

Coordinating Time-Critical Work with Role-Tagging

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ABSTRACT

A Level-1 US trauma center introduced role-tags in their trauma resuscitation rooms to help team members identify respective medical functions, and to limit the number of people in the rooms to required staff only. We use this in situ experiment with a paper prototype to investigate the role-driven nature of coordination and to identify system requirements for computerized support of role-based coordination in time-critical work. While role information is useful in coordinating time-critical work, our findings show that the current low-tech solution did not provide significant improvement in team coordination. The situations that were most in need of role-identification were the least likely to achieve it because role-tags required work by trauma team members. Similarly, because role-tags allowed workarounds and misuse, they proved ineffective in controlling the number of people in the room. We suggest technological ways of identifying roles to help coordination in the trauma bay.

Author Keywords

Team coordination, role-tags, expertise, health informatics.

ACM Classification Keywords

H.5.3 Groups & Organization Interfaces—collaborative computing, computer-supported cooperative work, organizational design, K.4.3 Organizational Impacts—computer-supported collaborative work.

General Terms

Design, Human Factors

INTRODUCTION

Expertise in team coordination has been a prime topic of research in CSCW. Studies have shown that awareness of team members' expertise, although often tacit, supports collaboration and coordination in finding answers, getting help, solving problems, and making decisions [7,8,10,11,14,22]. Research on transactive memory systems shows that knowledge about each team member's expertise enables team members to obtain more accurate information [9].

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Similarly, research on organizational memory and expertise location supports the idea that finding local and timely expertise is a basic part of everyday work activity [15]. Although face-to-face communication is important in identifying experts in a particular area, researchers have explored other means used by team members to find out about one another's expertise. For example, Borovoy et al. [5] explored wearable technology—GroupWear—to support formative stages of collaborative work in the conference-type settings.¹

Team coordination is especially important in time- and safety-critical work where knowledge of expertise and responsibilities of coworkers can be essential in identifying and addressing problems [7,8,10,14,24]. Studies of coordination in healthcare settings have mostly focused on the role of artifacts [4,27], common information spaces [20], and temporality [2,19]. Unlike office settings, where pre-defined features of work are altered by informal and practical actions carried out by workers [23], attendance to roles in medical settings may have a different or more extended function. For instance, a recent study examined the role-based distribution of information in an emergency department and found that workers' roles facilitated access to and making sense of information [18]. However, the function of roles in coordinating time-critical tasks remains under-explored in socio-technical studies.

In this paper, we examine the effects of a low-tech artifact—a wearable, self-adhesive paper tag indicating each member's role—introduced to achieve improved coordination in the trauma center of a major urban, pediatric teaching hospital. More specifically, this artifact, which we refer to as a *role-tag*, was introduced to assist with identification of the role of each trauma team member. The introduction of this artifact illuminates features of role-based coordination and suggests directions for computerized support of role identification in safety-critical but high-turnover work environments.

Research Context and Research Questions

The fast-paced, high-risk environment of trauma resuscitation is a rich site for studying team coordination and the tools that support it for several reasons: (a) trauma

¹ We note that even the CSCW conference has included “Ask me about” on the paper badges to encourage communication and knowledge about the community's various areas of expertise.

teams form in an ad-hoc fashion for a brief time; (b) medical staff experience high turnover; (c) levels of experience vary; (d) work is coordinated through disciplinary expertise rather than through personal connections; and (e) decision-making depends on information provided within the task context.

In this primarily role-driven coordination work of trauma resuscitation, we ask: How does the institution of role-tagging support work coordination? How does it affect group behavior? How did role-tags usage evolve over time? What issues emerged as a result of wearing role-tags?

The use of role-tags in the trauma center afforded an ecologically valid yet almost controlled experiment for answering these questions. To improve team coordination through explicit role-identification and, at the same time, restrict access to the immediate patient area to medical staff involved in patient care, the Chief of Trauma instituted the role-tagging practice. Over time, the performance improvement staff made changes to this practice, including modifying the distribution of role-tags and introducing new role-tags as teams' needs evolved. Our study commenced two months after the role-tags were initiated and then followed their use over a subsequent six-month period.

COOPERATIVE WORK IN TRAUMA RESUSCITATION

Goals of Trauma Resuscitation

The primary goal of trauma resuscitation is to *stabilize* a critically injured patient. To understand the work of trauma teams, it is important to make a distinction between the concepts of stabilizing and providing a long-term care. The work in a trauma unit centers around stabilization, which consists of several steps: a rapid primary survey of major physiological systems, resuscitation of vital functions, detailed assessment for injuries, and the initiation of definitive care [1]. In contrast to other critical care settings, such as the intensive care unit (ICU), trauma resuscitation requires that care providers identify and treat potentially life-threatening injuries during a short period of time—an average of 20 minutes—while relying on emerging rather than existing patient information. To ensure optimal patient outcome, tasks are simultaneously performed by individual team members. Effective coordination and integration of team activities is therefore needed.

Assembly and Composition of Trauma Teams

Upon learning of an incoming trauma patient, members of the trauma team rapidly gather in the trauma bay—a room in the emergency department (ED) designated for conducting trauma resuscitation. Trauma team members are not dedicated to trauma care only and usually perform other duties between trauma resuscitations. Most trauma teams are interdisciplinary and consist of personnel from a range of medical disciplines. The interdisciplinary nature of team composition is dictated by the anticipated needs of the trauma patient. Because patients come with a range of

injuries, specialists in more than one area are needed to provide timely and efficient care [1].

The care of trauma patients involves surgeons who provide primary care and leadership during resuscitations. A senior surgical resident, a fellow, or an attending surgeon assumes the leadership role (*team leader*), while a junior resident (*physician doer*) performs hands-on evaluation. In some trauma centers, leadership is shared with an ED physician. Other specialists, such as neurosurgical, orthopedic, or pediatric intensive care unit (PICU) fellows, may also be involved. An anesthesiologist and a respiratory technician are needed for managing the patient's airway. A primary nurse is dedicated to patient care, while a technician is responsible for connecting the patient to monitoring devices and other procedures. A medication nurse or pharmacist prepares medications, and a scribe documents the event. Supporting staff includes a radiology technician, nurse administrator, social worker, and security officer.

The size and composition of the team varies depending on the hospital size and severity of injury. A highest-level response to a severely injured patient includes a complete team, while a response to a less injured patient may include only a surgeon, an ED physician and a few nurses. In this paper, we focus on full trauma team activations.

What makes the work of trauma teams somewhat unique compared to other kinds of collocated, time-critical work, is that team members may not necessarily know each other personally. This structural characteristic of trauma teamwork arises from two features of hospital life. First, as Zerubavel described in his observations of the rhythmic structures of social organization [28], hospital life is characterized by five major social cycles: the year, the rotation, the week, the day, and the "duty period." Trauma resuscitation is a setting where most of these social cycles converge at once, and more importantly, only for a brief period of time, and are thus more evident. For example, work of surgical, PICU and ED fellows is structured along an annual cycle; work of surgical, anesthesiology, and ED residents is structured along monthly rotations; work of attending surgeons and ED physicians is structured along daily cycles; and, nurses' work evolves around duty periods (though nurses work in 12-hour shifts, their trauma shifts are only four hours long). This mix of social cycles can result in two sequential trauma resuscitation events differing in team composition. Second, although team members know each other within their own disciplines, they may not know team members from other disciplines. A common example is that trauma nurses often have problems identifying surgical residents.

Role-Based Coordination

The high turnover among trauma team members, the multiplicity of temporal rhythms, and the interdisciplinary nature of team composition highlight the importance of role-identification in coordinating trauma resuscitation work. Rather than using personal connections, as often

happens in other safety-critical environments, e.g., [24], trauma team members coordinate resuscitation tasks using their knowledge of one another's role and expertise. For example, to make a decision, the team leader relies on other people in their designated roles to acquire, retain, validate and report information needed for decision making [21]. When assigning tasks, the leaders often direct their orders to the team as a whole rather than to an individual. For instance, a request for the latest blood pressure value is typically given as "Can we get a blood pressure" vs. "Pat, can you give me a blood pressure." Insufficient awareness of roles and responsibilities of others in the team may lead to delays in both assigning and accomplishing tasks. Note that team members within the same discipline may address each other by first names to micro-coordinate their tasks, e.g., two nurses working on the establishment of an intravenous (IV) access. It is the coordination across disciplines, directed by the team leader that is primarily driven by roles and expertise.

Each trauma team member has a clearly defined role with an associated set of responsibilities [1]. To identify each other's roles, team members use several cues. First, roles can be inferred from team members' positioning around the patient stretcher. Although positioning may vary, some consistencies can be observed across trauma centers: anesthesiologists and respiratory technicians are at the head of the bed; physician doers, nurses and technicians assume bedside positions; and, medication nurses or pharmacists stand close to a medication cart. Team leaders' position varies the most, but is usually configured in a way that provides an overview of the activities in the room. Positioning of team members frequently reconfigures based on the patient status and needs. This in turn makes it difficult to rely only on positioning when identifying roles.

At some trauma centers, roles may also be determined by the color of care providers' scrubs. For example, surgeons may wear green scrubs, nurses light blue and technicians dark blue scrubs. Still, protective gowns required during trauma resuscitation come in uniform colors and size and often cover most of the body making this feature more difficult to use. At our research site, most care providers wear blue scrubs and yellow gowns, which makes distinguishing roles by colors unreliable.

AN OPPORTUNITY FOR STUDY: INTRODUCTION OF ROLE-TAGS

The performance improvement staff led by the Chief of Trauma at our research site became aware of two coordination problems through observations and post-resuscitation video review sessions. First, they realized that team members had difficulty identifying roles of others and communicating information to those who needed it. Second, they observed that trauma rooms were often overcrowded. Overcrowding usually occurs in cases with severely injured patients. In addition to physician and nursing trainees who respond to trauma activations to assist, critical cases attract many observers, including medical

students and residents. In one trauma resuscitation event at our site, we observed 47 different people in attendance.

To help team members identify each other and to reduce the number of people in the room, the Chief of Trauma instituted the practice of role-tagging. Role-tagging was initially limited to the core members of the team and required them to wear a self-adhesive, pre-printed tag on their gowns. As a result of education and feedback through direct contact and video review, the practice was adopted among medical staff as a potential solution to overcoming coordination problems.

To further support role-based coordination, performance improvement staff instituted an additional practice of introductions by team members before patient arrival. After gathering in the trauma bay, team members would briefly state their names and roles in the forthcoming resuscitation. Because the arrival of trauma patients is usually announced with warning of at least a few minutes, it was believed that teams would have sufficient time for this preparatory step.

By the time we started our study, role-tags had been in use for two months. During our study period, two significant interventions were made: the distribution of role-tags was changed from controlled to self-selected and new role-tags were added to better reflect trauma team composition.

METHOD

Research Site

The study took place in a pediatric Level-1 trauma center located in a major pediatric teaching hospital in the US mid-Atlantic region. It is the only hospital in the region dedicated exclusively to the care of children. The hospital serves over 320,000 patients per year, of which about 1,500 are admitted through Emergency Trauma and Burn Service.

Trauma patients at this hospital have sustained injuries caused by a range of mechanisms, including motor vehicle crashes, falls, burns, and gunshot and stabbing wounds. The patients are treated in one of the two designated rooms within the emergency department. Each room can treat two patients simultaneously and has immediate access to lifesaving equipment, monitoring, and medication.

Participants

The participants in this study were trauma team members. Trauma teams at our research site consist of inner and outer core team members. The inner core is comprised of clinical staff with an active role in patient care. It includes a team leader (a surgical fellow or senior surgical resident), attending surgeon, ED physician or fellow, physician doer (a junior resident or a nurse practitioner), anesthesiologist, respiratory therapist, scribe nurse, medication nurse, and two bedside nurses. The outer core plays a supportive role in patient care and consists of a nursing administrative liaison (NAL), a social worker, a radiology technician, a nursing transport technician, a security officer, a trauma coordinator, and a unit clerk.

Data Collection and Analysis

The first author spent six months in the field (December 2009—May 2010), as a research fellow within Trauma Service team at the hospital. She had access to the emergency department, including two trauma rooms, operating rooms, pediatric intensive care unit, and other hospital units. She also participated in weekly surgical conferences, bi-weekly video review sessions with trauma team members, monthly trauma committee meetings, and trauma courses for nurses and other personnel. Data was collected using ethnographic techniques including participant observation, video recording of trauma resuscitation events, documentation review and semi-structured interviews with trauma team members [25].

Observational activities included detailed observations of 56 resuscitation events across shifts, shadowing trauma personnel, clarifying information through informal conversations, and jotting down notes. Observed trauma resuscitation events were also videotaped using a high resolution recording system that includes two cameras and microphones in each of the two trauma rooms. The first author reviewed video recordings and collected additional information about the use of role-tags, such as counts of role-tags usage, distribution of role-tags, tagging activities, and members' interactions with their role-tags.

Semi-structured interviews were conducted with four senior surgical residents, two surgical fellows, two attending surgeons, four ED physicians, four nurses, one technician, and two performance improvement staff members. Interviews lasted between 30 minutes and an hour. Topics discussed included the character of trauma resuscitation work, individual roles and responsibilities, and members' perceptions of role-tags. All interviews were audiotaped and transcribed. We analyzed the data first by listing instances of role-tags usage and then ordering them as they emerged throughout the study. We then tabulated the data and used an abbreviated grounded theory approach with an open coding technique to identify themes and issues related to role-tags usage and their effects on team coordination.

RESULTS

We report our results as they emerged chronologically, across two stages. This allows us to present the evolution of role-tags usage, their effect on group behavior, teams' adaptations to performance improvement interventions, and issues that emerged throughout the study.

Stage 1: Controlled Distribution of Role-Tags

The administration of the role-tagging task was initially assigned to the nursing administrative liaison (NAL). As a liaison between the inner and outer core of the trauma team, the NAL is responsible for ordering labs, scheduling CT scans and calling consultants. Because of the administrative nature of this role, the performance improvement staff thought that the NALs were best suited for enforcing role-tagging practice. Multiple role-tags were printed on an 8.5"

× 11" sheet of self-adhesive paper and were placed outside the trauma bay in a non-standardized fashion, in an area used for administrative work. This arrangement required the NALs to first locate role-tag sheets—they were often seen searching through cabinets—and then bring them to the trauma bay to distribute those to present team members.

The administrative work area is positioned between the two trauma rooms and is used by NALs, nurse educators, surgical residents, and transport personnel for performing their respective administrative tasks. Because each resuscitation event requires a great deal of paperwork, keeping this area in order was challenging and papers were easily shifted from one shelf to another. In addition to the trauma flowsheet for documenting patient encounter, several other forms are filled out by the NALs. Role-tag sheets were often mixed with other papers and sometimes difficult to locate. To expedite the distribution of role-tags, other nurses helped with this task. We observed several issues emerging in this stage.

Distribution of Role-Tags

Role-tagging required NALs to be proactive in distributing role-tags and tagging team members: Because NALs owned the task of tagging, it was their responsibility to ensure that everyone in the team had a role-tag attached to their gowns. To accomplish this, NALs developed several strategies. One strategy was to take the role-tag sheets into the trauma room, leave them on the patient stretcher and let everyone in the team take their role-tags. Another strategy was to attach tags directly to team members' gowns as they entered the room. Selection of the strategy depended on urgency and personal preferences.

We often observed team members ignoring the role-tag sheets lying on the patient stretcher, which required the NALs to be proactive and enforce tagging:

The nurse brought role-tags to the room and hollered, "Stickers!" Only those within close proximity reacted and took their role-tags. Sheets were then left on the stretcher. Other team members came in but no one noticed the role-tag sheets. Realizing this, the nurse pushed the sheets towards the other end of the bed for people to take them.

This vignette exemplifies two important aspects of role-tags usage. First, it implies that team members were indifferent to using the role-tags because they ignored them for some time. Though this may be true for some members of the team (e.g., one surgical resident thought they were "cheesy"), our interviews revealed that most members believed that role-tags helped them identify other roles in the room. One senior surgical resident commented:

"If everything is getting done, it doesn't seem like it's important to know who does what, but if there is some gap in the patient's care, then it's important to know who gets to take care of what. So we are trying to introduce each other before trauma starts, and we are wearing those great

giant stickers that say what the roles of the people are... so it helps me recognize all the people in the room.”

Anesthesiologists also pointed out that role-tags helped them in identifying respiratory therapists with whom they work while managing patient airway during trauma resuscitation. Because both anesthesia and respiratory therapy often send their residents during trauma activations, the likelihood that the two have never met before is high.

Second, it appears that letting team members take their own tags was inefficient (though it was later introduced as an alternative to controlled tagging). As we learned from the interviews, role-tagging was a practice unique to this trauma center. Although already in use for two months, role-tagging came across as a novel requirement to many trauma team members. For example, rotating residents coming from other hospitals needed some time to get used to the idea of wearing role-tags. This observation also explains why the NALs sometimes directly placed the role-tags on team members' gowns. Performing the actual tagging, however, required that the NALs know who in the team assumed what role, which was not always possible. In those situations, NALs asked for help in locating the unknown team member.

Role-tagging often took place after patient arrival. Because NALs had problems locating role-tag sheets and distributing them on time, role-tagging often took place either at the time of the patient arrival or after the patient had already arrived. This practice was especially problematic in “trauma now” cases, when the patient came in without sufficient warning for the team to assemble. For example, in one such case, as team members were entering the trauma bay, they were donning protective gowns but not the role-tags. The patient was already in the room and evaluation was underway. The NAL started looking for role-tags at about 7 minutes post admission. By the time she found them, the team leader completed his task, took the gown off and left the room.

Missing Role-Tags

Even with an assigned team member actively involved in distributing role-tags and tagging people, role-tags were missing in many resuscitation events that we observed. These events were either “trauma now” or the highest-level trauma team activations that require presence of an attending surgeon (“trauma attending”). Role-tags missing on some or all team members point to an important issue. When there is a limited time to prepare for the patient arrival or the patient is in critical condition, team members either forget to put their role-tags on—as if role-tags do not exist—or they do not have enough time to put them on. Missing role-tags were also observed on team members who arrived late to trauma resuscitation events.

Missing tags appear to be a problem that subverts the purpose of wearing role-tags. Role-tags were initiated to help the team identify roles to improve coordination and

communication. Efficient coordination and communication are especially important in critical cases when the number of people tends to increase and decision-making happens under extreme time pressure. A nurse who often assumes the role of a medication nurse described the atmosphere:

“[Medication orders] come from everywhere and it’s your job to kind of say ‘I need you to agree and tell me one thing’ because it doesn’t always happen. Or it’s the whoever is closest to me is saying ‘yeah, this is what we want’ and sometimes, especially before the nametags, we had no idea who that person was, assuming they are surgery but they are not, or they are a resident from ED which is not who we take orders from.”

However, as our observations showed, team members often failed to put on role-tags in these cases because there was no time to prepare and their attention was primarily on the patient. In other words, the situations that were identified as being most in need of role-identification were the least likely to achieve it with the current low-tech solution.

It also appears that the role-tags were unsuccessful in accomplishing the goal of controlling the number of people in the room during highest-level response team activations. A nurse technician, after participating in a critical trauma case, reported that role-tags did not work “... because in chaotic situations, people don’t have time to put stickers on and it’s hard to identify those who don’t have any roles.”

Working with the “Rigidity” of the Role-Tagging System

People not only adapt to technology, but also adapt the systems to suit their needs [17]. The role-tags generated a mix of uses that their initiators had not anticipated.

Defacing role-tags: This phenomenon emerged as a result of selective tagging. For the purpose of controlling the number of people in the room, role-tags were created for members of the inner core only. This practice meant that most of the outer core members of the team—except the NAL and social worker—did not have tags. Selective role-tagging appeared to be a problem for several reasons. Being at a teaching hospital, ED and surgical residents and fellows attend trauma resuscitation events for learning purposes, even if they are not on call. Additionally, senior nurses who are orienting junior nurses attend events to be able to guide and monitor the work of their trainees. Still, none of these members had tags assigned to their roles. Exceptions were later made for nurse trainers who were allowed around the patient without role-tags.

Selective role-tagging was a decision that matched the intent of fewer people in the room to reduce noise levels, prevent chaos, improve communication, and thus the overall quality of patient care. However, by providing role-tags for only selected team members, trauma management instituted unintended meanings into the act of wearing role-tags. Wearing role-tags started to symbolize one’s status. It meant membership in the team and a right to be in the room. Those without role-tags felt slighted. For example,

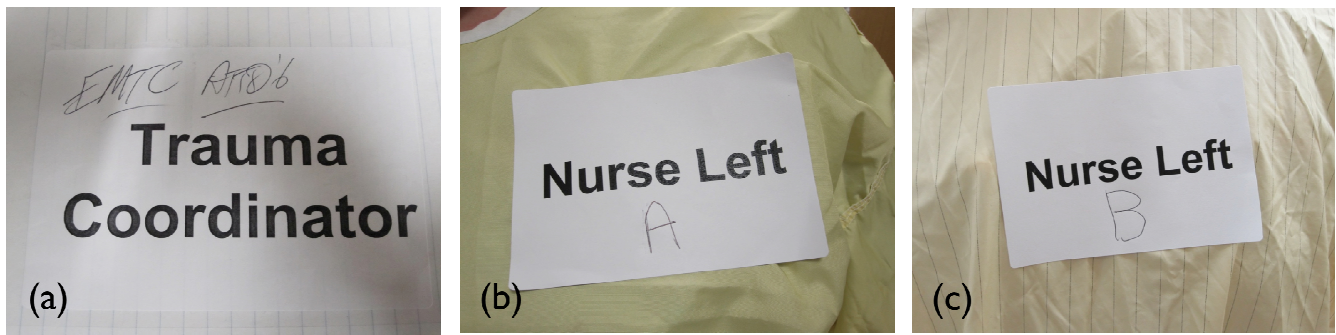


Figure 1: Annotated role-tags: (a) ED physician adapting a randomly selected role-tag to his actual role. (b) Nurse left indicating that she is a nurse trainee by writing “A” below her role. (c) Senior nurse indicating her role as trainer by writing “B.”

radiology technicians—as members of the outer core needed around the patient only during x-ray imaging—complained to trauma management that they felt left out without role-tags. Others devised workarounds to get around the system’s rigidity, such as splitting and annotating role-tags.

Split role-tags: We observed people splitting role-tags when more than one team member responded to a trauma call for the same role. In one event, a senior nurse instructing a junior nurse with a “nurse right” role accompanied the trainee to the inner core. Even though nurse trainers were allowed in the patient area without a role tag, the two nurses tore the “Nurse Right” role-tag, which resulted in one half showing “Nurse” and the other half showing “Right.” Similarly, ED fellows who needed experience in co-leading trauma resuscitation were often accompanied by their attending physician. In those situations, we observed ED attending tearing their role-tag, attaching the half showing “ED” to their gown and giving the other half, showing “Attending,” to fellows. These examples imply how important it was for team members to justify their presence by sharing role-tags with their senior counterpart. In these acts, we see that the role-tag evolved to the point of being socially understood as legitimating presence.

Annotated role-tags: Team members were also seen adding information to their role-tags. These annotations reflected members’ needs that appeared to be important for their work as well as for team coordination. For example, those who came late often had trouble locating their role-tags. As a fast workaround, they just picked any available tag and wrote their actual role on it (Figure 1(a)). We also observed nurses writing their first names on the role-tags. When asked about the reason for this practice, one of the nurses described: “It is useful to have names so that people know who we are and to call us by name if they need anything.” Even though role-based coordination drives much of the interaction, it appears that direct address, when possible, remains a desired feature in this form of teamwork.

Introducing play: Team members often used role-tags as a means of socializing and even introducing play into their routines. We observed this happening in cases when there

was enough time to prepare for patient arrival. To fill mere moments of time, team members were seen tagging someone on the back, or tearing a tag in half and sharing it with a role partner, or tagging oneself by putting a tag in a funny location before relocating it to its more formal place. Nurses who split their role-tag used this act to show attachment to each other. After adhering complementary pieces of a torn role-tag to their gowns, they leaned on each other, as if to say: “Look, we are two in one!” At other times, when role-tags were left on the stretcher for team members to take, a team leader was seen taking the sheet, going around and jokingly asking those without role-tags: “Okay, which role do you want to play today?” As these examples illustrate, role-tags added levity to the policies of role-tagging in an otherwise stressful environment.

Role-Tags as a Potential Source of Information

Team members felt that role-tags could carry additional information that might improve one’s work and overall team coordination. A group of anesthesiologists during a video review session expressed the need for a list of responsibilities displayed on their role-tags. Anesthesia is a good example for explaining members’ need for this additional information. Work of an anesthesiologist in the trauma bay differs from work they do in the operating room (OR). First, they do not verbally report the size or position of an endotracheal tube (ET) to anyone in the OR, whereas in the trauma bay, they need to state this information for the record. Because there is no equivalent to the scribe nurse in the OR, the act of reporting is unknown to them. Second, reports of an anesthesiologist in the OR are documented in his own notes. Finally, in contrast to surgical residents who are oriented to trauma resuscitation in a “walk-through” session held in the trauma bay at the beginning of their rotation, anesthesia residents do not have orientation sessions. Thus, the rules and norms in trauma resuscitation are not as familiar to them. It appears then that a list of responsibilities—perhaps displayed on a role-tag, but conveyed in some other way—may be useful.

In addition to displaying members’ responsibilities, interviews with senior surgical residents and ED physicians revealed the need for displaying information about junior

residents' expertise, level of experience, and training. A surgical fellow explains:

"I know the residents I bring along. As a matter of fact, all residents that are physicians right are on my team. I work with them every day so I know them very well. But I may not know the anesthesiologist sometimes, so when an anesthesia resident comes down I either ask them 'what resident are you' and if they say 'oh I am a fourth year anesthesia resident' then I know I can trust them, but if they say, 'oh I am an anesthesia intern' I may need a back up because they don't have the experience I need."

Similarly, because ED physicians do not work with surgical residents on a daily basis, it is useful for them to know about residents' level of experience and training.

Stage 2: Self-Tagging

Two months into our study, the performance improvement staff decided to intervene in the process of tagging. They realized that distribution of role-tags through the NAL was inefficient. Instead, role-tags were now placed in bins next to the sign-in board (Figure 2). The expectation was that people would fetch their role-tags as they signed in for trauma activations. Because signing-in was routine, the performance improvement staff believed that people would remember to take their role-tags and put them on before traumas. The staff also introduced two new role-tags (nurse trainers and radiology technicians) for the roles that were overlooked in the first phase of deployment. We observed several positive and negative outcomes:

Increased peer pressure to conform: When team members entered the room without their tags, others who were already inside with their role-tags on reminded newcomers to go back and pick up the role-tags. For example:

A surgical resident entered the room wearing a gown, but not the role-tag. Nurse Left asked him to introduce himself. After he did so, the nurse asked him to get the role-tag.



Figure 2: Arrangement of role-tags after introducing self-tagging.

This peer-pressure reflected team members' belief that role-tags supported coordination and communication among the personnel. For instance, a nurse explained in an interview:

"Before stickers, we had no idea who was who, you would think anesthesia was surgery and that the resident was actually an attending so you would take their word without verifying anything."

Similarly, a senior surgical resident with considerable experience at different trauma centers explained how role-tags made a difference in accomplishing the tasks of a trauma leader:

"Here, there is much more of an institutional practice of identifying who does what in the sense that we have stickers and introductions, which I think is a good thing. At other places I've been, it is not as nearly as formal as that, it is sort of just knowing who does what is left to be determined... so here, it's much easier for anybody to identify who is who... It makes it nice, at least from my perspective, being the trauma leader I can delegate to somebody and say, 'okay, you are the respiratory therapist, we are going to intubate this patient, can you get the vent setup,' or 'you are the nurse, can you drop the medications for this patient' and it's easy, if you don't know somebody or you've never worked with them in a trauma situation, you can easily know what everybody's role is."

Persistence of missing tags during highly critical traumas: The problem of role-tags missing on some or all team members persisted in resuscitations that occurred with minimal warning and events with severely injured patients. Even the sign-in rate decreased because team members did not have time to stop by the sign-in board. Because role-tags were now next to the board and self-regulated, role-tags compliance was decreasing as well. Conversely, when there was enough time to prepare, team members regularly put their role-tags. For example, in one event, team members waited for the patient for 25 minutes, which gave them enough time to do introductions, don gowns and role-tags, and prepare equipment for the incoming patient.

Role-tags placement: We observed team members putting role-tags in all kinds of orientations and at various places on their bodies. Typically, they would be placed on a person's chest. Often times, however, team members would put the role-tag on their shoulder, stomach, hip, or arm. These practices became an issue because other team members could not see the role-tag clearly or read what it said.

Irregular use of role-tags: With self-selected tags, people no longer had to annotate or split their role-tags. Instead, they would take the role-tag closest to their medical function. For instance, we observed ED fellows taking "ED Attending" role-tags and ED residents taking "Surgical Resident" role-tags. This meant that crowd-control was more challenging now than before the role-tagging practice was instituted. Because role-tags were freely available and

there was no NAL to control distribution, identical role-tags started to appear on more than one person.

Self-selected tagging provided an opportunity for people who were not part of the team to “join” it. For example, ED residents are not considered part of the trauma team, but they attend trauma activations to gain experience. We observed an ED resident taking the surgical resident’s role-tag, striking-through “Surgical” and writing “ED.” Similarly, the newly added role-tag for a “Preceptor” (trainer) allowed nurses who were not required to attend resuscitations to be in the room. Or, two nurses in the same role, rather than having “Preceptor” and, say, “Nurse Left” role-tags, would instead annotate their tags to denote that one is in training and the other is mentoring (Figure 1(b-c)). Several explanations may account for these observations. First, in teaching hospitals, training of medical residents is mainly conducted on the job. Education is part of trauma resuscitation work, which explains why so many residents want access to the trauma bay. Second, there is a *sense of duty* to respond to trauma activations, especially to highly acute cases, even when personnel are not on call. Finally, the above observations reinforce our finding that role-tags were often perceived as a symbol of belonging and status.

DISCUSSION

Supporting Team Coordination with Role-Tagging

Our findings suggest that the institution of role-tagging did support certain aspects of team coordination during trauma resuscitation. Role-tags augmented existing cues for distinguishing between roles and allowed team members to identify each other more easily. Although roles can be inferred from members’ initial positioning around the patient stretcher, constant movement within the room makes positioning an unreliable cue. Additionally, colors of scrubs and especially the protective gowns worn over them are relatively uniform at our research site. (We note that another low-tech solution to support role awareness would be using distinct gown colors, although, in times of urgency, the nearest gown, regardless of color, would likely be the choice.) With role-tags, anesthesia residents described being able to quickly identify and coordinate with respiratory technicians. Team leaders, knowing what roles were represented in the room, were able to quickly assign tasks. Even nurses were now able to quickly verify orders from multiple people in the room.

Our observations also show that role-tags helped in building camaraderie between people who have not previously worked together, and even added a degree of levity to the formal and stressful matters of trauma resuscitation. To complement the tags, people introduced themselves to others. The role-tags, however, achieved even more to support camaraderie. They became objects of play when time allowed. This feature of role-tagging allowed for a degree of comfort in addressing previously unknown team members. The fleeting moments of play and socializing before patient arrival made the atmosphere in the room

more friendly, which team members reported helped them to cope with their upcoming role in the resuscitation.

Nevertheless, role-tags sometimes failed to support team coordination. This was most evident during events with little warning or with critically injured patients, when role-tags use decreased significantly and number of people in the room increased. As our observations showed, the problems of role identity and coordination worsened during those resuscitations. Core team members moved around more often to address rapidly changing needs of the patient. Additional personnel joined the team, with a designated function or not, and did not have prescribed positions, which further made coordination more challenging.

Additionally, as distribution of the role-tags changed from managed to self-selected, use of role-tags became irregular. Identical role-tags started to appear on more than one person; handwriting on pre-printed role-tags occurred more often, which circumvented the goal of crowd-control. With this shift in role-tag distribution, it became evident that the tags came to symbolize one’s status and to legitimize presence in the room. Self-selected tagging enabled people to become part of the team, even if they did not have a role.

These mixed experiences with role-tags indicate not mere success or failure of this approach. Rather, they show that the role-tag solution addressed to an extent the role-identification problem, but was inadequate for the crowd-control problem. In other words, *two conflicting goals were set for the same target of interest*: role-tags were meant to support both work practice and a larger organizational consequence of the practice of apprenticeship.

The investigation revealed that role-identification is a matter of intra-group coordination that occurs within the scope of the task and within the trauma room. It is here where explicit role-identification showed promise. The other matter of coordination is crowd-control or over-convergence that is tied to larger, socio-organizational issues. Over time, and especially with a shift to self-selected tagging, it became clear that individuals whose presence was not required in the trauma bay could still justify being there. Those without a pre-designated role struggled to legitimize their presence and so misused the role-tags to become part of the team. In effect, the role-tags were trying to solve an “out-of-the-room” problem within the confines of the task itself. Thus, controlling the number of people in the room requires a solution distinct from tags, but not without the knowledge that tags convey, which is important to both onlookers and learners. Physical exclusion alone cannot solve the problem because the excluded personnel need access to the information from the trauma bay for their work.

Our study suggests that coordination in trauma resuscitation and perhaps in other safety- and time-critical domains could benefit from introduction of computerized solutions that address these different but intersecting goals.

Implications for Computerized Support

We propose that the following need to be considered:

Role-Based Information Needed for Team Coordination

Our findings indicate that team members wanted additional information about roles displayed on their role-tags. We identified five role-based information types: (1) person's role in the team, (2) person's name, (3) experience level, (4) area of expertise, and (5) responsibilities for the role.

Displaying information as desired by trauma team members may result in disturbing what has been referred to as the organizational "moral order" [6], and should be considered carefully. As Harper found in his study of active badge deployment in two research labs, people perceived the technology in relation to their roles and the amount of information to which they were entitled. As active badges started revealing researchers' locations to system administrators, the relationship between the two roles changed. Similarly, displaying information about residents' level of experience may negatively affect relationships. Although a trauma leader should have access to this type of information, making this information accessible to other roles may introduce interpersonal tension.

Sustaining the Practice of Role-Tagging

As we have seen in our study, the situations that were identified as being most in need of role-identification were the least likely to achieve it with the current low-tech solution. Because the belief among the personnel is that role-tags support coordination, the challenge is to determine how to enable—both for the short-term and long-term—the practice of wearing role-tags, especially during highly critical cases where there is little time to prepare.

One of the reasons paper-based role-tags failed to support team coordination during highest-level response trauma activations is that role-tagging required either an assigned person to distribute role-tags or team members to remember to take them on their way to the trauma room. Initial difficulties in locating paper-based role-tag sheets among the many forms used during trauma resuscitation imply that a future solution should also avoid paper. To succeed in this dynamic environment, and by extension to other time-critical and ad hoc work settings, role-tagging should be automatic or easily enabled by another person.

Advances in context-aware, wearable and mobile computing have opened up a space for exploring smart badge applications for enhancing people's experiences in a wide variety of contexts [5,12,13,26]. As hospital employees, trauma team members already wear badges that indicate names and occupations. These badges could be augmented using smart badge technology to include the wearer's role-based information.

Among the five role information types, only the person's role may be changing on a short-term basis. Even then, role assignments are usually known ahead of time because they are determined by schedules and organizational rules.

Because role-based information types are available before resuscitation events, we notice that system administrators or unit managers could easily encode them at the time of role scheduling. This approach would relieve team members from encoding their role information at the time when their priority is patient care.

Displaying Role-Based Information

Personnel badges are currently small in size and covered by protective gowns, so they may not be suitable for displaying role-based information. Still, these badges could be augmented using smart badge technology to transmit the wearer's role information to another display. This display should be designed to allow quick absorption of information. Text-based displays using smart badge applications or public displays [3] seem unrealistic as a solution because of size constraints and the burden of textual representations that would divert attention away from the patient and the activities of co-workers. The limited space of the trauma room poses additional restrictions. "Smart clothing" on the other hand, offers promise as a means for augmenting information during time-critical work [16]. For instance, we can envision protective gowns gleaming with different colors and intensities to represent roles and levels of experience. A simpler and a cheaper solution may be displaying color-coded role information on a small patch of the gown (similar to a shirt pocket).

Managing the Number of People in the Room

As our study revealed, wearing role-tags failed to support the crowd-control goal. To achieve better crowd-control, we propose remote observations of trauma resuscitation events through live video feeds. Since this trauma center is already using video recording for the purposes of performance improvement, the existing equipment could also be used for providing "observation rooms" in which those who do not have a role, could still benefit by watching live resuscitation events. However, information about the roles that people assume in the trauma room need to be conveyed over the video display. It is here where ambient information communicated by smart clothing shows additional promise.

CONCLUSION

In this paper, we examined a particular feature of team interaction in time-critical situations: identification of "job role" in supporting coordinated work. We presented findings from an ethnographic study of trauma teams in a pediatric teaching hospital, and focused on a decision to introduce a technique to make job roles explicit in this setting. Our study was able to identify separate but conflicting features of role-based coordination and crowd-control, and to show that one solution was inadequate for both problems. Whereas role-tags showed promise in improving intra-group coordination within the trauma bay, they failed to address the problem of over-convergence to a trauma room, which is tied to bigger, socio-organizational

issues. We thus suggested directions for computerized support for solving both problems. The two solutions however must work together because the object of interest is the same—trauma resuscitation.

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