley, 2017). When considering team SA, another layer of complexity is added. Beyond achieving individual SA, team members need to act interdependently with one another (Stanton *et al*., 2017). Team SA can be of two types: (1) complementary SA, in which team members possess individual, non-overlapping SA, and (2) shared SA, where they share the same knowledge and SA (Melanie C Wright & Endsley, 2017). Many aspects of teamwork processes require shared SA. Shared SA requirements are a function of the interdependencies between the tasks of individual team members. For example, in a resuscitation event, different team members have specialized functions and work with specific IT, for which they have unique SA requirements. If present, an anesthesiologist will most likely provide advanced airway management (using e.g., a video laryngoscope), while a cardiologist may be in charge of cardiac rhythm analysis or echocardiography (using e.g., an ECG). Yet, the anesthesiologist and the cardiologist must also operate on commonly held knowledge of what CPR interventions entail, and what the expertise and role of the other are. Furthermore, the tasks performed by the anesthesiologist will have a direct impact on the perceptions, comprehensions and actions of the cardiologist, and vice-versa (Melanie C Wright & Endsley, 2017). It is such interdependences between team members that require shared SA. A high level of shared SA enables team cognition and is a precursor to effective team decision-making and coordination in complex and dynamic environments.

While the popularity of SA as a theory to explain team dynamics continues to rise, debates have emerged on where SA "resides". Is it "all in the mind" (i.e., a cognitive process), can it be externalized and embedded in IT and artifacts, or is SA a function of the interaction among individuals, and between individuals and IT and artifacts in their environment? (Stanton *et al*., 2010). When considering the many medical devices and IT resuscitation teams interact with, the premise for this study is that SA is achieved by integrating multiple IT, artifacts and communication processes that provide teams with access to situational information. The arising need is thus to understand the interplay between IT use, team SA, and team coordination. Yet, only limited research has empirically investigated this topic. Nevertheless, the notion has been debated at a theoretical level. From a socio-technical perspective, Stanton et al. (Stanton et al., 2017) posit that technological artifacts have some level of SA, in that they hold contextually-relevant information. To that effect, task-oriented knowledge is activated when individuals interact with IT. While not dismissing the impact of IT on SA, critics argue that IT may be detrimental to SA altogether. For example, Woods and Sarter (2010) argue that new IT capabilities create new challenges for SA, since they create coordination demands on individuals working together to "keep track of more interconnected processes and introduce new difficulties in assessing and anticipating how highly interconnected situations will evolve or cascade" (p. 9).

These theoretical works suggest that through their role in team and individual awareness and cognition, IT artifacts have the potential to enhance or to hinder team coordination processes in complex and unpredictable work environments. This observation is aligned with most IS research on IT and team coordination, which suggests that team coordination can be both enabled or restricted by the use of IT artifacts, which are sometimes used in different and novel combinations to suit the emergent needs emergent of teams (e.g., Beane & Orlikowski, 2015; Claggett & Karahanna, 2018; Kanawattanachai & Yoo, 2007; Seeber, Waldhart, & Maier, 2014). However, most IS and organization research to date has focused on the role of IT on coordination in distributed teams. To that effect, IT artifacts are often conceptualized as boundary objects that enable coordination among distributed individuals by, e.g., facilitating input from different expert groups, building shared commitment, and aligning task contributions (e.g., Doolin & McLeod, 2012; Havakhor & Sabherwal, 2018; Nevo, Benbasat, & Wand, 2012; Okhuysen & Bechky, 2009; Venters, Oborn, & Barrett, 2014). In co-located teams however, IT artifacts play a less important role in facilitating cross-disciplinary input, since co-located team members share information through direct interactions. Consequently, understanding the role of IT in co-located team coordination requires a different approach to studying the performative interactions between teams and IT the artifacts in their environment, focusing on the information processing capabilities of IT artifacts and on their potential to enhance or inhibit cognitive processes at a team level. To begin this development, we conceptualize IT artifacts as non-human actors with information processing capabilities that are partial, provisional, and embedded in complex and dynamic social contexts (Orlikowski & Iacono, 2001). In doing so, we focus on the cognitive effects of IT use on co-located teams, and on their implications for team coordination.

3 Method

This paper explores IT use patterns, information sharing behaviours and communication processes in order to reveal how IT use influences team SA during CPR interventions. These aspects are relevant for understanding the impact of IT use on team SA, since team SA depends not only on individual SA, but also on team processes such as planning, information sharing and communication of knowledge about teamwork objectives, status, team capabilities, or interdependencies among individuals and tasks (Prince & Salas, 1993; Salas, Prince, Baker, & Shrestha, 1995). For exploring IT use patterns and communication processes in resuscitation teams, we employed a qualitative research approach, which allows for an in-depth investigation of in-hospital CPR interventions (Patton, 2014). Specifically, video data of in-hospital CPR interventions were analyzed by means of communication content analysis. This approach is suitable for our aim, since it allows the identification and categorization of verbal and non-verbal information exchanges among team members, as well as between team members and IT.

3.1 Data Collection

The empirical data were collected as part of larger research project investigating issues of in-hospital CPR organization. The data were collected at a Danish hospital, where the project members have been granted permission to video record in-hospital CPR interventions by means of body cameras attached to the uniforms of resuscitation team members. All participating health professionals and patients (or relatives when the cardiac arrest resulted in death) have consented to the data collection.

The body cameras started recording as the team arrived at the cardiac arrest location. The cameras were turned off once the treatment was discontinued or in case of return of spontaneous circulation. The total number of recorded interventions is seven. The recordings were stored securely in a Redcap database, to which only authorized personnel had access. The video data was accessible for a period of 30 days, after which all recordings were deleted. To ensure continued access to the data in some form, conversations from the video recordings were transcribed verbatim. Whenever possible, a distinction was made between the sender and receiver in the communication process. Furthermore, the video data was used to take notes describing the context of each intervention, including available technology, team members present, as well as observations regarding actions, tasks, and behavior of resuscitation teams. The transcripts and observation notes were loaded into NVivo software and formed the basis for data analysis.

3.2 Data Analysis

The data were analyzed by means of qualitative communication content analysis (Cald*er et al*., 2017). This approach is suitable, since it allows for the identification, categorization and aggregation of information exchanges, utterances, as well as non-verbal communication exhibited by team members during CPR interventions (Calder et al., 2017).

The analysis process involved segmenting the communication protocols of resuscitation teams into meaningful communication sequences involving two or more participants, and taking detailed notes of all non-verbal interactions (Parush *et al*., 2011). Given the purpose of the study, instances of IT use (e.g., handling of medical devices, information retrieval, queries, data input) related to each communication sequence were also coded. The process of coding IT use instances, communication sequences, and information exchanges served the purpose of identifying interaction patterns between individuals and IT and communication patterns among individuals, which reflect how team SA is built.

After identifying all relevant first order codes, we categorized them according to Endsley’s three-level SA model (Endsley, 1995). Specifically, codes containing situation-specific IT use, utterances or exchanges of information related to patient history, vital signs, team members present, role clarifications and time were categorized as evidence that team members had a basic perception of the situation at hand (i.e., level 1 SA). Next, comprehension of the unfolding situation (i.e., level 2 SA) was noted through instances of team members recognizing and reacting to changes in the environment. These included interventions (e.g., defibrillation, adrenaline administered) as well as utterances and interactions through which team members kept track of treatment progress, and acknowledged interdependences between tasks. Assigning tasks, planning future treatment and seeking specialized advice were categorized as evidence of team members’ ability to project future scenarios and plan for contingencies. Table 1 provides an overview of the used theoretical constructs, codes and examples pertaining to each code.

Construct	Description	Codes	IT artifacts	Examples
Level 1 SA	Perceptions of elements in the environment	Patient status	SATs monitor Defibrillator	Team leader: [checks the defibrillator] “We still have no pulse” Junior cardiologist: “Stop the chest compressions! [Checks the heart rhythm on the defibrillator]. It is asystole.”
		Patient history	Computer on wheels EMR	Team leader: “The anesthesiologist is in the room! [Goes to the patient]. Who do we have here?” Nurse: [Tells patient name]. It is a rib fracture. Admitted after traffic accident. Junior cardiologist performs multiple search queries in the EMR and provides additional details on the damage from the accident.
		Time	Defibrillator Smartphone	Team leader: [checks phone] “There is heart rhythm check in 30 seconds” Nurse: [checks phone] “A minute has passed after adrenaline was given.”
		Team members present	n/a	“The anesthesiologist is in the room”
		Role clarifications	n/a	“I am just the service assistant”

Level 2 SA	Comprehension of the current environment	Interventions and intervention status	Defibrillator SATs monitor Video laryngoscope Ultrasound scanner EMR CO2 measuring instruments	A SATs monitor is placed on the patient and the patient is intubated using a video laryngoscope. Anesthesiologist: "The patient is intubated" Junior cardiologist receives ultrasound scanner and at the same time analyzes heart rhythm on the defibrillator. Junior cardiologist to orderlie: "Can you just wait 2 seconds [orderlie stops chest compressions]. Junior cardiologist: I think we can try to shock her heart now. I can see a good rhythm. [Defibrillator charging] Team leader: Continue chest compressions, we charge.
Level 3 SA	Projection of future status	Assistance and consultations	Smartphone	Team Leader calls another department or specialty for assistance or consultation.
		Reversible causes and future treatment	EMR Ultrasound scanner Video laryngoscope	Team Leader: "Do we think is something reversible?" [Reviews of the 4 Hs and 4 Ts - mnemonic device used for remembering the possible reversible causes of cardiac arrest]. Junior cardiologist checks for reversible causes using the ultrasound scanner.
		Task assignment	n/a	"Take over this, I have to intubate" "Could you please keep an eye on the time?" "We need someone to perform chest compressions"

Table 1. Coding scheme and examples

After coding the data, we performed within-case analyses for each of the seven cases, in order to gain in-depth understanding of the specific circumstances under which certain IT interactions and communication instances emerge (Paterson, 2010). Thereafter, we performed a cross-case analysis, where the focus was on identifying recurring patterns (Burns, 2010) in terms of how IT impacts different levels of SA during in-hospital CPR interventions. At this stage, several patterns emerged such as links between IT type and SA levels, and ways in which IT use influences complementary SA, shared SA, and team coordination. These patterns guided the subsequent writing process.

4 Results

The in-hospital resuscitation interventions included in our study took place in environments best characterized as dynamic and uncertain, which had an impact on the how resuscitation used IT to build team SA. In particular, all resuscitation teams faced a great deal of uncertainty and constant changes in patient status and treatment requirements as events unfolded. Consequently, resuscitation teams engaged with a wide variety of IT artifacts in their environment in order to clarify various aspects of the intervention: cardiac arrest cause, patient status, reversible causes, task clarifications or equipment needed. As a first step, however, the resuscitation teams needed to make sense of their (new) environment and initial task requirements. This usually implied several information exchanges between the resuscitation team and the ward personnel who summoned the resuscitation team. These exchanges included crucial patient information such as medical history, admission cause, current condition and possible cardiac arrest causes. However, this information was often only briefly communicated, with detailed information subsequently acquired from sources such as EMR, defibrillator, or ECG results, all of which provided the resuscitation teams with various levels of information and awareness as the interventions unfolded. In particular, we observed that resuscitation teams engaged with the IT artifacts in their environment in order to enhance their SA in two ways: either by delegating an individual to a task requiring specific task-oriented IT (e.g., “the junior cardiologist is standing by with the defibrillator ready”, “a nurse brings in a computer on wheels to access the EMR”), or by collectively engaging with IT and medical devices (e.g., checking the vital signs monitor, checking time on the defibrillator, looking at ECG results). We elaborate on these themes below. First, we discuss our findings related to how IT use influences different levels of individual SA. Thereafter, we discuss how both IT use and individual SA shape the way team SA is built in dynamic and unpredictable environments. Last, we discuss the relations between the main analytical concepts as they emerged from our data, and propose a conceptual model of the impact of IT on team SA and team coordination.

4.1 IT use and SA levels

Across cases, we observed a pattern of resuscitation teams most often operating under level 2 SA. That is, team members interact with a constant stream of data and information to maintain awareness of rapidly unfolding situations. To that end, team members synthesize, interpret, and prioritize patient- and task-related information in order to attend to sudden changes in patient status and intervention requirements. Utterances such as “adrenaline was given after the first and third”, “measure blood pressure” or “it is asystole, continue chest compressions” reveal a need to assess the case on a continuous basis, since patient data and task requirements are constantly changing. This, in turn, implies that resuscitation teams are often in a state of continuous situation comprehension, similar to the notion of level 2 SA.

Interestingly, our results show that the IT resuscitation teams interact with, most often support either level 1 or level 3 SA. To exemplify, IT in the form of EMR and vital signs monitors facilitate level 1 SA by enabling information gathering. All observed teams used the EMR for retrieving medical, pharmacological and surgical patient history, as well as laboratory results. Furthermore, they used the vital signs monitors to gather data on patient status, such as SATs, blood pressure and CO2. However, while the technologies hold contextually relevant information, they do not by themselves enable situation comprehension, which requires information and data from various sources to be synchronized and interpreted before action can be taken. As such, we did not observe actions driven by patient information alone. Rather, instances in which team members recognized and reacted to changes in patient status and intervention requirements required additional team-oriented non-technical skills, such as communication of patient information, task status, and leadership utterances. To that end, situation comprehension (i.e., level 2 SA) was achieved only when team members synthesized, communicated and interpreted contextual information provided by IT.

Another example where IT enabled level 1 SA was in relation to time keeping. Team members used either defibrillators or smartphones to perform this task. Time keeping was essential to many CPR tasks, since chest compressions, ventilation, drug administration, rhythm analyses and defibrillation are all time-dependent and rhythmic interventions. Accurate time perception allowed team members to work efficiently with repetitive and time-demanding tasks without the need for explicit coordination (e.g., planning, task status utterances, task assignments).

The information provided by available IT and medical devices also enabled team members to consider possible scenarios, and establish level 3 SA as a consequence. For example, when engaging with diagnosis tools in the form of ECG or ultrasound, we observed that team members were compelled to elevate their communication from that of level 1 SA (i.e., factual information) to more abstract discussions regarding possible reversible causes, future treatment (e.g., drugs to be administered later in the process), and future action (e.g., tasks assignments and consultations). Because diagnosis tool usage was directly followed by utterances and interactions revealing the ability of team members to predict treatment trajectories and anticipate task requirements, we find that such tools enable resuscitation teams to achieve level 3 SA.

Another technology that enabled projection-based decision-making and action was the EMR. Beyond laboratory results and pharmacological history, the EMR may contain information about previous diagnoses (i.e., higher-level information). This information can potentially inform health professionals of possible reversible causes, which enables projection-based action. Consulting the EMR for this purpose enabled level 3 SA by facilitating projection-based decision-making.

At a general level, we observed that IT enabled team members to gather context-specific information in a timely and sustained manner, and to anticipate future patient needs and treatment trajectories. This, in turn, supported rapid comprehension of unfolding and unexpected situations, and allowed for rapid responses adapted to case contingencies. However, shared situation comprehension and team SA were also necessary for coordinating such timely responses.

4.2 IT use, individual SA and team SA

In all observed CPR interventions, team members gathered large amounts of patient data and information from multiple sources in dealing with cardiac arrest situations. As the teams arrived at the cardiac arrest location, information-gathering activities were carried out in parallel with BLS procedures (e.g., chest compressions and ventilation). Accordingly, tasks such as chest compressions, airway management, time management, data collection, and information retrieval were performed concomitantly by different members of the team. The team member in charge of retrieving information from the EMR would often use a mobile computer to access patient's medical files and then read aloud the accessed information. This ensured that any subsequent interdependent tasks were performed on the same basis (i.e., same information). In such situations, we observed that the EMR facilitated complementary team SA. However, since patient information was often communicated as simple data or observations (i.e., level 1 SA), it was not always supportive of shared SA (i.e., overlapping, shared situation comprehension). For example, in one of the cases, we observed a moment of confusion following the communication of patient information. The confusion was related to the type of drug that needed to be administered, and arose due to inadequate communication and lack of experience. While we did not observe such incidents across all cases, the example is illustrative of how information sharing, in the absence of effective leadership and adequate, higher-order communication, can create a false sense of shared SA that may lead to interruptions in the CPR process, e.g. chest compressions, drug administration and ultimately suboptimal care.

Other technologies that facilitated complementary team SA were vital signs monitors, defibrillators, and smartphones. First, vital signs monitors facilitated the implicit coordination of interdependent tasks, since the displayed vital signs were visible to all team members at all time. Second, because defibrillators and smartphones were used to keep time, they augmented the teams' complementary SA in terms of initiating or completing specific time-dependent tasks. For example, by keeping track of time, the person performing chest compressions and the person responsible for rhythm assessment were able to synchronize their respective tasks. In this situation, complementary SA was sufficient for team members to coordinate their interdependent actions, and to efficiently perform time-demanding tasks. That is, each member contributed to team performance by means of individual skills and actions, enabled by their shared sense of time.

By contrast, we find that diagnosis tools such as ultrasound and ECG, which facilitate high levels of individual SA, were also supportive of shared team SA. We observed across the cases that diagnosis tool use was commonly followed by higher-order communication content such as reversible causes, future treatments, and task distribution. In turn, such higher-order communication ensured that subsequent interdependent actions were based on a common comprehension of the diagnosis, required tasks, and treatment. For example, the ultrasound was used on several occasions with the objective of identifying reversible causes. This sometimes led to the identification of cardiac arrest causes, which were subsequently communicated to all team members. Because diagnosis tools such as ultrasound or ECG provide abstract information in the form of images and graphs, team members were compelled to engage in higher-order communication, in which the exchanged information was already synthesized and interpreted. This likely facilitated the creation of shared mental models, since coordination processes became more implicit, as evidenced by decreases in communication frequency and increases in treatment-oriented activities across the investigated cases.

Based on insights gained across the resuscitation incidents, Figure 1 (see below) shows how the use of task-oriented IT artifacts affect team SA and team coordination. In particular, it shows that IT use can influence team SA and coordination in two ways. On the one hand, IT artifacts with e.g., shared displays, or complex IT whose use is shared among multiple individuals, provide team members with the same environmental cues (e.g., shared information, data), which ensures that individual decision-making and action, for example in relation to own tasks, are not dissonant across team members. This implies that team members can achieve complementary SA when the same IT artifact is the source of information about changes in the environment across team members. Achieving complementary SA is often sufficient for team to manage task interdependencies, in cases where tasks are routine and predictable, such as the cyclic performance of chest compressions, ventilation, and heart rhyme check.

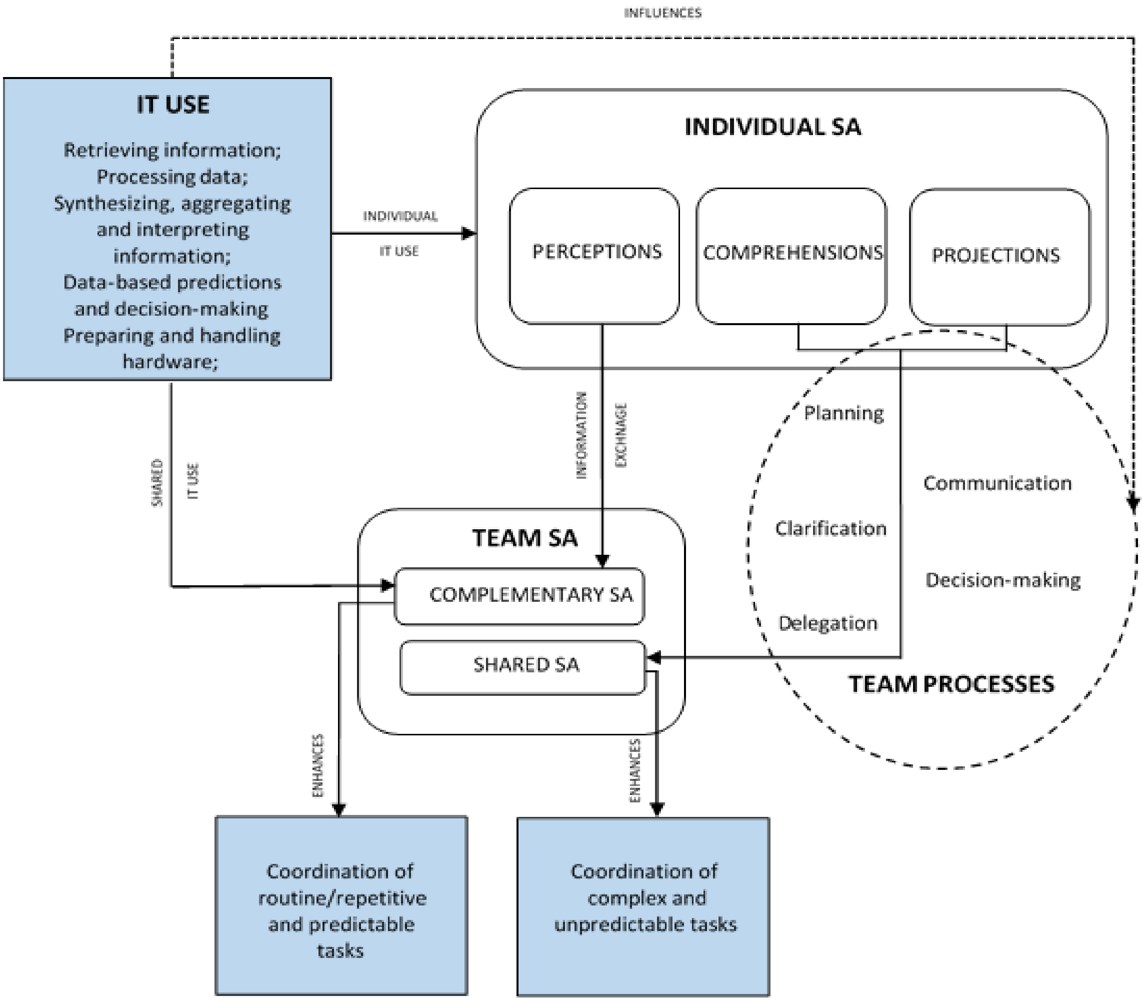

Figure 1. Conceptual model of the role of IT artifacts in team SA and task coordination

On the other hand, the use of IT artifacts during team performance also influences team SA indirectly. As illustrated above, IT use influences different levels of individual SA (perception, comprehension, projection). At the same time, team SA is also a function of individual SA. This is because an individual's communication of his or her awareness can enhance (or hinder) team processes in a number of ways, including task clarification based on new situation comprehension, decision-making based on projected future scenarios, or ad-hoc task planning as a result of new data and information from IT artifacts and other elements in the environment (Salas et al., 1995). Communicating at higher abstraction levels (levels 2 and 3) implies that information should not only be clearly passed from one team member to another, but that through team processes such as clarification, planning, and action-oriented decision-making, information should also interpreted the same way, and a shared projection of actions in formed to guide the expectations of team members. Through the interplay between IT use, individual SA and team processes, teams can build the shared SA necessary to coordinate complex and unpredictable tasks, and to anticipate ad-hoc interdependencies as events unfold in unpredictable and dynamic environments.

5 Discussion

The purpose of this paper is to address an often debated but rarely investigated aspect of team processes: namely the role of IT in establishing and maintaining situational awareness in dynamic and fast-paced environments. The uncovered interaction patterns reveal that while task-oriented IT artifacts promote the development of task knowledge and complementary team SA, they may hinder team SA when it comes to team-oriented knowledge necessary to manage task interdependencies in dynamic and unpredictable work environments. We elaborate on these below.

5.1 Key findings

In terms of individual SA, our results suggest that IT enables health professionals in gathering patient information, but also in projecting future patient needs, illness trends and treatment trajectories. These activities are akin to level 1 and level 3 SA, as proposed by Endsley (1995). However, our study reveals that IT does not directly support level 2 SA. The explanation for this finding is twofold. First, the fact that IT use does not directly lead to situation comprehension can be explanied by the nature of IT and medical devices available to resuscitation teams. While level 2 SA implies information synthesis, interpretation, and prioritization (Rosenm*an et al*., 2018), the technologies available to resuscitation teams are “passive actors”, and do not perform tasks independent of human action. Rather, many of the available IT provide mostly observational data and low degrees of information synthesis, with which team members must continually engage in order to understand their contextual relevance and reach level 2 SA. Second, whereas level 1 (i.e., information gathering) and 3 SA (i.e., predicting possible trajectories, contingency planning) involve some degree of visible action and interaction with the environment, level 2 SA (i.e., comprehension) can be conceived as a purely cognitive process, residing “in the mind”. As such, the impact of IT on level 2 SA is diffcult to investigate from a socio-technical perspective (Stanton et al., 2010). This theoretical argument further explains the finding that resuscitation teams most often operate under level 2 SA, since utterances and action-oriented behaviors can be conceived as expressions of situation comprehension processes.

In addition, our study demonstrates that particular types and functions of IT enable SA at different levels (Müller *et al*., 2021). Whereas vital sign monitors and EMR were particularly important for resuscitation teams in achieving level 1 SA, other types of IT helped establish level 3 SA. Such types of IT were most commonly, but not exclusively, diagnosis tools in the form of ultrasounds and ECG. Their output format (e.g., images, graphs) compelled team members to engage with their environment at higher SA levels. While the above are case-specific examples, the common denominator is the way in which information is structured and presented through IT (Van de Walle, Brugghemans, & Comes, 2016). Therefore, factors such level of abstraction and aggregation of information affect the way individuals enage with IT, and the situational awareness they can achieve. These findings are in line with previous research suggesting that IT impacts different levels of SA, and that particular types of IT may enable SA at different levels (Müller et al., 2021). However, our study adds to these insights by also showing how IT use impacts team cognition and collaboration aspects of teamwork. To this end, our study reveals the interplay between IT use, individual cognition and different types of team SA, namely complementary SA and shared SA.

With regard to team SA, our results suggest that IT may enable both complementary and shared SA. However, shared SA is hindered when related information sharing and communication processes revolve around data and observations, since these can create different or even divergent individual SA.

Complementary SA as a concept builds on the premise that team SA can be achieved by summing the SA of individual team members (M. Wright & Endsley, 2008). If the SA of individual team members is not divergent, team SA can be established without the need of explicit coordination processes (M. Wright & Endsley, 2008). Our results suggest that IT providing patient information coupled with communication processes ensure that team members base their interdependent actions on a common set of information. For example, IT such as the vital signs monitors, defibrillators, and smartphones played an important role in augmenting teams' complementary SA, since they provided members with the same environmental cues. By using the defibrillator or smartphones, team members were able to manage their task interdependencies without the need for additional, explicit coordination. Similarly, because data displayed by vital sign monitors were visible to everyone, team members could efficiently perform and align interdependent tasks. Our findings add to extant literature on team SA and IT (e.g., Parush *et al.*, 2011, 2017; Müller *et al.*, 2021) by showing that IT providing shared access to environmental cues enables complementary team SA. To the best of our knowledge, this is the first study investigating the distinct ways in which IT impacts complementary and shared team SA.

Lastly, the concept of shared SA implies that members of a team have overlapping comprehension of unfolding situation. Individuals' higher-level SA, such as comprehension and projection, need to be converging and aligned to ensure effective team coordination. In relation to the impact of IT on shared team SA, our study reveals mixed results. Whereas diagnosis tools, smartphones, and paper-based resuscitation guidelines were particularly supportive of shared SA, other types of IT providing health professionals with raw data such as laboratory results or vital signs hindered on occasion the development of shared SA.

Information provided by diagnosis tools, such as ECG and ultrasound, are abstract, requiring team members to communicate at higher SA levels, and to expose individual interpretations of information, rather than relying on shared data and observations in the communication process. These types of IT enable teams to communicate at higher abstraction levels (e.g., diagnoses, treatment), and to develop overlapping mental models as a consequence. On the other hand, when health professionals used the EMR and vital signs monitors, team members often shared information at the level of data or observations (i.e., level 1 SA), which was not always supportive of shared SA. In addition, such IT was sometimes preventive of a shared SA, since the information provided led to dissonant individual SA among the members of resuscitation teams. Our findings thus add to literature on team SA and IT e.g. (Parus*h et al*., 2011, 2017; Müller *et al*., 2021) by showing that some IT features (e.g., abstracted data display and higher-level information processing) may support shared SA, others (e.g., low data synthesis and aggregation) may inhibit it. In the absence of leadership and explicit communication, IT providing detailed and non-aggregated task-oriented information can negatively impact team SA, since it can lead to dissonant situation comprehension and SA.

5.2 Implications for research and practice

Our study has several implications for research and practice. Extant literature on team SA and IT has focused on deriving IT design principles that compensate for information loss, and consequently SA degradation in teamwork (e.g., Parush *et al.*, 2011, 2017; Müller *et al.*, 2021). In a distinct manner, our study addresses the impact of existing IT capabilities on team SA in dynamic and fast-paced environments. In doing so, we show that IT capabilities facilitate team SA both by ensuring shared access to information, and by aligning members' higher-level situational awareness. Because shared access to information ensures complementary team SA, we show that team members work more efficiently on repetitive, but time-demanding tasks, without the need for additional, explicit coordination (Cain et al., 2016). Conversely, by aligning members' higher-level situational awareness, we show that IT facilitates team coordination in dynamic environments, where many contingencies and new situations require team-oriented knowledge and explicit coordination processes (Cain et al., 2016). Our unique insights into the interplay between IT, team SA, and implicit and explicit team coordination warrant additional research on two fronts. First, as seen with the use of medical devices and IT in CPR interventions, the capabilities and features of available technology impact different aspects of team SA, and lead to distinct coordination needs. How this plays out in contexts other than CPR interventions, with different IT capabilities and coordination needs is an open area for further investigation. Second, future research is needed to study the extent to which team SA mediates the relationship between IT and team coordination needs (i.e., implicit vs. explicit). Human and environmental factors such as team expertise, training, or task complexity are beyond the scope of this study, but may also play an important part in how IT use impacts team coordination.

Our results also have implications for practice. In particular, our insights regarding IT features and team SA suggest the need for IT design that supports both task efficiency and higher-order cognitive processes in dynamic and fast-paced environments, such as healthcare. The general implication here is that information presentation and accessibility have a direct impact on team SA, and on team coordination as a consequence. To that effect, IT design ensuring shared access to some form of higher-order information (e.g., synthesized, aggregated, interpreted, abstracted) may better enable resuscitation and other medical teams to deal with rapid changes in their environments in an efficient manner. Contrary to extant research, our study does not support the assertion that shared displays alone enable higher-order team SA (e.g., Parush *et al.*, 2011, 2017). It is rather information structuring and aggregation that plays an important role. While shared displays may ensure complementary SA, they do not by themselves facilitate higher-level team SA necessary in dynamic and new situations.

5.3 Limitations and directions for future research

While shedding light on the role of IT in establishing and maintaining SA in dynamic and fast-paced healthcare environments, our study is not without limitations. First, our dataset is limited to seven CPR interventions. While each of these presented us with unique and deep insights into the coordination practices of resuscitation teams on account of very rich observational data, data saturation may not have been reached (Fusch & Ness, 2015). Furthermore, since the video cameras were not stationary, the quality of recordings sometimes made it difficult to capture meaningful conversation sequences and to understand what was happening. Thus, to complement our study, future research should, in addition to video or observational data, conduct interviews with selected members of resuscitation teams in the effort to compensate for some of the blind spots in the data.

5.4 Conclusion

This research article addressed the research question: *how does IT use impact team situational awareness during cardiac arrest interventions, and what are the implications for team coordination?* Based on insights from CPR interventions, the article shows that IT artifacts support the development of task-oriented knowledge, and can enhance team coordination when complementary SA (i.e., different, but non-conflicting mental models) is sufficient for team members to manage the interdependencies between their tasks (e.g., for routine or easily predictable tasks). However, when team members work across multiple task-oriented IT, their higher-level awareness levels (i.e., comprehension and projection) may not be aligned, which can hinder the development of shared SA, i.e., common understanding among team members about interpersonal interactions, roles and task interdependencies. Under these circumstances, IT artifacts may hinder team processes such as communication, planning and interdependence management, and ultimately impact team coordination.

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