Supporting Coordination in Surgical Suites: Physical Aspects of Common Information Spaces

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ABSTRACT
To accommodate frequent emergencies, interruptions, and delays, hospital staff continually make and coordinate changes to the surgery schedule. The technical and social aspects of coordination in surgical suites have been described by prior studies. This paper addresses an understudied aspect of coordination: the physical environment. Based on a field study of four surgical suites in two large academic centers, we show how the physical layout of hallways and rooms, and barriers and spaces around displays and key coordinators, support or fail to support the common information spaces used for coordination. We use the concept "information hotspots" to represent how physical places and their characteristics facilitate coordination. We developed design principles based on the concept of information hotspots that should guide architectural considerations for coordination in dynamic environments such as hospitals.

Author Keywords
Coordination; physical environment; shared displays; electronic scheduling; whiteboards

ACM Classification Keywords
K.4.3 Computers and Society: Organizational Impacts: Computer-supported collaborative work.

General Terms
Human factors.

INTRODUCTION
High medical costs and the need to improve efficiency, quality, safety, and privacy are leading concerns of hospital-based health care. Information systems and architectural designs are two areas that have been targeted to address these concerns. Traditionally, studies and design principles related to architecture and information technology have little interaction. With the advances of information technology, more and more information technology is part of architectural design (see Figures 1 and 2). Such technology includes large displays, embedded devices, and kiosks.

Figure 1. Nurse at control desk and schedule whiteboard. (Photo ©Andrey Kiselev. Reprinted with permission.)

Figure 2. Nurse at electronic schedule board.

For example, surgical information systems are traditionally designed to address scheduling constraints, allocation of personnel, and supply management. Adjustments to surgical schedules are usually considered to be independent of the architectural design of a hospital, even though the changes must be relayed instantly to all clinical staff, who are constantly on the move throughout large building complexes [7]. Much of the literature on surgical information systems is focused on operational scheduling [e.g., 12]. Scheduling surgeries is difficult due to the uncertainty of each surgery's length and the need to accommodate emergencies, complications, staff shortages, workload rules, resource unavailability, variations in surgeons, patient responses, and many other factors. A surgery cancellation risks wasting operating room (OR) space and staff time unless a new surgery replaces the cancelled one. To keep the flow of surgeries constant, changes to the schedule, and of people's locations in physical space, can happen hundred of times in a single day.

The organizational and social processes surrounding scheduling also cause information systems and architecture to intersect. Many groups—surgeons, anesthesiologists, nurses, and other medical workers—constantly coordinate their tasks on the day of surgery, after schedules for the day have been produced [13]. Ongoing interaction is needed to arrange staff, patients, surgical rooms, and equipment for each surgery [4, 55]. Artifacts, many created by the users themselves, are widely used [e.g., 11]. In addition to articulation of activities to resolve constraints of various types [27], staff is confronted with managing organizational and social conflicts inherent in complex organizations whose workers are distributed in space but whose tasks are tightly coupled [49, 54].

Uncertainty, variation of work processes, and social conflicts are also reflected in how hospital staff coordinate their work. Informal oral communication dominates coordination [31, 32]. Staff from different specialty groups negotiate how they will adapt to a schedule change [37, 38, 47, 54], for instance by postponing a non-urgent surgery versus requiring nurses to stay overtime. Such negotiations require synchronizing tasks across groups, time, and place, and estimating physical resources and staff workload [6].

To support these work processes, hospital staff rely on a variety of artifacts, including paper schedules, electronic records, whiteboards, and mobile devices [e.g., 40, 48, 56, 33]. Together with people's shared understandings of the information they contain, these artifacts comprise one or more *common information spaces* [3] that help guide staff behavior. How rich and timely the information in the common information space is depends not only on the artifacts themselves and people's understandings but also on how well the physical environment of the OR suite supports interaction with those artifacts. Whiteboards with valuable information about patient status, for example, may go unnoticed if they are located off the beaten track, or if it is difficult to update them.

In this paper, we examine the impact of the physical environment surrounding two critical spots in OR suites, large displays and nursing control stations. We explore how the characteristics of this physical environment influence the common information spaces that develop and how well people can use them to coordinate their work. Based on detailed observations of four OR suites, we propose a set of design guidelines aimed to improve the quality of common information spaces, reduce coordination burdens, and improve coordination efficiency. We discuss how these design guidelines can be applied in traditional hospital settings that rely on large displays for coordination and inform the design of new coordination tools such as handheld devices that are less constrained by physical architecture.

The physical environment of coordination

Hospital coordination takes place in distributed physical space. Staff, patients, and equipment move through different hospital areas that are usually highly specialized [7, 50]. For instance, patients are prepared for surgery in one location, have surgery in a second location, are taken for post-operative care to a third location, and then go to a patient room in still another location. These architectural dimensions of hospitals can significantly impact information access and interpersonal interactions [44]. They can constrain possible locations for whiteboards and other large displays and the likelihood that a person will encounter these artifacts in the course of his/her normal work activities. In addition, the physical environment of buildings shapes where people move and pause to converse, where they place information for others to see, and ultimately how much they collaborate [1, 19, 26]. For example, placing a schedule whiteboard where nurses and anesthesiologists are likely to pass by at the same time can make collaboration feel natural and signal that the organization sees them as a team.

In research organizations, when offices are nearer to each other, co-workers like each other and communicate more [1] and are more likely to co-author papers [26]. Visual and auditory access between workspaces increases communication opportunities whereas barriers such as walls and stairways reduce opportunities for eye contact and conversation [15]. Similarly, the easier it is for people across groups to share scheduling information, the more effectively they will coordinate the schedule. Unfortunately, in many older hospitals in the U.S. and elsewhere, staff who have to coordinate their work are separated by a maze of corridors, stations, and walls.

The schedule board and nursing control center as hubs for information and coordination

Researchers have identified two physical locations where staff are very likely to coordinate the surgery schedule. One of these places is at the nursing control desk. Originally tasked to guard the sterile areas surrounding ORs, today's control desk nurses, especially the charge nurse, play a key scheduling role. They manage the moment-to-moment schedule for the surgical suite, emergency and new "add-on" cases, day-of-surgery support services, work

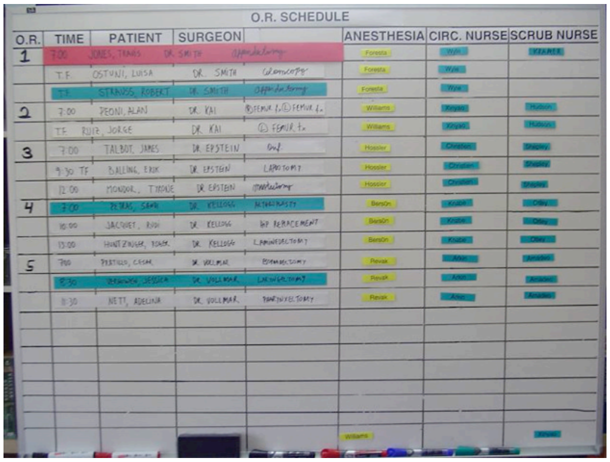

Figure 3. Whiteboard with surgery schedule listing operating room, patient name, procedure, time, and staff assigned to the case.

assignments related to transport of patients and specimens, and equipment and supplies for delivery to the surgical suite. People standing at the control desk can discuss the schedule in real time, as the control desk nurses make changes on paper or into a computerized scheduling system.

Another key location for coordinating the schedule is in front of a manual scheduling whiteboard that displays the schedule and can be updated using erasable markers or magnetic strips (Figure 3). A manual whiteboard puts information pertaining to different staff groups "in the world," which reduces memory load [36] and mistakes [33]. It serves as a shared tracking system [5, 23, 55]. The whiteboard also provides an interactive physical interface to the schedule. Staff within and across groups can stand around the board and see changes to the schedule as they are made. Typically, the charge nurse or charge anesthesiologist is responsible for making changes, but others can participate in decision making.

The physical environment and common information spaces

In many OR suites, the nursing control center and public whiteboard play central roles in the creation of *common information spaces* (CIS) [3]. CIS bring people and information together, through artifacts (e.g., paper notes, public displays, electronic records) and interpersonal communication, and they help ensure uniformity of interpretation. In hospital suites, CIS have both virtual and physical aspects [e.g., 48]. Staff are constantly on the move [7], carrying paper artifacts and exchanging information by phone and other mobile devices from distributed locations in the hospital. They also congregate in physical places, such as the floor in front of the whiteboard or the nursing control desk, where surgery schedules, staffing information, patient status, and other information can be found.

Because of the rich information available at the nursing control desk and whiteboard, the physical dimensions of these places may be especially important in determining the quality of the common information space. When architecture makes it easy for people to interact with the information, we propose, that information is more likely to become part of the CIS. When the architecture makes information sharing difficult, the quality of the CIS will be reduced and coordination will be more difficult. For instance, in one study, coordination breakdowns happened when staff separated by a long corridor and barriers had to call around to find their patients [38]. In the present study, we explore the role of the physical environment in shaping common information spaces, exploring how the environment around the nursing control desk and the public whiteboard displays shapes how well OR staff can interact with the artifacts found therein, talk to one another, and reference common information [17, 46].

We explore two aspects of this physical environment: architectural structure and local positioning of displays within this architecture. By architectural structure we mean features like hallway width, wall locations, and room size that influence how easily people can congregate. With regard to positioning, we consider factors such as display height that have been shown to affect how much people engage with a public display [e.g., 20, 24, 39, 45]. We also explore how these characteristics of physical space affect whether people have easy access to an up-to-date schedule, whether they participate in shared decision making around the schedule, and how well they can coordinate their work. We show that the physical environment surrounding an artifact such as the schedule whiteboard affects the role it will have in the common information space of the OR suite.

METHOD

Our field study examined the impact of the physical environment around surgical scheduling whiteboards and nursing control desks in four surgical suites. Two suites were located in a large academic medical center in Pennsylvania, USA, and the other two surgical suites in a large academic medical center in Maryland, USA.

Pennsylvania site

One surgical suite at the Pennsylvania site, which we will refer to as PA-General, had 25 ORs. PA-General is associated with a level one regional trauma center and thus has the mission to care for trauma patients who need emergency surgery. The suite accommodated surgical procedures common to large tertiary medical centers, such as cardiothoracic surgery, organ transplantation, neuro-vascular surgery, orthopedic surgery, trauma services, and neurosurgery. The procedures tend to be long and highly variable.

The other surgical suite, which we refer to as PA-Ambulatory, had 14 ORs. PA-Ambulatory specializes in small bowel and liver transplant, and orthopedic procedures. The surgical cases at PA-Ambulatory tend to be short in duration compared to those at PA-General. On a

Figure 4. The area around the whiteboard and control in MD-Trauma surgical suite. On the drawing at right, the route to the sterile corridor is indicated by a S. the symbols a, n, c. and s represent anesthesiologist, nurse, clerk, and surgeon.

regular workday, PA-General performed 40 to 50 cases and PA-Ambulatory scheduled 30 to 40 cases. PA-General had more rooms and scheduled cases, but on average fewer cases per room as compared with PA-Ambulatory.

Maryland site

The two surgical suites in Maryland will be referred to as MD-General and MD-Trauma. MD-General is a surgical suite with 21 ORs that serves the tertiary medical center for ambulatory and in-patient surgical procedures. MD-Trauma is a surgical suite with 6 ORs as part of a regional referral center for trauma. MD-Trauma specializes in trauma injuries. More than 50% of the cases were unscheduled due to critical and unstable state of its patients.

The two suites were adjacent but in two different buildings, MD-General in a new building and MD-Trauma in a smaller, older building. During our study, on a regular workday, MD-General scheduled 37 to 61 cases and MD-Trauma scheduled 7 to 22 cases. MD-General had on average, fewer cases per room as compared with MD-Trauma.

Observational data collection

In all locations, we observed and talked with administrative clerks at the control desks, anesthesiologists, anesthesia technicians, surgeons, and nurses. Because our purpose was to understand the physical environment of coordination, we wanted to observe actual behavior and map the spaces in which coordination occurred around information artifacts. Our focus was the areas around the whiteboards that were used by all four surgical suites. The observations and interviews were about contrasting how the whiteboard was used across the suites. We looked at the interactions with the whiteboards by individuals and by several people, the social interactions in front of the whiteboards, and behaviors in general in the areas surrounding the whiteboards. We leveraged the architectural training and experience of one of the authors in our data collection.

At the Pennsylvania site, the first author observed at the scheduling whiteboards 185 hours over a period of 6 months during 18 separate field visits in each site on different days of the week and at different times of day. He began daily observations by counting the number of scheduled ORs on the whiteboard and the number of cases posted for each room. He recorded people's behavior at the whiteboard (e.g., looking at whiteboard, talking with one another, updating whiteboard, making phone calls, leaving the whiteboard, and so forth), noted what people said, and described their conversation partners. Each event was time stamped. After a day of field observation, the observer typed up field notes, adding detail to explain the environment of the recorded events.

At the Maryland site, using a similar procedure but observing behavior at both the whiteboards and the control desks, the first and second author spent 110 hours in the field observing, 58 hours over 41 days in MD-General, and 52 hours over 39 days in MD-Trauma. They collected data over a period of three months.

Field notes were analyzed for themes of coordination activities and inter-personnel interactions around the whiteboard areas.

Mapping of physical environment

We followed the tradition of architectural analysis and sketched the layout of each whiteboard's location and nursing control desk, photographed them to record their setting, and compared the different kinds of information and artifacts each held. We used these data to create three representations for each site: a three-dimensional model of the area around the whiteboard and control desk, a photograph, and a schematic diagram of the suite. Figure 4 shows one such set of representations.

Based on our initial analysis, we developed six characteristics of the physical environment in relation to information artifacts and sources:

- Physical distance between information sources and where people were working
- Visibility of information sources
- Spaciousness of an area around information sources (allowing for conversation)

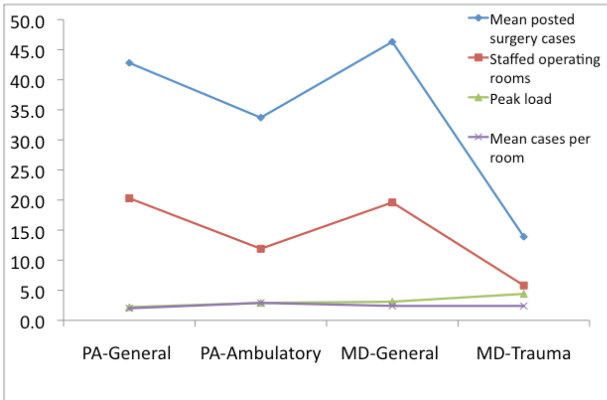

Figure 5. Number of cases, number of rooms, mean cases per room, and peak load (most cases in a room on busiest day) in each of the four surgical suites.

- Connectivity (central location) of information sources, pause locations near information sources and their geometric shape
- Presence and shape of dwell locations (counters, benches, chairs) where people could lean or sit to talk
- Display size and information content

We measured walking distance from one place to another, visibility between work locations using the isovist overlap technique [41], and spaciousness of hallways and the area where people could stand in front of whiteboards and control desks. We also measured connectivity between key locations in the OR suite [21, p. 126]. We were especially interested in task-related connectivity, that is, the number of surgical task-related locations accessible from the whiteboard or control desk without opening any doors, or after opening one door. We also measured the size and information content of whiteboards.

RESULTS

Overall, work in all four locations was similar to that reported in previous studies in terms of interdependence of staff from different groups, the constant mobility of staff, the use of multiple information artifacts, and the constant need for coordination. All sites also experienced significant workload, as measured by surgeries per OR room per day, peak surgeries per day (see Figure 5). Here, we describe the ways that the physical environment shaped common information spaces and coordination in the four OR suites.

Physical environment of whiteboards and control desks

We compared the suites within each hospital organization (PA, MD), to control for hospital policies and procedures regarding scheduling.

PA-General. In PA-General, a scheduling whiteboard was located on a 5-foot wide hallway off the main hallway to the sterile corridor and outside the anesthesia lounge (Figure 6). It sat between the unrestricted area and the restricted sterile corridor, the staff lounges, and a post-anesthesia care unit (PACU).

The PA-General control desk was around the corner from the whiteboard, through an automatic door, and faced the main path heading towards the sterile corridor. In PA-General, the out of way location of the whiteboard from the non-anesthesia staff, and its distance from the control desk, discouraged face to face coordination around the board, especially across staff groups. To interact with someone from the anesthesia team at the board, control desk nurses had to leave their station, pass the automatic door, and walk around the corner.

Figure 6. Schedule whiteboard in PA-General, located off the main hallway to the sterile corridor. The control desk is behind an opposite wall.

Because the whiteboard area was not visible from the control desk, nurses did not know if the trip was worth the effort. People pausing at the whiteboard could not hear conversations at the control desk that might affect them. They generally called or walked over to the control desk to discuss changes to the schedule.

The comparatively low levels of ongoing coordination between nurses and anesthesiologists meant that people did not always know what others were doing, and delays in attending to emergencies, as noted in these shouts at PA-General's whiteboard:

"*Didn't anyone hear the overhead? There is a code in the PACU, bed 7.*"

"We have an emergency in room 1 and Dr. X is not answering the phone!"

In both instances, everyone at the whiteboard and in the nearby anesthesia lounge ran to respond.

PA-Ambulatory. PA-Ambulatory suite's whiteboard and control desk were located at the intersection of three hallways (Figure 7). The hallways led to the patient holding area, the elevators, the unrestricted area, the ORs, and the post-anesthesia care unit.

The whiteboard hung next to the U-shaped control desk. The U-shaped control desk, surrounded by hallways,

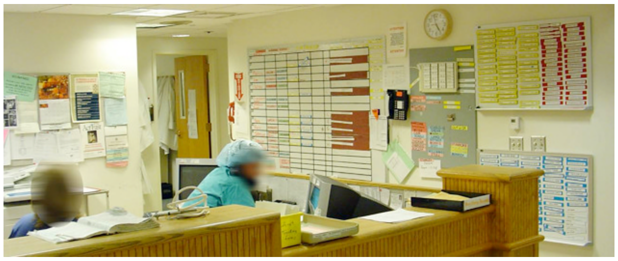

Figure 7. PA-Ambulatory surgical suite's control desk and whiteboard.

encouraged staff to interact with others on three sides, and to passively monitor bystanders at the whiteboard, the placement of which allowed for mutual visibility. The charge nurse sat closest to the whiteboard and a receptionist sat in a central portion facing the main hallway.

To allow patient gurneys to pass the control desk, the main hallways were eight feet wide. Anesthesiologists frequently passed by and looked at the whiteboard. They also congregated at the whiteboard side of the control desk, which seemed to be their territory, leaving the other sides for nurses and surgeons.

Due to PA-Ambulatory's high coordination load, and the convenient location of the whiteboard, we expected staff members to visit PA-Ambulatory's whiteboard more often than in other surgical suites. We compared behavior there to that in PA-General, the connected hospital in Pennsylvania with similar procedures for patient care and scheduling. Notwithstanding the higher number of posted cases in PA-General, the mean number of trips to the whiteboard per person was higher in PA-Ambulatory than in PA-General (4.1 trips vs. 2.4 trips).

We also counted staff members at the board alone or with others at the board. (To normalize we divided the total number of interactions by the mean number of staff working in the ORs.) We found more interpersonal contact at PA-Ambulatory's whiteboard than at PA-General's whiteboard. There were no differences in coordination conversation topics between PA-General and PA-Ambulatory.

We also looked at behavior by role. In both PA-General and PA-Ambulatory, the charge anesthesiologist made the most trips to the whiteboard, especially in PA-Ambulatory; on average 16.7 times per day in PA-Ambulatory versus 12.4 times per day in PA-General. Anesthesiologists seemed to depend on the whiteboard more in PA-Ambulatory; they also were less likely to be carrying or marking up paper records than in PA-General (but no less likely to be using a phone). The charge nurse and receptionist stationed at the control desk frequented the whiteboard much more frequently in PA-Ambulatory than in PA-General (7.5 times per observation period versus .01 times per observation period). Finally, the arrangement in PA-Ambulatory seems to have promoted cross-group coordination. The charge anesthesiologist interacted with control desk nurses at the whiteboard more often at PA-Ambulatory than at PA-General (25% vs. 6% of total face-to-face interactions by the charge anesthesiologist with others around the whiteboard).

The roles of people who updated the whiteboard were associated with the information displayed. In PA-General, the whiteboard did not display nursing staffing information; thus, only anesthesiologists updated that whiteboard. In PA-Ambulatory, a wider variety of information was available on the whiteboard, including OR nursing staffing information and the name of the attending surgeon for each room. The anesthesia staff updated the anesthesia information columns and the patient information column. The control desk nurses placed the nursing and surgeon assignments on the board. During the study, neither group ever updated the other group's portion of the whiteboard.

The absolute display area on PA-Ambulatory's whiteboard was less than on PA-General's. Thus the location and content of the whiteboard, rather than its size, seemed to matter most.

MD-General. By way of contrast, in MD-General the scheduling whiteboard was located eight feet from the control desk counter, on the opposite side of a hallway (Figure 8). This hallway was just off the main hallway leading to the sterile corridor, separated by an automated door. Clerks and a charge nurse sat behind the control desk facing the whiteboard. Although the whiteboard was closer than in PA-General, this setup was not ideal either. First, the whiteboard was not legible from the control desk. To inspect and update the whiteboard, a nurse at the control desk had to walk around the counter and across the hallway. A constantly ringing phone with a short cord at the control desk kept the charge nurse tethered, so the whiteboard was frequently out of date. Further, staff interacting with control desk nurses had their backs to the whiteboard. They could passively monitor people in the control desk area but not the whiteboard or any whiteboard bystanders.

Just as important was insufficient information content on the whiteboard, due to its location. The hallways in MD-General were designed so that patients' family members could reach the PACU without passing in front of the whiteboard. Nonetheless, family members often missed a turn and took the staff-only path in front of the whiteboard and the control desk. Patient privacy regulations led to limitation of the information on the board such that the name of the patient was not listed. This limitation reduces the whiteboard's usefulness. Instead of interacting in front of the whiteboard, the staff at this suite interacted around the control desk as the main area of coordination. Such behavior further limited the whiteboard area as a place for group memory, negotiation, and mutual coordination.

MD-Trauma. The whiteboard and control desk in MD-Trauma were located in a separate staff-only area requiring surgical attire. Within this area, the whiteboard was in the main hallway leading into the sterile corridor (Figure 4 above). On the hall opposite the whiteboard was an eight-

Figure 8. Whiteboard and control desk in MD-General surgical suite. The charge nurse is on the phone at the control desk.

foot bench. People sat on it to rest, put on shoe covers, or wait for a patient, and from there could easily read the contents of the whiteboard. They sometimes spoke with people standing at the whiteboard or with the charge nurse. Others stood side by side and looked at the whiteboard together, sometimes with the charge nurse. Next to the bench was a wall-mounted phone and metal cart used by the charge nurse. The charge nurse often stood next to the wall phone, which had a long cord. The charge nurse updated the whiteboard by walking over to it from the bench, often while still on the phone.

The control desk was in a separate room, without doors, diagonally located opposite the whiteboard. The control desk was mostly occupied by an administrative clerk. The charge nurse used the control desk infrequently. The whiteboard could not be seen easily from the control desk, and to reach the whiteboard, one would have to walk out of the room and across the hallway. Over 75% of those who paused in the hallway stood or sat with others within readable distance of the whiteboard, and as it was frequently updated by the charge nurse, the whiteboard rather than the control desk served as the focal place for coordination.

The whiteboard in MD-Trauma was filled with frequently updated information [55]. Figure 9 illustrates how the information on the whiteboard in MD-Trauma, where coordination was frequent at the board, differed from information on the whiteboard in MD-General, where few people used the whiteboard for coordinating the schedule.

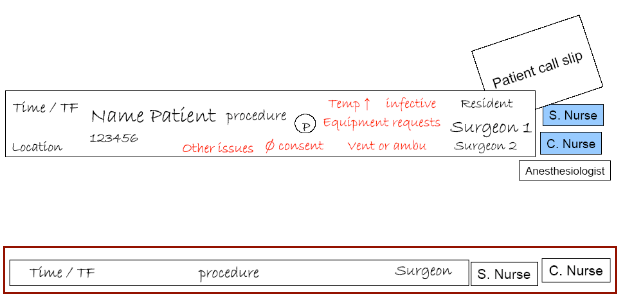

Figure 9. Top panel shows information about a surgery on the whiteboard in MD-Trauma. Bottom panel shows information about a surgery on the whiteboard in MD-General.

In MD-Trauma, rich information prompted real-time coordination, encouraged impromptu discussion among different groups, and created an accurate feedback loop at the whiteboard area. To illustrate, we note the following exchange that took place around the whiteboard in MD-Trauma between an anesthesiologist and the charge nurse. A PACU nurse sitting on the bench overheard the conversation, and joined it.

Dr. G, an anesthesiologist walks up to the charge nurse and says while pointing to the whiteboard, 'The second case in room 6 is intubated and in the PACU.' The charge nurse looks at the patient strip on the whiteboard and says,'well that means the patient is not in the unit as it says here.' The charge nurse updates the patient strip to say that the pre-surgery location of the patient is in PACU. The anesthesiologist says, 'We should also mention that the patient needs a PET scan.' The charge nurse writes, 'Needs PET scan.' The PACU nurse sitting on the bench joins the conversation discussing clinical aspects of the case.

Another way people participated in coordination was to leave notes, messages, or other information on the whiteboard itself, on the wall next to the whiteboard, where others would see them, or at the control desk on papers or files. The charge nurse in MD-Trauma placed frequently used telephone numbers on the wall so workers could avoid a trip or phone call to the control desk.

Visibility of information sources may explain how certain locations became a focal place for synchronous coordination. For instance, in MD-General, contact information was not visible, but rather available on demand at the control desk. In MD-Trauma, contact information was posted on the wall next to the phone and around the whiteboard (Figure 4).

To determine how often this additional information was updated, we calculated how much of it survived after one month (July to August). MD-Trauma had the most information posted around the whiteboard and control desk, a shorter information survival rate overall, and a faster update rate than the other suites did.

DESIGN PRINCIPLES

The results of our study point to four principles for the design of the physical environment of surgical suites. The surgical suites that conformed best to these principles were associated with richer and more up to date common information spaces:

Connectivity between information hubs (the whiteboard and the nursing control station) and highly trafficked work paths (e.g., central hallways), to facilitate the convergence of information and people from different staff groups.

Space adjacency and *visibility* between the whiteboard and the nursing control station, such that they are mutually visible and their access areas overlap, so that staff can easily monitor and update the schedule board.

Access areas around the whiteboard and nursing control station that provide adequate space to dwell (e.g. sit or lean out of the way of traffic).

Staff-only area positioning of the whiteboard, so that patient privacy legislation does not prevent the display of some of the relevant information.

These features influenced how much information was displayed on the whiteboard, how up-to-date the information was, how often people stopped by to look at it, and whether they exchanged information with colleagues informally as they stood there.

Physical areas that had most or all of the properties above we call *information hotspots* to indicate that they are, in essence, physical locations that serve as tangible points of entry into the larger common information space. When an artifact such as the schedule whiteboard was positioned in an information hotspot, such as at MD-Trauma or PA-Ambulatory, it became a central element in the development and maintenance of shared bodies of knowledge and shared frames of interpretation. When it was not positioned in an information hotspot, staff sustained their common information spaces through alternative means such as pagers, telephones, and paper schedules.

Connecting architecture and information systems

The characteristics of successful information hotspots that we have identified (connectivity, space adjacency, visibility, access areas, and staff only area positioning) can be used as rough guidelines for design, no in a variety of ways. Most obviously, architects and interior designers planning new hospital OR suites can design to maximize adherence to these guidelines. Currently no architectural guidelines for supporting coordination exist for highly dynamic settings such as surgery and emergency response. The characteristics of hotspots we have identified are an initial step towards formulating these guidelines. At the same time, we suspect no set formula can exist for following the guidelines—every solution will need to be particular to its context.

Less obviously, personnel in existing OR suites can use our design guidelines to evaluate their physical environment and make changes where necessary. We believe it is unlikely that any OR suite will follow all of these guidelines. In our sample, even MD-Trauma, which had the most active information hotspot at a whiteboard, had some shortcomings. For example, the location of the control desk in a room by itself and the whiteboard on the central hallway resulted in the charge nurse standing in that hallway next to a wall phone for long periods, not an ideal arrangement for the nurse. Depending upon budgetary limitations, OR personnel may decide that it is worth making changes to their physical environment to bring it more in line with our guidelines. In unpublished work, the first author has explored several tiers of design solutions, ranging from the cheap and easy to implement to extensive renovations.

Perhaps least obviously, our guidelines can be used to inform the design of other kinds of artifacts to create common information spaces in OR suites that do not rely on physical white boards. Increasingly, hospitals are installing large displays [e.g., 14], in some cases combining them with hand-held devices [18]. Details that once might only have been available on paper schedules or the whiteboard can now be presented via interactive displays [5], or video monitors [23]. With ubiquitous computing, the architecture of the built environment will become part of the interface to common information spaces [5, 22, 29, 30].

How then can our guidelines help designers building for this new world of ubiquitous computing devices in OR suites? We argue that the characteristics of successful hotspots we have identified are those that need to be provided by all successful tools for information sharing, whether physical or virtual. For example, we believe that connectivity between the information displayed (whiteboard, in the traditional OR), the people who update this information (nursing station, in the traditional OR), and the people who need to rely on the common information space, will still be important. Similarly, the informal communication that currently happens around physical whiteboards will need to be recreated in OR suites that rely solely on small personal devices.

To solve these design problems, we will need new ways to create awareness of others' locations and to support informal communication. Bardram et al. [8] describe a large display that shows who is present in which OR. A similar mechanism could show who is consulting the schedule. Bluetooth or other signaling properties of the phones staff members carry with them could communicate the presence of their owners in the environment, which in turn could be displayed on the other electronic boards via people's names, photographs, or icons [10]. To initiate discussion between sites, people could simply use their phones or a more advanced voice system such as Vocera [49].

CONCLUSION

Hospital architecture is a culture's contribution to an agreeable and orderly environment for the sick, and an intrinsic part of the practice of medicine. We have shown how properties of the physical setting of the schedule whiteboard and nursing control station influence how the information available in these locations becomes or fails to become part of the common information space of the OR staff. Our design guidelines based on the concept of information hotpots are an initial attempt to guide future design of information and coordination artifacts for the OR suite.

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