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Interdependence and Handoff Coordination in Resuscitation Teamwork: A Socio-Technical Perspective

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Abstract

In this paper, we examine the impact of socio-technical interdependencies on coordination in resuscitation teamwork. We employ a relational perspective on handoffs to reveal how resuscitation teams manage complex socio-technical interdependencies to deliver timely and effective treatment responses. Our analysis shows that resuscitation activities vary greatly in terms of task complexity, and in terms of knowledge and technological requirements. We find that activities involving complex tasks create multiple interdependencies. Transitioning between work activities under these circumstances requires complex socio-technical handoffs and high degrees of explicit coordination. Conversely, activities involving simple or repetitive tasks do not create complex interdependencies. Transitioning between such work activities requires simple handoffs, where either social or technical elements change. Such handoffs are coordinated implicitly, or via pre-defined structures. Our results contribute to literature by revealing how socio-technical interdependencies are managed in complex and uncertain work environments, and with what consequences for work coordination.

1. Introduction

The notion of interdependence has long been of interest to information systems and organization scholars [1]–[3] and it has been intricately linked to how social and technical agents interact to produce reliable collective outcomes [4]–[6]. However, drawing predominantly on organization theories, research to date has primarily focused on task interdependencies and on the social interactions they entail [4]–[6]. As a consequence, interdependence is typically conceptualized as the extent to which organizational tasks require individuals to work together toward a common goal [4], and the focus is placed on work coordination and handoff strategies among individuals [5]. Interdependence is therefore understood as the result of pre-defined work divisions that are exogenous to organizational practices and technology use [7]. Interdependencies among technologies or knowledge required to perform tasks are either not described or are viewed as congruent with task interdependencies [1], [8].

In contrast to this dominant view, more and more organizations operate in environments characterized by volatility [9] and complex socio-technical configurations [1], [8]. In the face of fast changing work requirements and emergent tasks, work-related interdependencies often arise as organizational individuals interact with their environment and make sense of their work as it unfolds [1]. Because the nature of work is more dynamic and uncertain, it is only partially based upon pre-defined tasks and technological structures [10], [11]. Consequently, task, knowledge or technology interdependencies cannot be fully specified in organizational designs [1], [2], [8]. Furthermore, as work in organizations is increasingly being carried out in teams [12], interdependencies are also less defined by sequential work distribution (e.g., production lines), and are more contingent on temporal coordination of resources needed to accomplish shared tasks.

Therefore, a gap exists between traditional views of interdependence as task-centric and deterministic, and teamwork in contemporary settings where complex emergent work is performed [12]. To date, only a few studies have investigated knowledge [1], [2] or technology interdependence [5], [8] as distinct from task interdependence. These studies show that task uncertainty and high work complexity lead to emergent work configurations and socio-technical interdependencies that require different coordination and handoff strategies. Managing knowledge interdependencies, for example, requires collaboration and inter-personal coordination [13]. Managing technological interdependencies, on the other hand, implies the need for system integration, control and automation [8]. Understanding how these socio-technical interdependencies are managed as work unfolds is important, since most organizations rely on

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interdisciplinary work, and on numerous technologies with different requirements and capabilities.

Work complexity and uncertainty are characteristics of healthcare settings, where non-routine medical cases, often with unpredictable development trajectories, are managed by interdisciplinary teams using multiple information systems and medical devices. Therefore, healthcare settings are characterized by non-linear, complex interactions requiring unique combinations of specialized knowledge and technological resources. However, despite high levels of socio-technical interdependencies and teamwork in healthcare settings, research in this area has primarily focused on asynchronous care coordination [14]. Here, the notion of interdependence has been addressed only to the extent that it provides a theoretical argument for exploring patient handoffs [15], in which sequential work interdependence manifests at the change of shift. Handoff and coordination strategies during synchronous teamwork such as resuscitation or trauma interventions are largely unexplored [14].

In this paper, we focus on emergent work configurations during resuscitation events, and emphasize the distinction between task, technology and knowledge interdependencies. We investigate how resuscitation teams manage interdependencies and coordinate work as it unfolds. Because resuscitation interventions are unique, context-dependent, and non-routine, team members define and delegate tasks as situations unfold, and continually manage interdependencies between available resources (e.g., knowledge and technologies) and emergent task requirements. Our guiding research question is: *What interdependence patterns are exhibited during resuscitation teamwork and what are the implications for coordination in complex and uncertain work?*

To answer this question, we present an observational study of resuscitation practices at a Danish hospital. Based on video data of seven in-hospital resuscitation interventions, we explore how resuscitation teams manage emergent socio-technical interdependencies to deliver timely and effective treatment. Our analysis reveals multiple types of handoffs as resuscitation work unfolds across activities. While some handoff types are more prominent than others, they all provide insights into how socio-technical interdependencies are managed in environments characterized by high levels of uncertainty and work complexity.

2. Interdependence and handoffs

Interdependence and the consequent need for coordination and handoffs among agents are vital concerns in organization and information systems research [2], [3]. By nature, systems and organizations are composed of multiple agents, e.g., individuals, groups, technologies, that may perform different functions, but that produce collective outcomes. The interdependence that exists between agents, and the subsequent interactions it enables are conceived as the micro-foundations of organizational work [1]. Interdependence has been described as existing between organizational units [16], roles and knowledge [17], tasks [18] or technologies [8]. However, extant research has primarily focused on task interdependence [16], [18], [19] and on how individuals coordinate collective action [13], [20]. Here, interdependence is typically defined as the extent to which interdependent organizational tasks require individuals to work with one another [16], [19] and the focus is placed on identifying coordination requirements and strategies as work is handed over among individuals [5]. Interdependencies between technologies and knowledge are assumed to mirror task interdependencies, and as such, to be easily specified and managed [1], [8]. While this may be true for work environments with linear, recurring and predictable tasks, environments with more complex, interdependent and unpredictable work require emergent and unique combinations of specialized knowledge and technological resources, which cannot be specified in advance.

This is the situation of much healthcare teamwork, which is challenged by emergent, synchronous interdependencies, complex technologies, variability of patient cases, incomplete data, and rapidly evolving situations [14], [21]. However, research in healthcare organization has predominantly examined handoffs in distributed work (e.g., sequential shifts), and has focused on interdependencies between social elements such as tasks or roles [15]. In contrast, our work examines both social and technological interdependencies as they manifest in collocated care teams, where the necessity of temporal socio-technical coordination plays a crucial role in shaping transitions between activities.

Construing of interdependence as socio-technical allows us to examine how individuals, tasks and technologies form mutually dependent ensembles as work activities unfold, and with what consequences for teamwork coordination [13]. Socio-technical interdependencies can be investigated by looking at handoffs, which are observable manifestations of socio-technical interdependencies, as teamwork unfolds [2]. Since handoffs are a consequence of the many ways in which work is divided during team organizing, e.g., across tasks, technologies, knowledge, and roles [5], they facilitate an understanding of the strategies necessary to coordinate and integrate work across divisions [5], [8], [22].

In line with a socio-technical perspective, Pentland et al. [5] define handoffs as "a sequential relationship between two activities or events" (p. 286). According to this perspective, handoffs occur when work passes from one activity to the next in the context of a stream of coherent activities. For the purpose of this paper, we define work activities based on three attributes: individuals, tasks and technologies. Consequently, we can describe seven types of handoff between organizational activities, since there will be one type of handoff for each attribute, and for each combination of attributes:

Handoffs between individuals occur when there is a change in the individual performing the work, but no change in the work task and technology used.

Handoffs between tasks occur when an individual performs two or more tasks using the same technology.

Handoffs between technologies describe situations in which an individual performs a task by using multiple technologies.

Handoffs between individuals and tasks describe multiple individuals using the same technology for carrying out different tasks.

Handoffs between individuals and technologies occur when task completion requires multiple individuals working sequentially using different technologies.

Handoffs between tasks and technologies describe situations in which an individual completes two or more tasks, each requiring different technologies.

Handoffs between tasks, technologies and individuals are complete handoffs that occur when a task is completed and a new one needs to be performed by another individual using a different technology.

Viewing handoffs as relationships between activities, and activities as ensembles of mutually interdependent tasks, individuals, and technologies enables the discovery of complex interdependence patterns, which provides greater insight into the different ways in which work is organized and coordinated in contemporary organizations [5].

3. Method

In this paper, we investigate how resuscitation teams deal with interdependencies under conditions of uncertainty and complex work requirements. To do so, we draw on the concept of handoffs as indicators of interdependencies between individuals, tasks and technologies [2]. We employ an observation-based research approach, which allows us to investigate work practices and relationships in situ [23]. Specifically, video data of in-hospital resuscitation practices were analyzed through the lens of handoffs as relationships between activities [5].

3.1. Research setting

The dedicated resuscitation teams at the investigated hospital are cross-disciplinary and cross-functional, and vary in terms of size and composition. The teams are usually composed of anesthesiologists, cardiologists, anesthetist nurses, medical technicians, orderlies and medical assistants of varying levels of medical training and experience. Moreover, the membership of a resuscitation team changes over time due to staff turnover and rotation patterns. Oftentimes, the team members do not know the colleagues they work with during resuscitation interventions, nor are they always aware of the expertise, knowledge, and experience of the other team members.

In-hospital cardiac arrests often occur in the emergency department and intensive care unit, where patients in critical condition are admitted. However, in-hospital cardiac arrest can also occur in medical or surgical wards, although more rarely. Because the work of resuscitation teams is distributed, there is no single setting in which resuscitation work takes place. As such, apart from the varying team composition, the work environment of resuscitation teams, including the available technology, also varies greatly. For example, when a cardiac arrest occurs in the emergency department or in the intensive care unit, resuscitation teams will often have more specialized technologies and equipment at their disposal, since these settings are already equipped with advanced monitoring and diagnostic devices. In contrast, when a cardiac arrest occurs in a medical ward, the resuscitation team will often need additional equipment and technology than what is readily available. In these circumstances, advanced cardiac arrest treatment may be delayed, and tasks need to be prioritized based on resources available at any given moment. The technology used by the resuscitation teams in our study can be summarized as a combination of information management tools (e.g., EMR and paper charts), monitoring and treatment equipment (e.g., vital sign monitors, defibrillators, and ventilators), and diagnostic tools (e.g., for ultrasound and ECGs).

Cardiac arrests are often called by ward personnel, who provide basic life support (BLS) to the patient while summoning the on-call resuscitation team to perform advanced life support (ALS). Upon arrival at the cardiac arrest location, the resuscitation team is required to adhere to a specific set of guidelines, stipulated by an internationally recognized ALS protocol. The guidelines define best practices including diagnosis, chest compressions, airway management, cardiac rhythm analysis, defibrillation, and drug administration following a time-dependent algorithm. The ALS protocol is instrumental in structuring interactions among team members in the absence of pre-defined roles and shared mental models. Furthermore, the protocol is used to manage expertise and technological interdependencies that emerge as the treatment unfolds. However, due to the particularities of each case and complications, strict adherence to the ALS protocol is often not possible.

Resuscitation teams thus operate in settings characterized by interdisciplinary work, technological complexity, and task uncertainty. In light of these characteristics, resuscitation teamwork provides a fertile ground for investigating how socio-technical interdependencies are managed in complex and dynamic work.

3.2. Data Collection

Due to the sensitive nature of resuscitation research, as well as the unpredictability of in-hospital cardiac arrests, conducting in-situ observations of resuscitation practices can be challenging. However, video recordings can be used as an alternative to in-situ observations when conducting sensitive research, since video data grant researchers access to the field in a less intrusive manner [24]. Video recordings capture emergent action as it unfolds [13] and afford in-depth accounts of moment-to-moment interactions [25].

The video data for this paper were collected as part of a larger research project investigating topics related to the organization and coordination of resuscitation teams in a Danish hospital. The project members obtained permission to video record in-hospital resuscitation interventions by means of body cameras worn by resuscitation team members. Consent was received from all participating health professionals, as well as from involved patients (or relatives when cardiac arrests resulted in deaths).

The body cameras were turned on as the resuscitation teams arrived at the cardiac arrest locations. Recording was stopped when the resuscitation intervention ended – either in case of return of spontaneous circulation or when treatment was discontinued. The number of recorded interventions is seven. The video data were stored in a secure database (REDCap), to which only authorized project members had access. The video data were deleted after 30 days. Prior to deletion, each video recording was verbally and visually transcribed. On the one hand, conversations from the video recordings were transcribed verbatim. Since conversations constitute social action and are situated in a physical work environment [13], they enable observation of material and social aspects of work-related handoffs. On the other hand, the video material was visually transcribed in order to obtain a detailed inventory of available technology, artifacts, people and space, as well as non-verbal interactions among individuals [25]. Our verbal and visual approach to data transcription as a substitute for in-situ observations supports an analytical perspective that is consistent with the tenets of sociomateriality, which emphasizes the inseparability of social and material aspects of organizational work [26].

3.3. Data analysis

To examine how socio-technical interdependencies impact handoff coordination in resuscitation teamwork, we engaged in analyzing the visual and verbal transcripts by searching for handoff patterns exhibited by resuscitation teams. To this end, we employed a relational perspective on handoffs, which allowed us to uncover interdependence patterns that other, human-centric perspectives would have ignored [5]. In line with this relational perspective, we drew on Pentland et al.'s [5] definition of handoffs as relationships between activities, rather than between people. Based on this definition, handoffs occur when work passes from one activity to the next in the context of goal-oriented action. In a resuscitation event, the goal is to restore spontaneous blood circulation and treat the cause of cardiac arrest.

In order to identify when work passed from one activity to the next, we focused on the similarity or difference between pairs of activities [5]. To that end, when either an individual, a task, a technology, or a combination of the above changed in the course of a resuscitation event, we noted that a change in activity occurred. For example, when a team member used the EMR to check the patient's medical history, and then ultrasound imaging to identify possible cardiac arrest causes, we noted a change in task and technology (difference), but no change in person (similarity) as work passed from one activity to the next. Conversely, when two team members took turns in performing chest compressions, we noted a handoff in which people changed, but the task and technology did not.

By conceptualizing activities as ensembles of people, tasks and technologies (three attributes) – seven handoff types are theoretically possible [5]. On the one hand, there are three handoff types where only one attribute changes – handoffs between people, handoffs between technologies and handoffs between tasks. On the other hand, there are four handoff types where two or more attributes change – where people and tasks change, where people and technologies change, where tasks and technologies change, or where all three attributes change, [5]. However, in our dataset, we did not observe any handoff in which either technologies or tasks change, but all other attributes remain the same. Table 1 provides an overview of the identified handoff types and corresponding examples pertaining to each handoff type. After identifying and coding handoff types across the dataset, we performed within-case analyses for each of the seven cases, in order to gain an in-depth understanding of the specific circumstances under which certain interdependence patterns emerge – team composition, technology, and artifacts available [27]. Thereafter, we performed a cross-case analysis, where the focus was on identifying recurring patterns [28] in terms of how resuscitation teams dealt with emerging work interdependencies in order to coordinate treatment.

During our analysis, we discovered multiple types of handoffs. While some handoff types were more prominent than others, they all provided insights into how resuscitation work is organized and the work coordination and integration strategies required to deal with different types of interdependencies.

Table 1. Handoff types - definitions and examples

Construct	Description	Examples
Handoffs between people	This type of handoff occurs when team members change, but the technology or task do not	Changes in the person responsible for BLS tasks such as chest compression and ventilation. “We need someone to take over the compressions.” “We need someone to administer the adrenalin.”
Handoffs where tasks and technologies change	This type of handoff describes a change in task and technology, where the team member(s) performing the tasks remain(s) the same	One person looks in the cardiac arrest guidelines to check reversible causes and afterwards, walks to the computer to check patient history. The anaesthesiologist places a SATs monitor near the patient, checks values, then intubates the patient using a video laryngoscope.
Handoffs where people and technologies change	Handoffs of people and technologies describe tasks undertaken by (an)other team member(s) with new technology	One person tracks time on the wall clock; another person takes over this task and switches to track time on the defibrillator.
Handoffs where people and tasks change	This type of handoff implies a fixed technology but (a) new team member(s) using it for a new task	One person uses the defibrillator to track time while another person uses it to analyze the heart rate. “28, 29, 30” – the person who performs the cardiac arrest counts down and this starts the task of ventilating the patient. Another person performs the ventilation task.
Handoffs where people, tasks, and technologies change	This type of handoff occurs when a task is completed and a new one needs to be performed by another team member using a different technology.	The cardiac massage performed by an orderly is paused in order for the cardiologist to perform an ultrasound. One person performs an ultrasound scan before another person can start the cardiac massage. “Stop the cardiac massage, check for heart rate.”

4. Findings

In this section, we describe patterns of interdependencies between tasks, individuals and technologies in the context of resuscitation work and discuss the coordination demands they entail. Table 2 presents a synthesis of our findings in terms of handoff frequency (in percentages) for each of the cases, and describes coordination demands for each handoff type.

4.1. Making sense of unfolding work

The in-hospital resuscitation interventions we observed took place in environments best characterized as complex and uncertain, which had an impact on the interdependencies and handoff patterns we observed. All resuscitation teams faced a great deal of task uncertainty and complex technology and knowledge interdependencies, as new activity and treatment requirements were constantly emerging.

As resuscitation teams arrived at the cardiac arrest locations, there was often a lack of clarity with regard to various aspects of the intervention: patient history and medical condition, cardiac arrest cause, team members present, designated team leader, as well as expertise and technologies available. As a first step the resuscitation teams therefore needed to make sense of their environment and work requirements. This usually implied an initial handoff between the resuscitation team and the ward personnel who summoned the resuscitation team. During this handoff, crucial patient information such as status, medical history and possible cardiac arrest causes, as well as resuscitation responsibility were transferred from the ward personnel to the resuscitation team. The next step was to make sense of the resources available. To that end, team members usually presented themselves in terms of profession, discipline, and level of expertise. Utterances such as "I am just the service assistant" "anesthesiologist in the ward," or "the cardiologist is on call here" helped the teams understand and devise ways in which expert knowledge and skills could best be allocated to emergent task requirements.

Lastly, making sense of the environment also implied understanding the specific technology needs of the case at hand, assessing available technology, and addressing unmet technology needs, such as bringing mobile computers and ECG or ultrasound devices to the ward. It is important to mention that these sensemaking processes often occurred concomitantly with the performance of BLS tasks such as chest compressions and airway management, since the first goal of resuscitation teams is to provide life support until spontaneous blood circulation is restored. Establishing a clear diagnosis (i.e., cardiac arrest cause) was therefore not required before initiating basic treatment. Advanced treatment was, in turn, administered by allocating available resources (knowledge and technologies) to emergent tasks. Utterances such as "we need an orderlie to take over chest compressions" or "can you find a computer?" show how interdependencies between resources, such as knowledge, skills, and technologies, were managed as events unfolded.

4.2. Knowledge and role interdependence

In terms interdependence patterns, we found evidence that resuscitation teams most often deal with interdependencies between team members as evidenced by the prominence of handoffs between activities in which individuals changed (Table 2). Here, two considerations were important. On the one hand, we observed interdependencies between roles. When interdependencies between roles (but not expertise) were managed, these were often related to repetitive, time- and physically demanding tasks such as chest compressions, ventilation, or defibrillation. Under these circumstances, managing knowledge and expertise interdependencies was less important, since all members present were skilled in performing chest compression and ventilation (BLS). Handoffs between activities involving BLS tasks were often the type in which only the team member changed, but the task and the technology did not. On the other hand, interdependencies between members also manifested themselves in terms of expert knowledge. More complex knowledge tasks such as leadership, advanced airway management, drug administration, cardiac rhythm analysis, and echocardiography were less dependent on team role – which was flexible – and more dependent on expertise and domain knowledge.
Handoffs between activities involving ALS and other knowledge intensive tasks were often complex handoffs, where at least two attributes changed. For example, in one of the cases, a cardiologist was not part of the initial team. However, the team suspected a cardiac (as opposed to non-cardiac) cause after consulting the EMR. The cardiologist on call was then contacted and asked to perform an echocardiography using an ultrasound machine. Under such circumstances, a complex handoff was required: between individuals (based on expertise), technologies (highly specialized), as well as between tasks, since performing an ultrasound requires hands-off time (i.e., time in which chest compressions need to be stopped).

4.3. Task interdependence

Apart from complex interdependencies among team members (based on either role or knowledge), we also observed high levels of task interdependencies. While some of the tasks presented sequential interdependence, others were performed simultaneously. For example, chest compressions and ventilation are two sequential tasks, performed in cycles. The ALS protocol suggest that thirty chest compressions should be followed by two ventilations, and vice-versa. On the other hand, some BLS and ALS tasks exhibited simultaneous interdependence. For example, two-minute cycles of chest compressions, drug administration and electrical activity assessment were concomitantly performed with information retrieval and leadership tasks. Here, we observed that task interdependencies did not mirror interdependencies between team members' roles. However, task interdependencies were more likely to mirror interdependencies between team members' knowledge. This is perhaps not surprising, since complex tasks require domain knowledge and expertise, which in a resuscitation situation are scarce, since there is only one anesthesiologist or cardiologist on each resuscitation team.

Table 2. Handoffs in resuscitation teamwork and implications for coordination

What changes?	C1	C2	C3	C4	C5	C6	C7	Handoffs coordination strategies
People	74%	85%	73%	94%	79%	95%	81%	• Used for repetitive or physically demanding tasks such as chest compressions, that do not require specialized knowledge. • Interdependencies are managed by means of communication strategies. • Require explicit coordination between team members. Coordination is achieved via communication and pre-defined structures (e.g., protocols).
Task and technology	2%	2%	1%	0%	0%	0%	1%	• Frequent in situations in which technologies are task-oriented. • Do not require high degrees of coordination among team members. • Imply a heightened demand for both task knowledge and expertise in technology usage. Switching costs may be incurred, due to high cognitive demands.
People and technology	1%	4%	5%	0%	8%	0%	0%	• Frequent in situations in which work handoff occurs before task completion. • Common for tasks requiring interdisciplinary knowledge, or when a certain approach fails to produce expected results. • Involve high degrees of implicit and explicit coordination, since interdependencies between technology and specialized knowledge, as well as between team members, need to be managed.
Task and people	13%	2%	12%	4%	4%	0%	6%	• Many task and people interdependencies must be managed during this handoff. Simultaneous interdependence between task and technology and sequential interdependence between tasks need to be coordinated in a single handoff.
Task, people, and technology	10%	7%	9%	1%	9%	5%	12%	• Shows the sequential interdependence between certain activities. Each activity implies different tasks and requires different specialized knowledge and technologies, and it requires high degrees of interpersonal and resource coordination.

However, there were also complex tasks that required interdisciplinary knowledge, such as identifying reversible cardiac arrest causes, which can be either cardiac or non-cardiac in nature. For example, across cases we have observed that the task of identifying reversible causes expanded across many activities and handoffs, and required extensive time and attention from the senior physicians and/or team leaders. In such contexts, many handoffs between technologies and individuals occurred before the task was completed.

4.4. Technology interdependence

Technology interdependence was less evident in our dataset, as compared to other types of interdependence. Because the technologies used by resuscitation teams were highly specialized and task-oriented, we observed that technology interdependence often mirrored task interdependence, as evidenced by the low frequency of handoffs in which technology changed, but the task did not (3%). Technologies such as ultrasound machines, ventilators, ECG, or video laryngoscopes performed unique tasks in the context of resuscitation work, and their use required a great deal of domain expertise and technical knowledge. Handoffs in which technology and tasks changed, often required individuals to completely change their mindset and adapt to both new knowledge tasks (e.g., determining electrical activity, identifying reversible causes) and new sophisticated technologies (e.g., hemodynamic monitoring devices and ultrasound).

However, some technologies were used to perform multiple tasks. For example, we observed that the EMR and defibrillator served multiple functions in the context of resuscitation work and were used to perform different tasks. The EMR was mostly used for retrieving medical, pharmacological, and surgical patient history as well as laboratory results. However, it was also used to identify possible reversible causes of cardiac arrests. In a similar vein, the main function of the defibrillator was to administer electrical shocks in cases of shockable heart rhythms. However, the defibrillator was also used to analyze the heart rhythm in the absence of other monitoring tools and track time in pacing BLS tasks. Conversely, we also observed that some tasks required the use of multiple technologies in order to be completed. For example, identifying reversible causes sometimes required the use of multiple tools and artifacts. A combination of the EMR, an ultrasound scan, and the ALS protocol (which provides a mnemonic device used for remembering possible reversible causes of cardiac arrest) was often used when trying to identify possible reversible causes. While a specific use sequence was not evident, these technologies were interdependent in the sense that failing to complete the task using one of the tools led team members to use another. Using multiple technologies to perform a task often required a number of experts with different domain knowledge, suggesting both task and technology complexity.

5. Discussion

The purpose of our study is to investigate the interdependence patterns exhibited during resuscitation teamwork, and to derive implications for handoff coordination in complex and dynamic work environments. Our investigation reveals two main patterns of socio-technical interdependence. On the one hand, we find that activities involving simple, repetitive tasks do not create complex interdependencies and handoff coordination needs. Performing simple tasks requires neither interdisciplinary knowledge, nor complex technological capabilities. Consequently, transitioning between work activities under these circumstances usually involves simple handoffs, where one attribute changes. Such handoffs, we find, require time management and resource coordination, with the purpose of minimizing hands-off time and maximizing efficiency gains. On the other hand, we find that activities involving complex tasks create multiple interdependencies between knowledge and technological resources. Performing such activities requires interdisciplinary knowledge, and the capabilities of a single technology are often exceeded. Transitioning between work activities with high human resource and technological demands usually involves complex handoffs, where two or more attributes change. Such handoffs, we find, often necessitate improvisation, as well as high degrees of resource and interpersonal coordination. We elaborate on these findings below, and discuss their implications for handoff coordination in organizational settings characterized by high levels of task uncertainty and work complexity.

First, our findings suggest that simple or repetitive activities requiring low levels of expertise and technological complexity do not create complex interdependencies and handoff coordination needs. In their study of a banking call center, Pentland et al. [5] identified low frequencies of handoffs in which an only organizational individuals changed, but the task and technology remained constant. Because the banking call center is a work system in which tasks are pre-defined and sequentially distributed across organizational roles and technologies, instances in which tasks are not completed before being handed over are rare or non-existent. However, the authors speculate that such handoffs should be more frequent in environments with time-demanding tasks, but less reliant on expertise [5]. Unlike the banking call center the authors investigated, the work of resuscitation teams is partly dependent on repetitive and time-demanding tasks, which require lower levels of expertise. According to the ALS protocol and best practices, performing more than thirty chest compressions leads to physical exhaustion and consequently, to chest compressions that are not sufficiently deep. This, in turn, can severely compromise the resuscitation efforts of the team. Therefore, it is because of the need to "change hands" frequently that this handoff type appears with such frequency in our dataset. While these interdependence patterns create the need for multiple handoffs, such handoffs are simple, and do not require high degrees of coordination.

Because in most organizational settings repetitive tasks are easy to predict, research shows that coordinating task interdependencies requires formal coordination such as standardization, plans, rules and roles, with the purpose of maximizing efficiency gains [11]. In our case however, there was a high degree of uncertainty even in relation to simple or repetitive tasks. For example, roles needed to be established as the resuscitation events unfolded, and tasks were assigned ad-hoc. Furthermore, the performance of simple tasks was highly dependent on all other tasks that needed to be performed, either simultaneously or sequentially. As such, under conditions of uncertainty and high complexity, transitioning between work activities requires ongoing temporal coordination, mutual adjustment, and explicit leadership and communication processes such as indicating task status, or assigning tasks based on availability of free-hands and technological resources.

Second, we show that domain-specific tasks often require equally complex technologies, and create additional demands on individuals and teams in terms of expertise. Because of the high expertise levels required, we find that interdependencies between complex tasks often mirror technology and knowledge interdependencies. That is, domain-specific tasks often require specific expertise and specialized technologies. Therefore, when interdisciplinary work transitions between complex tasks, it often transitions between both technologies and required expertise.

However, we also find that complex, inter-disciplinary tasks may require multiple technologies and diverse domain-knowledge and expertise. Such tasks create complex interactions between technology interdependencies, and necessitate high degrees of handoff coordination. In order to perform these tasks, technological and knowledge resources need to be temporally coordinated. That is, they both need to be available as new task demands arise. However, under conditions of uncertainty and emergent task requirements, coordinating scarce resources can be challenging, and often requires emergent planning and improvisation [12], [29], especially in situations requiring immediate response to novel and critical situations. Under such conditions, "intervention is often necessary irrespective of specialization, formal role, and reputation" [12: 1158]..

Because complex task requirements often mirror knowledge and technological requirements, handoffs between activities involving knowledge intensive tasks are likely to be complex, where many attributes change. We find that when complex handoffs are required, coordination demands are high. Many types of interdependence need to be coordinated at once, and require both interpersonal and technology coordination. Furthermore, because an individual may work across many knowledge-intensive tasks and complex technologies, such handoffs are cognitively taxing, switching costs are incurred, and efficiency may be compromised [5]. Previous research on coordination in complex organizations shows that handing work over between technologies with different capabilities and input standards may require significant time and effort, and imply a heightened demand for technological expertise [5], [8]. Additionally, ensuring timely application of expertise in environments characterized by uncertainty requires knowledge-sharing, reliance on ad-hoc teaming, cross-boundary interventions and improvization [12], [29]. In environments characterized by both work complexity and uncertainty, balancing time-demanding work requirements with improvisation and ad-hoc coordination is necessary.

Our study has several implications for research. First, we show that environments characterized by high levels of uncertainty and socio-technical complexity, such as healthcare, exhibit strong interdependencies between available resources (knowledge, technology), which are often scarce. Furthermore, these resources may be needed to perform multiple, simple tasks, but they also may be needed for the completion of one complex task. We find that using technology and knowledge resources across tasks necessitates many handoffs, but low coordination levels. Conversely, complex tasks demanding interdisciplinary knowledge and complex technological capabilities require fewer handoffs, but have higher coordination requirements. To the extent that work organizations demand increasingly sophisticated knowledge and technological resources, understanding how socio-technical interdependencies impact handoff coordination will invariably enhance the explanatory power of future organizational studies.

Second, we add to literature on interdependence and coordination [e.g., 3, 11–13] by showing that work handoffs in environments characterized by high levels of task uncertainty and complexity necessitate both interpersonal coordination and ad-hoc resource management. When work passes from one activity to the next, complex interdependencies between individuals (based on role or expertise), technologies (highly specialized), as well as between tasks (knowledge intensive) need to be temporally coordinated. Moreover, we show that effective handoff strategies are not only dependent on communication processes [e.g., 24], but also on mutual adjustment, and on ad-hoc resource matching when dealing with contingencies. However, other work environments have different human and technological capabilities, which influence the complementarities exhibited by different types of interdependence, and the handoffs they entail. Uncovering handoff unique to particular work environments is important for devising strategies necessary to coordinate and integrate work. How tasks, technologies and individuals interact in contexts other than resuscitation interventions, and with what consequences for handoff coordination, is an open area for further investigation.

While shedding light on handoff coordination in environments characterized by task uncertainty and work complexity, our study is not without limitations.

First, our dataset is limited to seven cases of resuscitation interventions. While each of the cases provided unique insights into how resuscitation teams manage complex interdependencies, data saturation may not have been reached [31]. Furthermore, since the video cameras moved as the team members were moving, it was at times difficult to conduct meaningful observations from a bird's eye perspective. To compensate for some of the blind spots in our data study, future research could conduct both observations and interviews with members of resuscitation teams, focusing exclusively on interdependencies between simultaneous tasks and the coordinative actions and mutual adjustments they require.

6. References

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