Multiple Group Coordination in Complex and Dynamic Task Environments: Interruptions, Coping Mechanisms, and Technology Recommendations

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ABSTRACT: Collaboration in complex and dynamic environments such as hospitals, airlines, and disaster response teams is challenging. High performance requires smooth coordination across multiple groups whose incentives, cultures, and routines can conflict. In this paper, we present an in-depth case study of a hospital's operating room practices to understand challenges associated with multiple group coordination and how information technology may help. We use the concept of trajectory to focus our observations and interviews on workflow across groups and critical events when coordination breaks down. A careful examination of the sources, coping mechanisms, and consequences of coordination breakdowns suggests three factors whose absence may impede effective responses to unexpected interruptions: (1) trajectory awareness of what is going on beyond a person's immediate workspace, (2) information systems

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integration, and (3) information pooling and learning at the organizational level. We conclude with technological recommendations to promote trajectory awareness and to automate information gathering and monitoring, so as to facilitate multiple group coordination in complex and dynamic task environments.

KEY WORDS AND PHASES: collaboration, coordination breakdown, group boundary, multiple group coordination, trajectory awareness.

ORGANIZATIONS OPERATING IN HIGH-RISK WORK ENVIRONMENTS are complex and dynamic, notably because they rely on collaboration among multiple groups of professionals to be successful and reliable. Unlike singular linear systems such as assembly lines, on which people collaborate with particular others on a predictable and routine basis, these organizations experience many unpredictable events requiring constant adjustments to planned or existing work schedules. Doing so requires smooth communication and coordination among different groups whose backgrounds may differ dramatically yet whose tasks are tightly coupled and highly interdependent on each other [15].

Previous studies of organizational coordination in places such as airline operations, trauma centers, and disaster response teams have identified failures stemming from breakdowns in materials supply and information flow across organizational boundaries [11, 42]. Failure to detect and address coordination breakdowns in a timely manner can cause significant consequences such as delays of service or rescue efforts, medical errors, and the loss of lives. Despite the critical consequences of coordination failure in these environments, our knowledge of the causes, consequences, and challenges of coordinating activities across multiple groups remains limited.

The existing literature on coordination and information technology to support coordination has focused on understanding coordination needs and how technology can support coordination in a colocated or copresent group. With some exceptions [33, 40], most research examines processes from the point of view of one role or a colocated group, such as workers in an emergency call center, a traffic control room, or an intensive care unit (e.g., [4, 12, 37]). This line of research has deepened our understanding of coordination processes, information exchange, and how workers switch attention between their own and collaborative tasks. It has also identified common problems that workers face in dynamic situations—distractions, conflict, obstacles requiring workarounds, and political allocation of resources (e.g., [23]).

The current paper differs from prior work in that we consider how the involvement of multiple groups separated by geographic and organizational boundaries affects coordination and coordination failure. The involvement of multiple groups alone is a common scenario and does not call for much special attention. The challenge lies in the complex interdependence among group activities, the tight coupling between group activities and their consequences, and the great time pressure under which the multiple groups need to function and to respond to unexpected events. Unexpected

interruptions and exceptions constitute part of daily routines in many high-risk organizations. As a result, group coordinators and key personnel get overburdened, important information fails to be communicated, coordination efforts fail, and severe consequences and losses can occur. In this paper, we describe an exploratory case study to address the following questions: (1) What are the key challenges associated with multiple group coordination in complex, dynamic task environments? (2) What are the sources and consequences of coordination breakdowns, and what mechanisms can be adopted to alleviate and to recover from the breakdowns? (3) How can we adapt computer and information technologies and managerial policies to facilitate multiple group coordination?

We collected data from the operating rooms (ORs) of a Mid-Atlantic hospital. We observed work practices of six groups involved in OR practices, and we interviewed key personnel from each group. Our goal was to gain a comprehensive understanding of coordination practice across multiple groups operating in and surrounding hospital OR units, as seen from the point of view and activities of each group involved. We used the concept of trajectory to orient our observations. We define trajectory as the sequence of activities and paths through which people, resources, and groups move [39]. We paid special attention to critical incidents where coordination efforts were interrupted or stymied, the sources and consequences of the interruptions, and the mechanisms that OR personnel deployed to cope with and recover from coordination breakdowns. Our qualitative data suggest three critical factors to promote effective multiple group coordination: trajectory awareness of what is going on beyond a person's immediate workspace, information systems integration, and information pooling and learning at the organizational level. We then discuss technical and managerial solutions to facilitate multiple group coordination in high-risk environments.

A secondary goal of this paper is to build on Malone and Crowston's [29] interdisciplinary approach to study coordination. Coordination is a phenomenon with multiple dimensions—cognitive, social, managerial, and technical—and has been studied in a variety of fields such as management, computer science, operations research, and economics. Motivated by Malone and Crowston's broad, inclusive survey of the coordination literature, we spotlight and focus on the social and managerial aspects of coordination. Researchers from several fields such as organization science (e.g., [1, 41]), computer-supported cooperative works (e.g., [4, 37]), and information systems (e.g., [7, 35]) have written on the topic, yet we have observed little interaction across these fields. We hope that our research serves as a bridge across disciplinary boundaries and stimulates more interdisciplinary efforts to tackle the challenges of multiple group coordination in complex and dynamic task environments.

Literature Review

WE BEGIN BY REVIEWING SEVERAL BODIES OF LITERATURE related to coordination in organization science, collaboration technology in computer-supported cooperative work, and technology adoption and business process reengineering in information systems.

Organization Science Literature on Coordination

The organization science literature examines means or modes of coordination and their use in organizations with different degrees of task interdependence and uncertainty. Coordination has been defined as the process of "managing dependencies between activities" [29, p. 90] or "integrating or linking together different parts of an organization to accomplish a collective set of tasks" [43, p. 322]. Interdependence is the extent to which an organization's tasks require its members to work closely with one another—that is, to coordinate their activities [41]. A central theme in the organization science literature has been the relationship between task interdependence and the use of various coordination mechanisms to minimize coordination costs.

Van De Ven et al. [43], for instance, examined three kinds of coordination modes: impersonal modes such as plans, schedules, rules, and procedures; personal modes such as face-to-face communication; and group modes such as meetings. They found that increases in task interdependence led to an overall greater use of all coordination mechanisms, and increases in task uncertainty led to a greater use of personal and group mechanisms. Argote [1] examined the relationships among task uncertainty, coordination mechanisms, and organizational effectiveness of hospital emergency units. She found that task uncertainty affected the relationship between the mode of coordination and organizational effectiveness. Impersonal modes of coordination made a greater contribution to organizational effectiveness under low uncertainty, whereas personal means of coordination made a greater contribution to organizational effectiveness under high uncertainty. Gittell [12] examined the concept of relational coordination, or frequent, timely, problem-solving communication. She found that relational coordination mediated the effectiveness of two social mechanisms—boundary spanning and team meetings. In general, the organization science literature highlights the importance of personal coordination modes and frequent communication in coordinating activities in dynamic environments.

Computer-Supported Cooperative Work Literature on Coordination Artifacts

The computer-supported cooperative work and medical informatics literature describes some of the fine-grained processes through which information is exchanged and people, resources, and tasks are coordinated. This research has the ultimate goal of designing and improving collaboration technology to support collaborative activities [28]. Researchers have conducted fieldwork in settings such as trauma centers, airport flight control rooms, and military operations (e.g., [14, 38]) to understand how information technology is, or could be, used to support collaboration. For instance, Bardram [4] examined how coordination activities unfold over time in a surgical department and presented a prototype design to support temporal coordination. Reddy and Dourish [37] examined information exchange in a surgical intensive care unit and the role of temporal rhythms in coordinating work. Moss and Xiao [32], Seagull et al. [38], and Xiao et al. [45] studied communication and coordination practices in a trauma center

and identified problems that complicated coordination such as overoptimistic schedules, temporal constraints, and status differences in the organizational hierarchy.

Many computer-supported cooperative work studies have revealed the importance of situation awareness, or people knowing what is going on in local and remote workspaces; some writers have proposed technological solutions to promote awareness [10]. Cognitive artifacts such as paper reminders, posted schedules, and whiteboard displays can increase awareness and help coordinate work in hospitals [8, 33]. Lasome and Xiao's [27] study of a public display board in an OR unit showed that the board served important functions such as support for task management, personnel assignment, and shared awareness. More generally, the computer-supported cooperative work and medical informatics literature suggests that cognitive and social artifacts are effective tools to support coordination in dynamic environments, and technology to automate or digitize these artifacts should be considered to complement informal, personal coordination.

Management Information Systems Literature on the Strategic Use of Technology

Compared with the other two bodies of literature, the management information systems literature on coordination is sparser, perhaps due to the slow adoption of information technology in health care and other such environments [20]. Recently, scholars and practitioners have begun to explore how information technology can improve medical decision making, transaction processing, patient information, and health-care quality [22]. Most studies examine the strategic use and business value of information technology [18]; adoption and resistance to information technology [26]; or factors that impact the adoption, usage, and effectiveness of information systems (e.g., [35]). Few directly tackle ways of deploying information technology to facilitate coordination in high-risk environments.

Nonetheless, valuable insights can be borrowed from the management information systems literature on technology adoption, information systems integration, and business process reengineering, all of which have been shown to influence the success of health-care information technology [20]. For a technology to have a substantial impact on organizational performance, it needs to be perceived as useful and easy to use and adopted by organizational members [9]. Most hospital information systems were introduced to meet specialized local needs such as scheduling, billing, patient administration, pharmacy, and radiology. These systems typically were incompatible with one another, leading to very limited integration [22]. Hospitals need to overcome technological and political barriers to integrate their systems.

In addition, an information technology project does not end when the new system arrives and starts working. Rather, it is often the beginning of the project because the organization's structure, processes, and work practices need to be modified and aligned with the technology. The business process reengineering literature provides some valuable lessons, such as building on current practices and involving workers at the lower levels of the hierarchy, both of which are crucial to alleviate user resistance and

increase the likelihood of success [16]. Overall, the management information systems literature suggests that proposed technological solutions need to be perceived as useful and easy to use, to be integrated into existing technological infrastructure, and to be aligned with the strategic goals and business practices of the organization [19].

Research Setting and Method

OUR RESEARCH SITE WAS A MAJOR HOSPITAL COMPLEX located in an urban setting in the Mid-Atlantic region. Its specialties include cardiothoracic surgery, organ transplantation, critical care and trauma services, and neurosurgery. It is also designated as a regional trauma center. We conducted observations in the OR units and all the groups that participate in surgical services. The units that we observed are distributed in two hospital buildings that are located more than 30 meters apart from one another [24]. The OR units in the two buildings have their own preoperative and postoperative holding areas and share personnel and resources. In this situation, coordination is required not only among multiple professional groups, units, and roles within each OR unit but across the two hospital buildings. The OR units are the biggest revenue generator in the hospital. They have 43 ORs located in the two hospital buildings that we refer to as building A and building B. On a regular workday, 40 to 50 surgeries are scheduled in building A and 30 to 40 surgeries are scheduled in building B.

We conducted this study between February and June of 2005, spending the first two months getting familiar with the environment and understanding the groups and procedures. We collected data using observations and interviews. We tried our best to take every group's perspective into account, including patients and workers who transport patients from place to place. We spent 195 hours observing and taking detailed notes in the ORs, at the OR desk, the anesthesia whiteboard, and work areas of other groups, and shadowing charge nurses and charge anesthesiologists. With each group, we observed and recorded the work responsibilities of its key personnel; how they performed their work; and when, where, and with whom they communicated and on what matters. We paid special attention to critical events where interruptions or exceptions occurred such as an emergency case or a delayed case. Due to the nature of hospital operations, we tried to remain as unintrusive as possible during the observations. We relied on observing and listening to conversations to understand the sources and consequences of an event and how OR staff responded to it. We then approached key individuals when they were less busy to fill in any missing information.

We also conducted 15- to 30-minute semistructured interviews with two surgeons, seven anesthesiologists, six nurses, and five others (secretaries, unit coordinators, and escorts). We used these interviews to amplify our observations and to hear from as many groups as possible about an event. We also collected samples of organizational documents such as floor plans, medical forms, logs, and daily OR schedules, and asked for a brief review of the organization's intranet (where OR schedules and personnel assignments are posted) and its various information systems. These additional experiences equipped us with rich contextual information to understand what we observed or heard during interviews.

We coded and analyzed observation and interview notes using Nvivo [36]. We took the grounded theory approach in analyzing the data [13]. During the five-month data collection, we went through an iterative process of surveying relevant literature, reading and coding data into theoretical categories, discussing and comparing emerging categories to insights from the literature, refining our research questions, collecting more data from additional sources or perspectives, and adding more theoretical categories. We started with three high-level categories—the sources, coping mechanisms, and consequences of coordination breakdowns—and gradually filled in the subcategories. We stopped collecting data when we felt that we had saturated subcategories and had taken inputs from all groups on the sources, coping mechanisms, and consequences of coordination breakdowns.

Operating Room Organization

The organization of surgeries in the OR is dominated by the primacy of the schedule [4, 8], which in turn depends on room and staffing resources. In the organization we studied, the schedule follows a daily block system. OR blocks are groups of rooms assigned to different services such as cardiac, neuro, thoracic surgery, and so on, as well as to individual surgeons. To optimize OR utilization, 48 hours prior to the operating day, unbooked OR times are made available for other surgeons or services. The schedule allows for a 30-minute break between scheduled cases to provide for anesthesia and room turnover time. The schedule is variable across time and room location. Schedulers specify surgery duration as whatever is requested by surgeons plus an adjustment based on the surgeon's historical record. Every morning, a daily OR schedule is printed with patient, procedure, and physician information. This schedule is updated during the day and is used by all of the groups that are related to surgery.

Multiple Groups

There are six groups involved in surgical services: ambulatory, preoperative holding, OR nurses, anesthesia team, surgical team, and postanesthesia care. Two other groups that are not primary care providers but key players are housekeeping and patient transportation.

- Ambulatory *surgery* is responsible for interviewing and admitting patients when they first arrive. Nurses and technicians get patients ready for surgery by making sure that they change to hospital gowns, have followed all preoperative instructions, and all required testing results are included in the patient charts. These workers also make sure that a patient's condition has not changed in any significant ways that may interfere with surgery.
- Nurses working in the *preoperative holding area* (POHA) monitor patients' vitals and double-check the patient charts to make sure that all required information is included. If there is missing information, they will contact relevant groups (e.g., surgical team for an updated history and physical exam). These workers also are

responsible for notifying the OR desk and anesthesia and surgical teams when patients arrive.

- When a patient arrives in an *operating room*, a circulating nurse greets the patient, records critical times and OR charges, and assists the surgical team in positioning the patient and finding equipment. Scrub technicians are responsible for setting up the sterile table and providing and keeping track of all sterile equipment. An OR charge nurse, who normally sits at the OR information desk, is responsible for running OR scheduling and for synchronizing and coordinating activities in conjunction with other groups.
- An *anesthesia team* usually consists of an anesthesiologist and one or two hands-on providers. These workers may be an anesthesiology resident or a nurse anesthetist, who sometimes supervises a student anesthetist. Anesthesia teams are responsible for visiting patients in the preoperative holding area, transporting patients to OR, anesthetizing patients, monitoring patients during surgery, and waking up patients and transporting them to postanesthesia recovery.
- When a patient is transported to the *postanesthesia care unit* (PACU), nurses there take a report from the anesthesia team, settle the patient in bed, and closely monitor patient pain and vital signs until the patient is stable enough to go to a floor or to go back to same-day postoperative to be discharged.

Groups follow different work trajectories that intersect with and join with other groups at different times. We use the concept of trajectory to focus our observations on workflow and coordination across groups. Trajectory is defined as the sequence of activities and paths through which people, resources, and groups move [39]. Patients, doctors, nurses, and other personnel each move through a trajectory through tasks and time. Resources such as ORs and equipment also have expected trajectories while being utilized case after case to serve different patients. A typical patient trajectory is arriving at the hospital, getting ready in the preoperative holding area, moving to a room to receive surgery, staying at the postanesthesia care unit, and being discharged. A surgeon trajectory may involve surgical duties in the morning and teaching or clinical duties in the afternoon, and nonhospital duties such as working on financial reports in the evening. An OR trajectory is normally scheduled for a series of daily surgeries that may vary in their time and usage. Different trajectories need to interweave and intersect at specific times to provide timely, safe, and high-quality patient care.

An Overview of the Patient Trajectory

We illustrate the complexity of managing and coordinating multiple trajectories using a patient trajectory as the focal point. The hospital treats both inpatients and outpatients, but we chose to study outpatient services because we had the opportunity to observe the full course of most outpatient cases. Many inpatients already had a history of being treated in the hospital or ORs well before they entered our zone of observation. An outpatient trajectory consists of three stages: preoperative preparation, operating, and postoperative recovery.

Suppose a patient is scheduled to have surgery between 10 A.M. and noon. The patient will be instructed to arrive two and half or three hours before the scheduled surgery. As shown in Figure 1, the patient first arrives at the ambulatory surgery unit located in building B where he or she is admitted and interviewed to get ready for surgery. The patient is then placed in a wheelchair or on a gurney and transported by escorts to a preoperative holding area located in building A (or a different floor in building B) to meet the anesthesia team. Someone on the team rolls the patient to the designated OR, also in building A (or B). A member of the surgical team needs to check the identity of the patient before the anesthesia team anesthetizes the patient.

After the patient is anesthetized, the surgical team opens the patient, performs surgery, and closes the surgical procedure. After the surgery, the anesthesia team stops sedation, wakes up the patient, and rolls the patient to the postanesthesia recovery area. At the same time, someone from the anesthesia team meets the next patient in the preoperative holding area and prepares for the next surgery. Once the patient is out of the room, housekeeping cleans the room, and the circulating nurse and a scrub technician restore the room with proper trays and equipment. The room is ready for the next patient.

All three types of interdependency are present and intermingled in a patient trajectory [11]. There is sequential interdependence; for instance, patients have to be interviewed and checked at the ambulatory surgery unit before they can move to the preoperative holding area or an OR. There is reciprocal interdependence; for instance, the anesthesia team needs to wait for the surgical team to ID the patient before putting the patient to sleep, and the surgical team cannot start operating until the patient is anesthetized. There is also pooled interdependency or dependence on shared resources; for instance, many activities in OR share common resources such as personnel, rooms, and equipment. When these interdependencies are not synchronized, coordination breakdowns may occur.

Coordination Breakdowns

IN PREVIOUS STUDIES, BREAKDOWNS IN THE HOSPITAL ENVIRONMENT mainly concerned deviations from the formal procedures or errors in patient care, such as failures to monitor patient status during a surgery (e.g., [15, 40]). Our focus is breakdowns observed in the coordination and workflow of multiple trajectories. We define coordination breakdowns as changes in, or barriers to, trajectories, to which people and resources must adjust. Breakdowns are thus triggers for essential changes in coordination. Most breakdowns that we observed occurred at group boundaries, especially around the time when patients moved in and out of ORs. Moving patients in and out of ORs involves the coordination of multiple groups. Further, pre- and postoperation are critical points because almost all groups are multitasking (finishing a case while getting ready for the next), patient-care activities are highly interdependent and tightly coupled, and both of these activities involve patient movement across space. The distribution of groups in separate locations and buildings imposes significant communication barriers, especially when patient movement is involved.

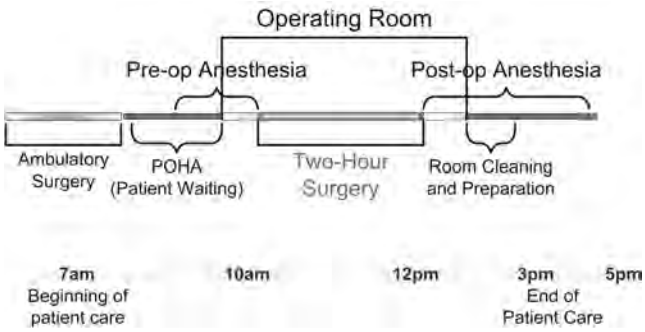

Figure 1. An Example Trajectory of an Outpatient Surgery

Sources of Coordination Breakdowns

OR SCHEDULING AND COORDINATION would not be a major challenge if events always ran as scheduled. Instead, breakdowns occur as an inherent part of medical care and OR practice in an environment of limited resources. Emergency cases consume resources that are originally assigned to elective cases. Unexpected changes in patient condition turn an elective case into an emergency. OR staff calls off due to personal reasons. Doctors get stuck with patient care outside of the hospital and arrive late. Following Miyata and Norman [30], we categorize sources of coordination breakdowns as internal and external interruptions. We emphasize internal interruptions as greater design opportunities because most external interruptions such as emergency and transplant cases are stochastic and difficult to predict or control.

Interruptions from Patients

Internal interruptions from patients include several sources, such as incomplete information, changes in their physical condition, and disruptive behavior. Our data suggest that most behavioral interruptions from patients are unintentional and stem from patients' ignorance of medical practices, or "poor medical management" on the hospital side. A common reason for patient delay is incompleteness of patient documents such as patient charts, consent forms, or history and physical forms.

> Patients come from all over the country, and their documents failed to be faxed ahead of time. . . . One difficulty in obtaining patient information is that a lot of places don't send you anything without a medical release. You call the lab and they can't give it to you until the morning when the patient comes in and gives a medical release. [Ambulatory Nursing]

Another common interruption happens when patients' conditions change—either for the worse, requiring emergency surgery (e.g., internal bleeding), or for the better, requiring cancellation of the surgery. Sometimes patients fail to follow diet or medication instructions (e.g., patients get dehydrated or eat shortly before the surgery). In

another case, the patient was multitasking. His surgery was scheduled at 10:45 A.M. and he made an appointment at his doctor's office at 10 A.M. After talking with pre-op nurses, the patient insisted on keeping his plan.

> Once the patient signs in, he is our responsibility. He was supposed to wait and we took him to bedside. The patient walked out anyway. His appointment was at 10 A.M. and his surgery was scheduled at 10:45 A.M. He said the office was aware. . . . Eventually we sent him over, but OR had to change their schedule to not lose OR time. [Ambulatory Nursing]

Interruptions from Surgeons

Surgeons' busy schedules and complex trajectories create the second major source of interruptions. As compared with anesthesiologists and nurses who work regularly in ORs, surgeons attend only when they have cases scheduled. They often have obligations elsewhere such as teaching and seeing patients in their offices or operating in other hospitals before or after their scheduled surgeries. When these activities run over time, they are not available to do their surgery at scheduled times.

> That was a surgeon issue. Surgeons work at different hospitals and they may be working overnight at another hospital and not available to start his case here. For this case, all we were told was the surgeon was not available. We don't ask about the details. It could be personal reasons as well. [Ambulatory Nursing]

In a teaching institution such as the one we studied, it is a common practice for surgeons to do the critical part of a surgery and have their residents or fellows do the opening and closing stages. On busy days, a surgeon (and his or her surgical team) may have two or three surgeries in different rooms ongoing at the same time. The surgeons "flip-flop" between the rooms. Although this practice enables them to serve more patients, it increases the probability of a case running late. In one case that we observed, the surgeon put a room on hold so that she would not lose it. In many other circumstances, it is more common for surgeons to request an additional room (mostly due to add-on cases) or a better-equipped room.

> Dr. [last name omitted] has sent for patient in 7 but we can't go back until she is ready. She has another case in 8 and she can't leave 8 yet. . . . We would have to wait 45 minutes to one hour to go back to the room. The patient is somewhere in the hospital. The surgeon doesn't want to lose the room as it gets closer to 3 P.M. [OR Nursing]

Interruptions from Anesthesia and Nursing

Hospital personnel call all of the nurses and technicians who provide care to surgical patients "nursing." From the nursing perspective, many interruptions are caused by frequent staff turnover and new nurses' lack of experience, as illustrated in the following comments:

> Cases get delayed because of this [lack of experience]. This is like sending soldiers to Iraq with only a sleeping bag. . . . We need to have some ways to assess this to make sure that qualified people are assigned to rooms. You don't assign untrained nurses to orthopedics. [Surgical]

In this case, we observed that a nurse involved in a complex surgery had been with the hospital for less than a year and "was not fine-tuned and did not know the surgeon's routines very well." This phenomenon is not unique among OR nurses. Similar issues may affect the anesthesia team. The anesthesia team's primary responsibilities are patient airway and sedation. Patients with special conditions may react differently to anesthetic procedures and medications. Therefore, anesthesiologists and their hands-on providers need "to anticipate problems and plan ahead." With difficult cases in more than one room, anesthesiologists need to triage and, if necessary, to seek for help from coworkers. Failing to do either can result in delays or mistakes.

Another major source of interruption is insufficient staffing, particularly of nonmedical workers such as escorts and housekeeping staff. Although these two groups do not serve patients directly, they have a significant impact on the OR schedule. Cases cannot start until rooms are cleaned and patients are transported to the room. Understaffing in these two groups results in bottlenecks and delays on a regular basis, so much that people constantly complain about it.

> In a short period of time, [building A] called for five patients and [building B] called for three patients. There are only two escorts who transport patients from ambulatory surgery to here and also between [hospital B] operating rooms and ambulatory surgery, which is one level apart. As a result, this case got delayed, which was frustrating. This surgeon was always on time. [Pre-Op Nursing]

> Room turnover is a big issue. . . . Most times people blame anesthesia for delays. But a lot of times rooms are not ready because of housekeeping or nurses not having equipment in the room. Why is room turnover not faster here? This hospital is too big. They don't have enough manpower, like housekeeping. There is a housekeeping team assigned to work in OR. They are too busy. [Anesthesia]

Interruptions Across Groups

Groups interrupt each other. Key decision makers such as charge nurses and charge anesthesiologists are constantly interrupted with requests for information and unexpected events that require adjustments in the schedule. As surgeons multitask and juggle their responsibilities, they not only interfere with the work flow in ORs but also with pre- and post-op patient care. For instance, it is required that someone from the surgical team talk to the patient and family before and after the surgery. Surgeons perceive these as peripheral activities and perform these duties whenever they are not tied up with other more important responsibilities. We observed many cases in which higher-profile workers interrupted lower-profile workers. Doctors and anesthesiologists interrupted nurses and nurses interrupted technicians.

> Sometimes patients are ready to go but have to wait for doctors to talk to them [there can be three doctors who need to talk to patient and family]. They might be very well ready, but can't leave until doctors come. [Ambulatory Nursing]

Coping with Coordination Breakdowns

PEOPLE WORKING IN THE OPERATING SUITES need to adjust to coordination breakdowns when they occur. Cases need to be rearranged, priorities need to be reassessed, and staff may be reallocated. We observed several mechanisms through which the multiple groups cope to respond to emergency and exceptions. The principal mechanisms are constant communication, joint problem solving, and role switching, all taking place within and across group boundaries.

Constant Communication

People coped with coordination breakdowns by seeking information (e.g., where is the patient), providing information to others (e.g., a case has been delayed or cancelled), and negotiating for a change in OR schedule or work arrangement (e.g., can you call in additional help to open another room). Much of the communication within groups occurs in person. The anesthesia team clusters at its whiteboards, OR nurses cluster at the information desk, and surgical teams work together in a room. Much of the communication across groups occurs over the phone—charge nurses call or receive a call from pre-op and post-op nurses and the charge anesthesiologist or surgeons stop by the information desk. As the information hub, charge nurses can easily get overwhelmed with the amount of information they have to process and share with other groups. The following quotations illustrate a typical five-minute episode of the charge nurse's (CN) workload.

> 11:47 A.M. [an OR called a CN]: They are out of OR 11. They are going to swap cases. Shall we send for the debrievement case patient? [Conversation continued . . .]
>
> 11:50 A.M. [CN to an OR]: Dr. XX's case. Send his patient in OR 1. I have assigned XX and XX [to the room]. This will work out. [I am] thinking about OR 8. They should be done.
>
> 11:51 A.M. [CN called Same Day Ambulatory]: Send two more patients, Dr. XX from OR 8 to OR 12 and Dr. XX from OR 1 to OR 5.

We observed many cases in which the timely sharing and communicating of information prevented local interruptions from spilling over and interfering with other groups' activities. We also observed cases in which important information, such as late patients, delayed cases, and missing equipment, failed to be communicated in a timely fashion and caused substantial delay and financial loss. Most of the communication breakdowns occurred at group boundaries. Thus our data highlight the potential value

of information technology to assist communicating across group boundaries and to cope with the frequency and unpredictability of interruptions and the extensive workload of boundary spanners such as charge nurses and charge anesthesiologists.

Joint Problem Solving

Coordination breakdowns that can be contained to a local group are usually easier to recover. For instance, a late or sick nurse or nurse anesthetist can be replaced with a free person. Coordination breakdowns that affect more than one group need to be resolved with the involvement of all groups affected by the change, which we call joint problem solving. The following quotations illustrate a joint problem-solving scenario where the charge anesthesiologist (CA), a nurse anesthetist (CRNA), and a charge nurse anesthetist (CC) discuss and respond to an emergency by opening a new room.

> CRNA to CA: Can we break up OR 1?
>
> CRNA to CA: Maybe we can open OR 26. There are seven cases scheduled in OR 27.
>
> CRNA to CA: If you open OR 26, I will go.
>
> CA to CC: They are going to open OR 26 and the surgeon will flip-flop back and forth between 26 and 27. Let me know if things slow down and I can help with post-op.
>
> CRNA to CC: If he flip-flops in 26 and 27, they will need breaks.
>
> CC: No, they have a resident in the room and they may be done early.

Our observations highlight the potential use of information technology to visualize room status and to assist joint problem solving, as one charge anesthesiologist describes below how an electronic whiteboard with dynamic information and color coding can help.

> We need an LCD screen about this size [as big as the whiteboard]. Data from the assignment sheet and schedule can be used to populate all the boxes on the board. Then we pull information from OR and have a field of estimated finish time. We compare the estimated finish time to shift and set rooms to different color (e.g., yellow means need people to cover rooms after 3 P.M.). Then we have a column of patient availability. That would allow us to give instant information to surgeons, to reduce phone calls, to do more patient care, and eliminate people not being able to leave on time. [Anesthesia]

Role Switching

Another approach to coping with coordination breakdowns is role flexibility or role switching. Within groups, role switching is enabled with slack resources and dynamic

delegation. Most groups schedule one or two additional personnel to give breaks and to prepare for unexpected events such as sick call offs or emergency cases. Each group also designates a list of people who can stay late in case the schedule runs late.

> I was not assigned to a room today, which means I am a free person to give breaks and to fill whatever needs that arise. I volunteered to do the trauma case and this emergency case. I checked at the board and saw this case and volunteered to come to the room. [Anesthesia]

Due to the high overlap of training and work responsibilities, pre-op, post-op, and same-day nurses can be shifted around during the day as workload fluctuates.

> We wear a lot of different hats depending when and where we work. It could be pre-op, post-op, or same-day services. . . . During the day we may have to run 15 patients in 12 spots [in pre-op] and we have overflow problems. By the end of the day, there are not many pre-op patients and this place can be used as post-op. Our staff is used to do that [switching between the two]. [Pre-Op Nursing]

We also observed many cases in which people assumed a temporary role across group boundaries. OR patient care requires specialized training and expertise. Therefore, pitching in across group boundaries only occurs in a limited number of scenarios when the vacant role does not require much specialized expertise or when the fill-in person has a higher level of expertise, such as an anesthesiologist filling in for a nurse anesthetist, but not vice versa. A common scenario is for nurses and anesthesiologists to pitch in and serve as temporary escorts.

> We have two escorts. They only assign two people to us. Sometimes nurses and anesthesiologists have to pitch in and take their patients from pre-op to OR, which is one level down. [OR Nursing]

Our observations highlight the potential use of information technology to promote awareness of emergent needs within the system and facilitate the ease of finding a substitute or replacement when the designated person fails to take responsibility.

> We talked about having a headset with a speaker belt mounted. It will work like a walkie-talkie. We can broadcast to call all anesthesiologists when there is a compelling need to respond. . . . Our OR is this big. Most of the time, someone is free and available [to help]. It is a question of effective communication to find that person. It doesn't matter who fills in as long as someone with similar qualifications steps up to the plate. [Anesthesia]

Consequences of Coordination Breakdowns

WHEN GROUPS FAIL TO ACT COLLABORATIVELY TO ADJUST TO BREAKDOWNS, negative consequences can ensue. In this section, we discuss consequences of interruptions and coordination breakdowns to the organization and to individuals.

Organizational Consequences

From an organizational perspective, interruptions can have both positive and negative consequences. On the positive side, interruptions instigate coordination in real time, which can be an efficient "market-driven" method of allocating people's attention and resources. On the negative side, interruptions may cause breakdowns that cannot be easily resolved and can lead to delays and reduced profit margins. Also, interpersonal tension and conflict arise when groups must continually attend to coordination when, at the same time, workload and stress are high.

Delays and Financial Losses

Efficiency and resource utilization are major concerns of the hospital administration. People adjust to coordination breakdowns to solve problems, synchronize activities, and sort out priorities. When people fail to adjust quickly, delays occur. Every time an OR is put on hold, patients, families, and the whole OR team will be waiting. A direct consequence of low efficiency is financial losses and low profit margins. OR is the biggest revenue generator in the hospital that we studied and in many other hospitals as well. Every time an OR is put on hold, the hospital has to pay people to wait instead of taking care of patients. Additional costs are also incurred outside of ORs. Preoperative and postoperative charges are either a flat rate across cases, or a flat rate by case categories (e.g., neuro, transplant, etc.). When a patient is stuck in one of these places and blocks personnel and resources that could be otherwise utilized, the delay boosts costs.

> It is a stochastic process organized around emotions. It is pointless to model it using the conventional orderly process. We have a $42 per minute OR team waiting for a $0.09 escort. This is the kind of disorder built into the system. [Anesthesia]

Intergroup Tension and Conflict

Groups have incentives, temporal cycles, and considerations that are not always aligned with those of other groups [31]. Surgeons have flexible working hours and are motivated to get many cases done. Like surgeons, anesthesiologists have flexible working hours so that they go home early on light days and stay late when necessary. In contrast, OR nurses work on shifts and are paid by an hourly rate. Already struggling with constant turnover and inexperienced nurses, charge nurses strive to get their staff out on time and to minimize overtime work.

People negotiate as part of their daily routine to solve problems, synchronize activities, and sort out priorities. The highly dynamic nature of the environment and constant interruptions to the OR schedule add an extra burden to negotiations. When a patient is delayed or a room is put on hold, groups blame one another. Surgeons get mad at anesthesia teams or nurses, and anesthesia and nursing teams complain

about surgeons' big egos and narrow focus. Everyone is frustrated with escorts and housekeeping. Some comments are very emotion intensive.

> Everybody yells at you. You have to be on your feet all the time and not piss off anybody. You need to keep peace on the floor. I have got [titles omitted] yelling at me. If you don't keep the peace, you get in trouble. [Ambulatory Nursing]

> [The biggest challenge is] resistance. People put up resistance to change. We are good within our department. Outside of our department, people don't want to be of help. I make phone calls and sometimes it is an unpleasant phone conversation. People say, no, we are not staffed for that and we can't work with that volume. [Ambulatory Nursing]

Individual Consequences

When a case is delayed, patients may experience unnecessary waiting or sedation, OR staff may have to work overtime to finish cases that are delayed or bumped during the day, and surgeons may be late for their responsibilities outside of the OR or hospital. Consequently, everyone experiences and suffers from frustration, stress, and fatigue.

Patient

When coordination fails and a case is delayed, patients may have to wait longer to go to surgery. If an interruption happens after a patient is already sedated, patients may get unnecessary sedation. Because the hospital that we studied is highly prestigious, patients come from all over the country. Although hospital policy gives higher priority to outpatients and patients with special constraints, it has happened that patients needed to come back the next day, which disrupted their families and their personal plans outside of the hospital.

> It doesn't affect me very much. But it is a waste of time and the poor patient has been waiting for one hour. We have nothing to do, but sit and wait . . . the patient family is waiting. [OR Nursing]

> The patient was getting anxious and they gave him [some sedation] to help him. [How did this delay affect work flow?] Every other patient that is coming after that patient will be delayed. Patient satisfaction decreases as a result. [Ambulatory Nursing]

Surgeon

Theoretically, surgeons have the biggest clout because of their specialized expertise and prestigious status. Surgeons' decisions may a have significant impact on other stakeholders. In practice, surgeons are affected by others' trajectories. One nurse

said surgeons are "guests who are invited to a party" that is organized and run by anesthesiologists and OR charge nurses. Breakdowns that happen anywhere along their trajectories can interrupt their own work plan both within and outside of the OR. A typical conversation between surgeons and OR desk or pre-op desk is, Where is my patient, or, Is my patient here? When their cases are delayed, surgeons get upset because they will finish fewer cases, may need to stay overtime and work with different nurses as nurses change shifts, and will neglect responsibilities that they are committed to outside of the OR.

> It delays your surgery. I have two surgeries scheduled for today. I have office hours [seeing patients in my office]. [Someone passed by and said to the surgeon, "You are fast."] "They put up every means to delay me. [Surgical]
>
> [What happened to the surgeon when the case was delayed?] They would go and sit in the lounge. In this case, it just so happened the surgeon had two rooms this morning. He was able to go to his second room. Or he may go get coffee or do some dictation. Then they come back to us and ask, "Where is my patient?" [OR Nursing]

Anesthesia and Nursing

As individuals who work primarily in the OR and are in charge of OR scheduling, charge anesthesiologists and charge nurses experience the most significant impact from breakdowns. When delays happen, these OR staff stay overtime, and become stressed by this aspect of their work. We were told that turnover rates in OR units have been consistently high in the past decade, nationwide.

> [When a case is delayed,] I send my people to get coffee. [As a result,] the room may not be done at 3 P.M. as it is supposed to be. I would have to pay overtime to have my people stay after 3 P.M. That would kill me if it was my fault [to put OR on hold]. OR time is $42 per minute. We will have to pay people to sit around and wait. [OR Nursing]
>
> People place blame on others and not take responsibilities. . . . Patients wake up and are ready to go. They get upset and say my surgery was scheduled a month in advance, why don't I have a place to go. They get upset with us. Family members get upset while waiting. . . . If a patient has been here for more than two hours, their family members can come and visit for a few minutes. They get angry when they have to leave. [Post-Op Nursing]

Lessons Learned from the Field

OUR QUALITATIVE DATA ANALYSES IDENTIFY THREE FACTORS that are crucial to smooth coordination across multiple group practices: (1) trajectory awareness of what is going on beyond a person's immediate workspace, (2) integration of a wide array of

information systems, and (3) information pooling and learning at the organizational level. In this section, we explain where these factors are important and speculate on how information technology might be adapted or designed to support multiple group coordination in complex and dynamic task environments.

Importance of Trajectory Awareness

Coordination breakdowns can happen anytime and anywhere in the OR workflow. Often these can be fixed on the spot. However, because of the tight coupling and high interdependence across group activities, small breakdowns within groups can escalate and spill across group boundaries. To minimize these escalations, people need trajectory awareness, which we define as being aware of critical events that happen along multiple relevant trajectories. These critical events are often separated from the focal person both geographically and temporally, and thus do not fall in the attention circle of normal situational awareness.

Trajectory awareness is important for several reasons. First, it facilitates proactive actions in responding to unexpected interruptions. Knowing that a patient is going to be late to be transported to OR (versus already late), the charge nurse can adjust the OR schedule to move the next case up or to fill in with an add-on case so that expensive OR time will not be wasted. Second, escalations often are caused by "waves" in OR workflow. Waves happen when OR calls for five patients or when five rooms finish at roughly the same time. Big waves can quickly and easily exhaust slack resources and create bottlenecks. Trajectory awareness can prevent waves from forming and alert relevant groups when waves do form so that they can be better prepared. Trajectory awareness can alleviate intergroup tension and conflict as well. OR is a very stressful environment and people must concentrate to get their work done. People communicate through mostly brief phone conversations and only have time to convey the most important pieces of information. Failing to share seemingly unimportant information may lead to miscommunication and misunderstanding. Trajectory awareness could help build common ground as a basis for effective communication and joint problem solving.

Recommendation I: Interactive E-Whiteboards

We support the idea of distributed, interactive e-whiteboards [6] to improve trajectory awareness, although we recognize considerable technical challenges in creating such digital artifacts. In one of the OR units we studied, there was only one whiteboard outside of the nurse anesthetist office used exclusively by the anesthesia group. OR charge nurses worked primarily with a printed OR schedule and the scheduling software to make changes. Pre-op and post-op each had their own small whiteboards that were primarily used for space and staff allocation within their own units. Consequently, every change made by OR charge nurses needed to be communicated by phone or face-to-face to all the other groups. Frustration and conflict arose when changes were not communicated in a timely manner.

We envision that e-whiteboards might be placed in pre-op, the OR desk, and post-op areas, respectively, as illustrated in Figure 2. These boards could be configured to display information needed by each group. The boards can be automatically populated using information from a supporting database (an extension of the current scheduling system, for instance). The three boards then communicate through the database. When charge nurses change the OR schedule, a request would be sent to the supporting database and the database automatically updates all e-whiteboards. Thus e-whiteboards become more than a visual display or a reference for interpersonal communication. They can prompt constant communication of every action and help minimize the need for communicating every action that each group initiates that may interfere with other trajectories or the overall workflow.

The Importance of Organizational Learning

When groups are separated by multiple boundaries, group members tend to focus their attention on local issues and fail to see the big picture of collaborating with each other. Activity theory suggests that coordination involves direct coordination, cooperation, and coconstruction [3]. Most of what we observed involved coordination (routine flow of interactions) and cooperation (interactions with shared objectives), but little coconstruction (reconceptualization of ways of organizing to achieve shared objectives).

Almost all of the groups we observed practiced heavy bookkeeping on paper. OR nurses recorded the start time of every case and documented reasons for delays. Post-op coordinators recorded the in and out time for every patient and reasons for overstays. Because these records were in paper format and the purpose of bookkeeping was to minimize errors and liability rather than to improve processes, all of these records stayed on paper and were not analyzed for business process reengineering purposes. Across group boundaries, there was little systematic reflection, learning, and adaptation based on a holistic view of how workspaces were configured and resources were allocated. As a result, we observed continuous recurrences of certain types of escalations that resulted from a small set of bottlenecks built into the system (e.g., the shortage of escorts to transport patients). Problems were solved locally by different groups over and over again using local evidence, rather than all of the groups pooling information to identify and solve the larger causes of these problems.

Recommendation II: Context-Aware Systems

We propose the use of context-aware systems to automate data collection and to ensure the accuracy and timeliness of the data. Context-aware technology can be used to acquire information about the physical location and social situation of a device or a person. Example systems in the OR context include context-aware beds or location-aware bracelets to keep track of patient status [5], location-aware PDAs to locate surgeons and anesthesiologists, and video and audio sensors to detect activities in the ORs [21].

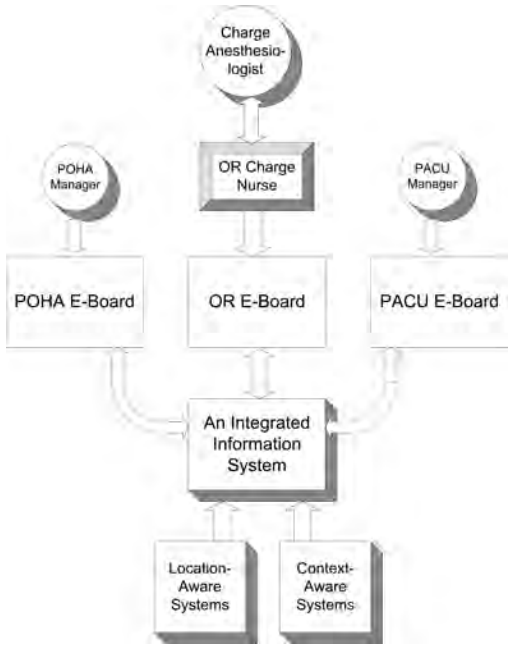

Figure 2. A Design Prototype for Interactive E-Whiteboards

Standardizing and delegating routine communication tasks to context-aware systems could improve multiple group coordination in several ways. First, such systems can significantly reduce the costs of gathering and sharing information. Information is collected and disseminated as a by-product of getting work done. As a patient is transported to the preoperative holding area, for instance, the context-aware bed senses its location and automatically sends signals to update the patient's status in the supporting database. The same thing happens when a surgeon enters the hospital building. These items of information are then distributed to the groups who will be serving the patients or working with the surgeon later.

Second, this arrangement enables the decoupling of information seeking and providing [37] and may reduce the negative effect of interruptions. In face-to-face or phone communications, information seeking and providing are tightly coupled—information is provided when it is solicited. Individuals and groups constantly interrupt each other for information, and key players such as charge nurses get overloaded as the hub of information flow [32]. This arrangement will also alleviate problems associated with the political use of information as it makes it difficult for one party to withhold information from another due to accountability concerns [40].

Gathering and synthesizing information using the context-aware technology also provides a basis for groups to examine and reengineer their business processes. Automating data gathering is an important design option to consider because users do not use information systems if the documentation can hold them accountable [2]. With

critical events recorded, systematic analyses can be conducted and used to diagnose and redesign the current way of organizing and coordinating. We propose the use of a business intelligent agent that mines the activity data to identify critical points at which coordination breakdowns happen most frequently or have the largest impact. These critical points can be brought to the attention of top management or relevant group meetings to be examined in greater detail, which may identify potential opportunities for business process reengineering. The goal is to hold inefficient practices accountable instead of holding people or groups accountable.

The Importance of Information Systems Integration

A technological solution is not successful unless or until it becomes accepted and properly integrated into the organizational practices. Collaborative technology does not necessarily engender collaboration unless organizational norms and incentives encourage it [34]. Our data revealed the importance of fostering a collaborative culture in implementing our technical recommendations and integrating the independent systems under a coherent information technology infrastructure.

Information systems integration is important because it facilitates local activities whose delay may interfere with activities in other groups and increase the chance of coordination breakdowns. For instance, many cases we observed in the ambulatory surgery unit occurred due to incomplete patient information. Like many other hospitals, the hospital we studied has spent millions of dollars on various information systems for billing, scheduling, pharmacy, material management, and patient administration, yet has been behind in integrating the various systems and building an information technology infrastructure to exchange information with other hospitals. The information systems are heterogeneous, incompatible, and developed by different vendors to meet local needs [22]. As a pre-op nurse commented:

> Our systems don't talk to each other. There is no unique information to identify a patient. A patient may have different account numbers or medical record numbers in different systems. That is why we have this $400 million deal with IBM [to improve information technology support]. [Pre-Op Nursing]

As a result, the lack of system integration, on one hand, leads to increased workload as care providers spend time logging in and inputting data in multiple applications and paper documents; on the other hand, it leads to low efficiency and suboptimal patient care as care providers struggle to gather information from various systems.

> [What happens if you have an integrated system?] Nurses would still need to give a detailed report about patients. But they save time for finding the information they need. Now they have to look through paper or in a different system. . . . Also, the system should be used in the community. Patients go to their family doctors. We should be able to see what happened [in the past several months] through the system. [Post-Op Nursing]

Recommendation III: Stakeholder Involvement and New Roles

Information systems integration and business process engineering require substantial involvement from all stakeholders, from top management to lower-level workers. Neither effort can succeed without top management's buy-in and hearty support. Likewise, no information systems can succeed or have an impact without being adopted and used by individual users. Before any new systems or technology gets introduced, the organization should consider holding information and training sessions and revisiting its incentive systems to minimize user resistance.

Meanwhile, the hospital should consider creating new roles such as collaboration engineers [7] who work with groups involved in OR services to integrate collaborative technologies and to (re)design collaborative work practices. Some hospitals have explored the use of multidisciplinary OR management teams, comprised of a charge anesthesiologist, a charge nurse, and a charge nurse anesthetist, to continually communicate throughout the day to review and manage OR schedules [17]. The preliminary results have been promising, with a substantial increase in OR resource utilization rate and a decrease in OR gap time. Similar teams or task forces can be formed at the administrative level with representatives from multiple groups to participate in joint problem solving and business process reengineering of coordination practices.

Our results also suggest the importance of a collaborative culture. By a collaborative culture, we refer to key organizational elements that will positively affect workers' attitudes toward collaboration and their perception and usage of collaborative technology. Most tension and conflict that we observed was task related. Some emerged due to different perspectives on a problematic situation or divergent goals and priorities, but in other cases, there were underlying organizational politics and conflicts over power. Inherent value differences and power struggles across professional groups have been shown to be a major barrier to system integration [21]. We argue that a collaborative culture encouraging relationship building, informal communicating, and perspective taking will facilitate multiple group coordination.

Conclusion

IN THIS PAPER, WE PRESENTED AN IN-DEPTH CASE STUDY in a local hospital to understand the challenges associated with multiple group coordination and how information technology can be deployed to address these challenges. Combining observations and interview data, we examined the sources and consequences of coordination breakdowns when groups failed to adjust to unexpected interruptions. Our data highlight a major challenge in multiple group collaboration—that is, the complex interdependence and tight coupling of multiple trajectories across group boundaries. We propose technological and managerial changes for the purposes of promoting trajectory awareness, information systems integration, and learning at the organizational level. We also discuss the important role of a collaborative culture in facilitating the effective utilization of collaborative technology.

Our goal is to provide insights and recommendations that information systems designers and managers can easily grasp and act upon. We believe our findings and recommendations have the potential to advance the development and application of information technology to coordinate complex trajectories spanning multiple groups in critical environments such as hospitals. Even though a hospital is one of many high-risk organizations, we believe that the lessons learned and conclusions drawn might be generalized to other high-risk settings such as airline operations and disaster response groups. The technological recommendations such as e-whiteboards and context-aware systems might be adapted to fit user needs and task requirements in other contexts as well. For instance, location-aware PDAs and cell phones can be adapted to establish a wireless sensor network among first responders to keep track of each others' locations, to alert each other of potential dangers, and to facilitate efficient allocation of resources after catastrophic events.

Although we are enthusiastic about our findings and recommendations, we realize they are preliminary solutions to a comprehensive, challenging problem. We acknowledge that technology alone rarely, if ever, solves any problems thoroughly. We propose the use of e-whiteboards to facilitate information sharing and to reduce workload but acknowledge they will not substitute for spontaneous, informal communication [25, 44]. We propose the use of context-awareness systems to automate information collection but acknowledge they may raise privacy and security concerns. We propose fostering a collaborative culture but acknowledge the importance of individual stakeholder groups. Addressing all of these issues is beyond the scope of this paper. We hope that our paper stimulates more interest among organizational, technical, and information systems scholars to study the challenges associated with adapting and managing information technology to facilitate multiple group coordination.

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