

Loosely Formed Patient Care Teams: Communication Challenges and Technology Design

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ABSTRACT

We conducted an observational study to investigate nurses' communication behaviors in an Emergency Department (ED). Our observations reveal unique collaboration practices exercised by ED staff, which we term as "loosely formed team collaboration." Specifically, ED patient care teams are dynamically and quickly assembled upon patient arrival, wherein team members engage in interdependent and complex care activities. The responsible care team then disassembles when a patient leaves the ED. The coordination mechanism required for these work practices challenges nurses' communication processes, often increasing breakdown susceptibility. Our analysis of the ED nurses' communication behaviors and use of communication channels highlights the importance of maintaining team awareness and supporting role-based communication. This points to the need for explicit efforts to coordinate tasks and informative interruptions. These findings call for the design of future communication technologies to meet the needs of loosely formed collaborative environments to provide team-based communication, lightweight feedback, and information transparency.

Author Keywords

Communication Behaviors, Loosely Formed Patient Care Team, Emergency Department, nursing work, collaborative work.

ACM Classification Keywords

H.0 [information systems], K.4.3 [organizational impacts] J3.Life and Medical Sciences: Health, Medical Information Systems.

General Terms

Performance.

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INTRODUCTION

Team collaboration in complex workplaces, such as healthcare and transportation domains [9, 13, 15, 23, 24, 31, 37], has been of immense interest to the CSCW community. These settings are characterized as being dynamic and information-rich, such that the success of their collaborative efforts relies upon effective communication among the team members. Previous studies in healthcare [4, 27] have shown that a lack of understanding of effective communication practices can lead to medical errors that threaten patient safety. Yet, effective communication in medical settings is not easily achieved since work collaborations in these settings exhibit distinctly different behaviors from other collaborative settings. In this paper we coin this unique work practice exhibited in medical setting as "loosely formed collaboration".

Collaborative work in many organizational settings is fairly stable [30], with team members generally knowing whom they collaborate with on a daily basis. However medical teams, particularly those in the ED, are often dynamically formed. As such, team members may not know *a priori* who they need to collaborate with when delivering care to individual patients. Furthermore, medical teams may consist of spatially distributed members who may simultaneously belong to multiple medical teams that are dynamically formed to treat different patients. In essence, these collaborative patient care teams are loosely tied together, thus posing considerable challenges to the communication required for time-critical patient care delivery.

Ephemerally formed collaborative teams have been studied previously. For example, trauma resuscitation teams were dynamically formed upon patients' arrival [28]. Without prior knowledge of other team members' roles, the trauma team members had to first explicitly reveal their roles in the collaboration process in order to concertedly perform surgeries under time constraints and stress. Role-based coordination was also common in less critical domains like the film industry where temporary collaborative teams are crucial to their success [5]. Although these studies made efforts to elucidate the importance of roles in dynamically formed team collaborations, they did not detail the communication behaviors and channels used for supporting

these collaborative behaviors, nor did they introduce the concept and characteristics of “loosely formed collaboration teams”. The current work reported in this paper contributes to a better understanding of the communication behaviors within and between loosely formed collaborative teams.

We present the findings of an observational study conducted in an ED, focusing on nursing communication to understand the communication challenges in loosely formed collaborative teams. We examined ED nurses’ work and their use of communication channels *in situ*. The focus on the nurses is justified for studying the communication of loosely formed collaboration since nurses are the ones who “weave together the many facets of the [healthcare] services and create order in a fast flowing and turbulent work environment” [1].

This study aims to answer the following questions:

- How does the unique work nature of nursing work influence communication behaviors in the ED?
- What does the use of communication channels reveal about the communication behaviors in the ED?

RELATED WORK

Communication is a fundamental activity for collaborative work. In most office settings, collaboration can be readily achieved through communication among well-structured teams [30] as workplaces often consist of clearly defined work boundaries and explicitly distinguished work teams. In other more dynamic settings such as in the London underground line control room [13], communication could also be quite easily conducted among the collocated Line Controllers, Divisional Information Assistants (DIA) and DIA trainees who coordinated the collaborative work through a variety of cues including eavesdropping of conversations and subsequent responses. Yet, the knowledge gained from studying the collaborative behaviors in these relatively stable work environments may not be applicable to the highly dynamic team collaborations, such as the medical setting.

Comparing with these settings, collaboration in medical field is more complex and dynamic [3, 6, 17, 31]. As such, much research has been conducted to examine important aspects core to work coordination and collaboration in healthcare. These include temporal coordination [2, 24], shift cycles [38], spatiality [3], artifact use [37], redundancy [8, 33], sense-making [23], information sharing [31], and communication breakdowns [24, 35] and workflows [9]. In particular, it has been found that improving coordination-related communication can potentially increase work efficiency in patient care [14]. This is particularly relevant to nursing work as nurses have been found to spend more than 30% of their time on communication-related activities during work [14].

Collaboration in time-critical medical settings is characterized by rapid configuration and reconfiguration of team members [25]. This is due to the increasing

specialization of modern medicine [29] that a single patient care team typically requires the involvement of many different professionals [31]. For example, a team treating a chest pain patient usually consists of a cardiologist, a neurologist, a charge nurse, registered nurses, a radiologist, technicians, and a case manager. As patients are continually admitted and discharged, each medical staff is often required to simultaneously participate in multiple patient care teams, each with distinctly different team members [25, 29]. These healthcare teams are often ephemerally and loosely formed within a short period of time, especially in urgent situations such as those formed in emergency departments. Yet members of these healthcare teams may not necessarily be collocated at the time of team formation. Thus it is not uncommon that team members are not immediately aware of other members in the team and their locations.

Given the dynamic nature of medical collaboration, to maintain effective team communication among healthcare providers within and across patient care teams is inherently challenging. Although communication technologies have been widely deployed in medical settings for addressing communication problems found in healthcare, discrepancies have been identified in the intended and the actual use of communication devices in healthcare [32]. Other studies conducted in the highly dynamic and time-critical healthcare settings have reported that role-based information distribution may support coordination-related communication by expediting information gathering and sense-making processes [22], and explicit role-identification facilitated conversations necessary for time-critical coordination [28]. These works have revealed the significance of roles in time-sensitive communication in such collaborative settings, but also called for the need to perform a more comprehensive analysis of the overall communication practice for time-critical teamwork.

Nevertheless, there has been little work done in the specific issue of communication behaviors within and among the dynamic and loosely formed healthcare teams. This paper reports findings from a field study that addresses specific communication problems in the highly dynamic and time-critical healthcare setting of an ED. The goals are to first acquire a better understanding of the communication behaviors exhibited in the loosely formed medical teams, and to provide useful insights to the design of future communication technologies for this type of collaborations.

METHODOLOGY

This study was conducted in an Emergency Department (ED) affiliated with a teaching hospital. The goal of our research was to understand nurses’ communication behaviors and the communication channels used in the ED.

Setting

The ED is divided into five areas: triage, ED1, ED2, ED3, and physicians’ charting room. In our study, we shadowed ED staff in all five working areas. The ED staff we studied

included 3 charge nurses, 15 registered nurses, 2 float nurses, 5 residents and 4 attending physicians, 2 front desk clerks and 1 hospital unit service coordinator (HUSC). The charge nurse of the ED is responsible for managing and expediting patient flow in the entire ED. Float nurses are mainly required to support nursing work in ED1 to help the registered nurses with care for the trauma patients who typically need close monitoring such as acute life support (ALS) procedures.

Since the focus of this paper is on nursing communication, we describe our findings obtained from the entire ED, with the exception of the charting room that is primarily for physicians' use.



Figure 1. A Floor Map of the ED

Triage is where nurses first conduct a brief assessment on a patient's condition and quickly decide the urgency before handing the patient off to an ED nurse assigned to the patient.

The ED consists of three units depending on the severity of patients' illnesses: ED1, ED2, and ED3. ED1 is a 16-bed unit that is perceived to be the central area in the ED for severely ill and trauma patients. This unit is partitioned into 6 enclosed rooms and a large space with 10 beds separated by curtains. All beds are equipped with a cardiac monitoring machine. ED nurses are assigned with a number of beds at the beginning of each shift. For example, a nurse who is assigned to bed #1 to #4 in ED1 will be responsible for patients admitted to these beds. The nursing station is an open area in the center of ED1 and patients' beds surround the nursing station as shown in Figure 1.

Patients with moderate illness or with psychological problems are assigned to ED2, which has 7 beds assigned to 2 nurses. ED3 is a 9-bed single-room unit for patients with mild illnesses, such as a cold or sore throat. It is located the furthest from ED1 and has an enclosed nursing station.

Data collection

Data was collected through field observations, including nurse shadowing, formal and informal interviews. We first observed communication flow in the ED, paying special attentions to nurse communication that mainly took place in the triage, ED1, ED2, and ED3. We also shadowed 20 ED

nurses working in all the ED units. The goal was to gain an in-depth contextual understanding of how ED nurses communicate with medical staff both inside and outside the ED, and to identify the communication channels used and the personnel involved in the communication process. When situation permitted, we asked them questions to elucidate the nurses' actions.

In total, 210 hours of observations were conducted over a period of 6 months. Each observation session ranged between 2 and 6 hours. Our observations were distributed across different time periods from early mornings to late evenings on both weekdays and weekends, but not including night shifts. 6 formal interviews were conducted to gather nurses' opinions and perceptions regarding ED communication practices and communication channels. The interviews were recorded and transcribed for analysis.

Data analysis

The data were first analyzed using various diagramming methods including affinity diagram, communication diagram and flow diagram [7]. Communication and flow diagrams helped us understand how and through which communication channels the ED nurses communicated with other staff working both inside and outside the ED. In addition, open coding was used to look for recurring themes emerging from the data regarding nurses' communication behaviors. We specifically coded data for communication channels used in the ED. For example, when mobile phones were used for communication, we identified the process of the phone calls, the sender, the recipient, the content, the objective, and the actions taken. Communication breakdowns were also noted and coded for analysis.

FINDINGS

Through our observation and data analysis we identified critical factors in supporting nursing collaborations at the ED. This section provides a detailed picture of the formation of an ED patient care team, the communication behaviors of the ED nurses, and the important factors contributing to effective patient care in the ED.

Overview of patient care team formation

As described previously, unlike many organizational settings where collaboration occurs in fairly stable teams, patient care teams in the ED are loosely tied together and each ED staff may participate in multiple patient care teams simultaneously. In this section, we describe the formation process of patient care team in the ED and explain why we consider it as "loosely formed team collaboration."

Figure 2 depicts how these patient care teams are loosely formed. Each ED patient care team is made up of a group of core members plus several peripheral members depending on the needs of a patient. An ED patient care team is formed dynamically *in situ* by the assembly of a group of core team members, including an ED nurse, the charge nurse, a resident, and an attending physician upon the arrival of a patient. These core members work together to

plan, update, and execute necessary care to the patient until the patient is discharged from the ED. Peripheral members such as a float nurse, a technician, an interpreter, HUSC, and a janitor may join the team as needed. These peripheral team members would leave the team as soon as their designated task is completed. To illustrate, a patient will be assigned to a bed by the charge nurse on his/her arrival and

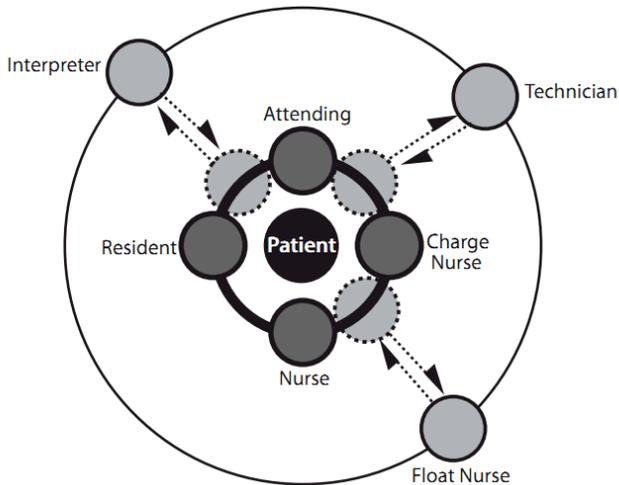


Figure 2. Core and peripheral members of a loosely formed patient care team. Dark and light grey indicate core and peripheral members respectively. The dotted circles show that peripheral members join the care team temporarily.

both the charge nurse and the nurse with the bed assignment become the first core members of the ED patient care team for the patient. ED residents and attending physicians on duty will then be notified of the new patient through the electronic patient board displayed on a desktop computer. An available resident and an attending physician will coordinate the task and subsequently join the patient care team. The core members may call for services of other peripheral staff for ad-hoc collaborations based on the patient’s condition. For example, the ED nurse may call a float nurse to temporarily join the care team to help with drawing a blood sample. But the float nurse would typically leave the team as soon as the task is completed so that s/he will be available for work requests from other care teams.

The unpredictable arrival of patients and the variability in severity of their illnesses complicate the formation of ED care teams (Figure 2). Specifically, an ED nurse is often a core member of 4-5 patient care teams simultaneously. Similarly it is not unusual that a resident is accountable for 6-7 patient care teams concurrently and attending physicians are generally involved in an even greater number of care teams. Overall, the charge nurse is a core member to all the patient care teams and is the key coordinator for expediting overall patient flow in the ED.

The underlying team dynamics poses considerable challenges to achieving effective communication. First, the team members are often spatially distributed. Residents and

attending physicians usually work in the physicians’ charting room and nurses are often found in a patient room or a nursing station. Such spatial separation makes communication between care team members difficult. Thus spatial movement becomes necessary during team collaborations. Moreover, care team members, particularly those of different roles, often work in different shift cycles and temporal horizons [24], adding more challenges to the team formation and reorganization process. This is aggravated by the temporary join-in of peripheral members such as a float nurse and an ED technician. Lastly, the research site being a teaching hospital further complicates the communication process. The involvement of both residents and attending physicians, who have different authorities and responsibilities bound by generally ill-defined work structure [24, 29], in the patient care teams undoubtedly increases the complexity of doctor-nurse and doctor-doctor communications.

ED nursing communication

ED nurses have to constantly communicate with different care team members in order to stay aware of patient care progress within the collaborative work. Consequently, nurses often proactively talk to the charge nurse, residents and attending physicians to obtain updated patient care plan.

Communication channels

Communication technologies in the ED include overhead paging, alpha paging, mobile phones, and stationary phones; face-to-face communication is also common during work. Although other artifacts such as patients’ medical records and digital patient boards are also used for communicating important medical information among clinicians, in this paper we only focus on verbal communication behaviors among care team members. The channels through which verbal communication takes place and their typical use by the ED nurses are described in more detail in the following scenario.



Figure 3. Communication devices at ED – Overhead page and stationary phones (left, in a circle), and mobile phones (right)

Sandy, an ED nurse from ED1, received a call to her mobile phone from Sylvia, the charge nurse, and was notified that a patient would be admitted to bed #3. After having examined the patient, Sandy broadcast an overhead paging to the entire ED to request a technician. Soon after,

David, an ED resident, came to examine this patient. On his way back to the physician's charting room, David briefly stopped by the nursing desk to inform Sandy his initial treatment plan. While Sandy was preparing the orders, she called the radiology department using a stationary phone to check the radiology schedule for another patient. When she found out the radiology services were behind schedule, Sandy sent a text message through alpha paging along with her number to Cathy, a resident in another department, to ask her to call back.

As shown in this scenario, each communication channel has its typical usage: overhead paging for broadcasting impending arrival of ambulance and conveying messages to a particular personnel or a target group; alpha paging for reaching people outside the ED such as an interpreter or a non-ED physician; stationary phones for inquiring about patient situation by other departments and receiving calls in response to alpha paging; mobile phones for reaching ED staff such as technicians, the charge nurse or physicians; and face-to-face interaction for getting immediate response.

Specifically, the mobile phones used in the ED are similar to those available for everyday use (Figure 3: right) except that there is no caller ID feature, nor does it keep a record of incoming calls. Mobile phones are randomly distributed to each ED nurse, physician, and technician at the beginning of a shift and must be returned at the end of their shift. Thus, each person's mobile phone number may vary in different shifts. As such, the charge nurse usually displays a paper list of phone numbers with respective staff's name in the nursing station at the beginning of a shift.

Additionally, a drawback of the overhead paging is that it fails to reach some of the areas in ED3 such as patient rooms in the corner.

Challenges to effective communication

Our study reveals new challenges that are present in the ED that need to be addressed so that nurses can more effectively communicate and collaborate, in addition to those already reported in previous literature [3, 24].

Frequently changing collaborative teams. The need for frequent assembly and subsequent disassembly of patient care teams in the ED poses major threat to effective communication. With the typically high turnover of patients in the emergency medicine setting, each care team member has to frequently adapt to the changing configuration of collaborators for individual care teams that s/he is involved in throughout a shift. Despite the availability of electronic patient boards for identifying the frequently changing collaborators, this information can only be gathered by examining individual patient lists for each ED unit rather than the arrival of patients, which poorly supported the rapid reconfiguration of team members .

Spatial movement for collaboration. Despite the availability of a variety of communication technologies described above, collaboration with spatially distributed

and highly mobile personnel in the time-critical ED setting is no trivial task. In a loosely formed patient care team as shown above, the ED nurses communicate with a variety of people, both in and outside of the ED. The people they communicate with are either the core team members or peripheral members in the patient care teams that a nurse simultaneously participates in. Collaborating with many different medical staff who are not always collocated is particularly challenging. To cope with this, some medical staff choose to physically move to their team members' default working area, e.g., the charge nurse spends most of her time in ED1. However, this strategy does not always guarantee one to timely find team members, since medical practices are highly mobile such that ED staff often move around while carrying out their work.

Temporal coordination of collaborative tasks.

Coordination of medical work is further complicated by varying shift cycles, temporal horizons, and job nature of collaborators. For instance, the ED nurses and residents have different shift cycles. ED nurses work on 12-hour cycles whereas their bed assignment usually changes every 4 hours. The residents have varying lengths of shift from 8 to 12 hours with different starting times depending on the length of the shift. Thus, the residents may have to work with different nurses for a single patient during a shift, causing troubles in communicating and recognizing team members in loosely formed team collaborations.

Unpredictable interruptions. Since ED work often deals with unexpected and emergent situations, it is almost impossible to foresee and plan for a patient's visit ahead of time. Because of this, interruptions are inevitable in nursing work. Consequently the need to manage these unpredictable interruptions, from both perspectives of being an interrupter and an interruptee, increases the complexity in ED communication. The ED nurses have different strategies to manage interruptions: pausing current task to respond to an interruption, taking notes as a reminder to respond later, or asking a colleague to handle the interruptions.

Coordination across multiple care teams. The communication challenges described above only evolve around a single patient, hence a single patient care team. However, when these challenges are extended to multiple patients and across multiple care teams, the complexity in communication and work coordination become highly intertwined and present amplified challenges to effective communications. Our analysis shows that the available communication technologies in the ED support certain aspects of collaborative work but none of them can address the complexities of communication needs in the loosely formed collaboration dominated in the ED.

Supporting communication in loosely formed patient care teams

Our analysis identified three key factors that are important to ED nurses' communication within the loosely constructed team collaboration process. They are: maintaining awareness within a team, making informative

interruption, and supporting role-based calling. Table 1 summarizes our analysis on if and how these three key factors are being supported by the communication channels described earlier.

	Overhead paging	Alpha paging	Stationary phone	Mobile phone	Face-to-Face conversation
Team awareness	++	+	x	x	+
Informative interruption	++	++	x	x	++
Role-based communication	+	+	x	x	x

Table 1. Varied support of communication channels on ED communication needs
 (++ : Good Support, + : Partial Support, x : No Support)

Maintaining team awareness

The loosely formed nature of collaboration makes it challenging to maintain awareness of patient care plan and progress among team members. Since each care team is made up of a different configuration of personnel who are often spatially distributed over the ED, it is not easy to maintain a natural awareness of individual teams’ operation and the respective patients’ status. Our observations also showed that nurses were often required to actively seek information in order to stay aware of the collaborative work. The following scenario shows how a nurse sought to maintain awareness in her care team.

Kate, an ED2 unit nurse, called Tyler, a resident, to update him on a stationary phone call from Internal Medicine that a patient in bed #17 needed a CAT scan. Tyler did not answer so Kate sent him an alpha paging instead. She also needed to update Joan, the charge nurse, to arrange a float nurse and a technician to transport the patient to the Radiology Department downstairs. Joan was passing by ED2 at that moment so Kate stopped her and gave her a verbal update. Joan also told Kate right there that she would look for relevant personnel to take the patient for a CAT scan.

In this scenario, Kate employed several communication channels to try to reach the patient care team members. After failing to reach Tyler at his mobile phone, Kate chose to send an alpha paging so that Tyler would get to the message on his pager later. Kate also grasped the opportunity to have a face-to-face conversation with Joan while she was walking by the unit. In this way, Kate was able to off-load the task of making arrangement for taking a patient for CAT scan to Joan. This scenario shows how spatial distribution, as part of the nature of loosely formed collaborations, is inherently challenging for achieving effective communication. In turn, this challenge aggravates the already loaded nursing work.

Among the communication technologies used in the ED, nurses generally prefer alpha paging to mobile phone since alpha paging will leave records in recipient’s pager and it also offers the benefit of *plausible deniability* [20] such that the recipient may postpone responding if s/he is busy at the time when the message arrives. Regardless, face-to-face conversation is often the most preferred channel as it allows direct communication and clarification, as well as getting immediate feedback. Thus, it is not uncommon that nurses make purposeful trips in the ED in order to talk to other team members directly.

On the other hand, overhead paging is frequently used for broadcasting announcements in the ED. It provides rich workplace awareness to all the ED personnel. However, the broadcast nature of the overhead paging may also distract personnel who are not the intended recipient of the message and may be interruptive to other ongoing patient care. The following quote from Brian, an ED nurse, reflects the potential distraction caused by overhead paging.

“...I try to listen to every announcement from overhead paging since I may need to hurry up and help someone.”

Informative interruption

Interruptions are inevitable, and sometimes excessive, in ED practices [18]. A simple case is when a new patient is assigned to a bed while the nurse responsible for the assigned bed is busy caring for other patients. In this case, the nurse is notified of, thus interrupted by, the arrival of the new patient. The emergent nature of the ED work makes it ever more important for nurses to constantly re-prioritize their tasks in response to the unpredictability of ED patient care [4]. However, such information, pertinent to interruptions emerged in the course of care, that is needed for task prioritization is not always available. This lack of information appears to be a barrier to effective communication and quality patient care.

Paul, a nurse in ED1, was at bed #5 drawing a blood sample from the patient. His mobile phone vibrated. Not knowing what the call was about, he decided to ignore it, unaware that it was in fact an emergency call to help with a critically ill patient in another room.

This scenario clearly shows the importance of conveying the content of an interruption to nurses so that they can decide whether to respond to the interruption or not. We refer to this need as *informative interruption* in this paper. Informative interruption could have made a difference to the nurse’s response to the incoming phone call in the above scenario, which in turn impacted the quality of patient care. Although the lack of caller ID display on mobile phones used in the ED may seem to be the primary cause for this ineffective communication, it is important to note that even if there was a caller ID, the nurse still would not know the content and the urgency of the interruption. Besides, the callee may also be occupied with both hands so that checking caller ID is not possible. Therefore, a caller

ID can offer some improvements but it does not solve the problem.

Instead, informative interruption can be achieved through the use of overhead paging. It however renders itself an interruption to the already highly interrupted ED work practices.

Sandra, a float nurse, heard an overhead paging that a trauma patient would be arriving in 10 minutes. She was taking vital signs of a patient for another nurse, Diana, in ED1. Knowing the imminent arrival of a trauma patient, Sandra quickly documented the measurements and updated Diana before rushing to the trauma room to receive the arriving patient.

Overhead paging, in this case, offers clear benefits in communicating important information to Sandra who can then make informed decisions on how to respond to the unexpected new task. Knowing the content of the interruption allowed her to mentally plan and adjust her workflow accordingly. Nevertheless, while overhead paging offers informative interruption to Sandra, it also creates unnecessary interruption to other ED staff who were not involved in treating the incoming patient.

On the other hand, the informative interruptions can sustain the professional image of nurses in front of patients as patients may not understand that the mobile phone is used for work-related communications, instead of personal matters. To illustrate, Irene, an ED nurse, expressed that,

"...when you are at the bedside with the patient, if [the mobile phone] rings; you pick it up to answer it. Sometimes they may think it's rude. I don't think the patients know it's a work phone. I think they think it's a personal phone. Or it's ringing, ringing, ringing and you are in the middle of doing IV. The patients can go like 'okay it's ringing.' So that is a problem!"

As evident in our study, informative interruption allows nurses to plan their work in response to interruptions, and uphold their professionalism in front of patients. Since unlikely can interruptions be entirely avoided in the ED, it is thus useful to make interruptions as informative as possible without creating an overly disruptive environment and revealing any confidential patient information.

Role-based communication

In medical care, services are often required from a specialty or an expertise rather than a particular individual. In other words, any individual in that specific role will be able to fulfill the requested task or service. Float nurses are a typical example: when an ED nurse needs help with her patient care tasks, any of the available float nurses would be qualified to provide the needed service. Similarly, any available technician can perform an EKG test. This unique practice indicates that the ED communication may rely on specific working roles, instead of individuals. Nevertheless, current communication channels do not provide sufficient

support for the role-based work coordination, as indicated in the following case.

Barbara, an ED nurse, needed an EKG at bed #8. She looked at the list of mobile phone numbers and called Kevin, the first technician on the list. Kevin answered that he was with a patient for a CAT scan. Barbara then called Thomas, the second one on the list. He did not answer. Next, she called Carlos who was available.

Apparently mobile phones failed to support desired role-based calling as shown in the scenario. The targeted point-to-point mobile phone calls can be time-consuming when repeated phone calls are needed. Moreover, this has led to an uneven workload distribution since the person at the top of the phone list was always called first, as observed in the study. Thus, to utilize these limited resources more effectively and efficiently, a system should ensure that people in specific roles are aware of and able to promptly coordinate and distribute work requests to a particular role, since a fair distribution of work is essential for sustaining job satisfaction and team morale.

On the other hand, alpha paging and overhead paging can be used to reach recipients based on their roles. Alpha pager numbers are associated with recipients' roles. That is, an alpha page will be broadcast to all the personnel in the specific role as specified by the sender. Needless to say, overhead paging can easily convey messages to the targeted staff working in a particular position.

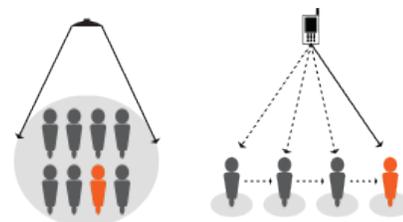


Figure 4. Role-based calling is well-supported by overhead paging (left), and poorly supported by mobile phones (right). Black and orange figurines represent people contacted, but unavailable and people available to work, respectively.

To revisit the above scenario where Barbara was looking for service of a technician, she could have made an overhead paging like "EKG to bed 8 please." Kevin and Thomas who were busy at the time would unlikely respond whereas Carlos who was available to take on a work request could then respond by bringing an EKG machine to bed #8 and carrying out the requested task. Nevertheless, without knowing who is available at the time, calling a specific role may cause multiple technicians rushing into the room or none of them reacts due to their unavailability. Therefore, although overhead paging and alpha paging can support role-based calling, they are also inherently limited and even leading to communication breakdowns in team collaboration process.

DISCUSSION

As we described earlier, the loosely formed collaborations challenge the use of traditional communication technologies in the ED. It becomes difficult to maintain team awareness while limiting unnecessary interruptions and miscommunications during work. In this section, we discuss two unique characteristics that we identified as critical issues to consider in order to maintain effective communication in loosely formed team collaborations: *explicit efforts to coordinate tasks* and *information transparency at interruptions*.

Explicit efforts to coordinate tasks

We have already described in the previous sections that the uniqueness of the ED patient care teams being loosely formed is attributed to a number of factors. These factors include ED staff concurrently engaging in multiple patient care teams while working in different shift cycles, their spatial separation as a result of the physical layout of the ED, and most importantly their lack of awareness of their collaborators in each patient care team that they belong to. Therefore, it is imperative for the ED staff to make explicit efforts to communicate patient care information with others for the purpose of coordinating and completing tasks.

To achieve explicit task coordination, role-based calling has been found to be useful such that all the ED staff of the same role will be notified of the same message all at once. In this way the requested task can be more promptly carried out assuming that one of the personnel is available to take on the task. However, role-based calling may decrease the efficiency of resource use when *redundancy of functions* [8] occurs. The problem lies in the lack of a feedback mechanism through which responses can be explicitly delivered to the sender. Thus an explicit feedback mechanism not only helps task coordination but also results in more balanced work distribution.

Information transparency at interruptions

Interruptions have been studied extensively in CSCW and HCI. Many of these studies analyzed interruptions in office settings [12, 21]. Nevertheless, these settings differ from an ED as interruptions in the former are not inherently part of the work practices while it is the case for the latter. In particular, the uniqueness of medical work heightens the complexities in interruption management when ED nurses are with patients. Findings from these previous work, thus, may not be applicable for the time-critical medical settings.

Previous research on interruptions taking place in EDs, reported that interruptions had adverse impacts on patient care work such as substantial threat to trains of thought and job efficiency, as well as contributing to job stress, fatigue, and sleep deprivation [10, 16]. Our work provides a different lens on how to deal with interruptions that interruptions can be utilized to support collaborative patient care work.

We have already presented in the findings section how informative interruptions can help facilitate the

collaborative patient care work. By including useful but non-sensitive information with an interruption, people can better determine how and when to respond to interruptions. This can be beneficial not only to the ED personnel but also the patients. As found by Dearden, et al., patients often associate interruptions with potentially disruptive effect on consultation and show negative feelings [11]. Therefore if patients can hear the information and perceive its urgency when interruption occurs, they may believe that the interruption is legitimate and comes from a valid source. Otherwise, they may feel ignored in the middle of a procedure. It is expected that patients will be more receptive to inevitable interruptions even if the interruptions may require the caregivers to deviate their attention and respond immediately.

Since interruptions are inevitable in the emergency setting, it appears worthwhile to design mechanisms to reduce interruptions' potential negative impact while making them better perceived and handled in collaborative work. One way to do this is to increase the level of information transparency when interruptions occur. The degree of transparency is closely related to the amount and the content of information to be revealed to the intended recipient(s) along with an interruption. In essence, if the information within an interruption is appropriately transparent to its recipient, the interruption can facilitate a more informed decision-making or adjustment to a work plan. Our study found that the ED nurses preferred knowing the contents of interruptions so them to decide if they would stop their tasks at hand and respond to the interrupting tasks. This is also why many of them opted for overhead paging, since the message conveyed through overhead paging is transparent to all the ED personnel including its intended recipient. This allows the intended recipient to assess the urgency of the message associated with the interruption and to determine subsequent actions in response. Nevertheless, this transparency afforded by overhead paging may in turn become additional interruptions to the already highly-interrupted ED environment.

DESIGN IMPLICATIONS

Prior studies on communication technologies in medical collaboration presented various design considerations. For example, technologies should be designed to offer communication channels through which an individual can be easily reached by his/her collaborators while the individual can also flexibly adjust his/her availability when needed [26, 32]. On a similar note, the challenges identified in the current study suggest that more robust communication technologies are needed to support the loosely formed collaborative practices in the ED. Specifically, the design of such technologies should encompass the concept of "patient care team" as a unified recipient, rather than only designing for individuals. The goal is to support the intertwined yet complex communicative activities while also allowing individual patient care team members to stay aware of patient situation.

This section presents three design guidelines for supporting loosely formed collaborative practices.

Designing for team-based communication

A loosely formed patient care team allows each team member, including the peripheral members, to join and leave the care team spontaneously as necessitated by changes in patient care tasks or schedule, such as changes in patient reassignment after shift handover or ad hoc collaboration for emergent tasks. Consequently the challenge is to support communication that centers around a patient care team, as opposed to a single recipient or the entire ED staff. Thus the system should allow direct communication with a specific care team to support loosely formed teamwork. In this regard, training for effective teamwork behaviors would be beneficial to the ED staff, which was also reported in [19, 27]. In addition, technology should continually be explored and designed to support these teamwork behaviors.

Another advantage of the team-based design concept is that it supports directed communication to selected members, thus reducing interruptions that may be disruptive to other colleagues. To illustrate, this communication metaphor may be designed in such a way that when a nurse needs to reach the care team responsible for the patient in, e.g., bed #8, s/he can simply press 8 on her mobile phone and leave a verbal message. All the team members involved with patient care for this patient will then receive the information without having to broadcast the message to the entire ED.

Providing lightweight feedback

Our findings echo those identified in prior studies [22, 28] on how role-based communication could help facilitate communication in loosely formed collaborative environments. However, most current technologies that support role-based communication lack the functionality of providing lightweight feedback to the sender [26]. Feedback is important for work coordination so that the sender will know if the work request has been accepted, or the sender may have to look for alternative resources if no feedback is received. On the other hand, feedback is also useful [33] for the recipients working in the same role to coordinate their resources so as to minimize redundancy.

We have shown that it is important to provide lightweight feedback for supporting effective team-based work coordination. However how a feedback mechanism can be designed to be effective and lightweight is challenging. While initiating feedback can be quite easily achieved through, e.g., a simple button press, designing for receiving feedback is more difficult. Factors such as the communication channel used and the timing that feedback is delivered must be considered with prudence, since the arrival of feedback may otherwise present itself as an interruption, thus disruptive, to the recipient's work. Given the heavy workload in the ED, we propose using visual feedback such as pre-defined symbols or color coordination, or audio cues such as designated ringtones to

maintain lightweight while less interruptive to support coordination in role-based communications.

Supporting informative interruption

While interruptions are indispensable in medical settings [18], we have already shown that appropriate level of information transparency that is associated with interruptions is crucial for the intended recipient(s) to make informed decisions on work plans, task activities, etc. Therefore when designing communication tools for these settings, it is important to consider how the intended recipient(s) will receive the information and how the content should be delivered so that an optimal degree of transparency is present while still protecting patient confidentiality. In the meantime, the design should also consider that the information communicated would be transparent enough to allow patients to understand the importance and urgency of the information and their caregivers have to promptly attend to other more urgent tasks. For example, communication devices can signal different ring tones based on the urgency of the tasks so both the nurses and patients perceive a sense of information transparency when using them. Nevertheless, the issues of information transparency with respect to how much, to whom and what kinds of information to reveal deserve further investigations.

CONCLUSION

In this paper, we investigated communication behaviors and the use of various communication channels by ED nurses in the context of their collaborative work practices. Our observations reveal a unique collaborative behavior that we term as "loosely formed team collaboration." Our analysis of the ED nurses' communication behaviors and their use of communication channels highlight the importance of maintaining team awareness, making informative interruptions and supporting role-based communication in the ED. Based on these findings, we suggest three guidelines for designing communication technologies for loosely formed collaborative teams: designing for team-based communication, providing lightweight feedback, and supporting information transparency. Beyond ED practices, loosely formed team collaborations are also present in many other work domains, such as firefighter practices [34] and temporary film projects [5]. The knowledge acquired in the current study may also contribute to a better understanding of more general communication and coordination behaviors in CSCW field.

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