Robots in Organizations: The Role of Workflow, Social, and Environmental Factors in Human-Robot Interaction

Bilge Mutlu

Human-Computer Interaction Institute
Carnegie Mellon University
5000 Forbes Avenue, Pittsburgh, PA 15213 USA

bilge@cs.cmu.edu

Jodi Forlizzi

Human-Computer Interaction Institute
and School of Design
Carnegie Mellon University
5000 Forbes Avenue, Pittsburgh, PA 15213 USA

forlizzi@cs.cmu.edu

ABSTRACT

Robots are becoming increasingly integrated into the workplace, impacting organizational structures and processes, and affecting products and services created by these organizations. While robots promise significant benefits to organizations, their introduction poses a variety of design challenges. In this paper, we use ethnographic data collected at a hospital using an autonomous delivery robot to examine how organizational factors affect the way its members respond to robots and the changes engendered by their use. Our analysis uncovered dramatic differences between the medical and post-partum units in how people integrated the robot into their workflow and their perceptions of and interactions with it. Different patient profiles in these units led to differences in workflow, goals, social dynamics, and the use of the physical environment. In medical units, low tolerance for interruptions, a discrepancy between the perceived cost and benefits of using the robot, and breakdowns due to high traffic and clutter in the robot's path caused the robot to have a negative impact on the workflow and staff resistance. On the contrary, post-partum units integrated the robot into their workflow and social context. Based on our findings, we provide design guidelines for the development of robots for organizations.

Categories and Subject Descriptors

H.5.0. General. H.5.3. [**Group and Organization Interfaces**]: Computer-Supported Collaborative Work, Organizational Design. K.4.3 [**Organizational Impacts**]: Computer-Supported Collaborative work.

General Terms

Design, Human Factors

Keywords

Organizational technology, Organizational interfaces, Groupware, Autonomous robots, Robots in organizations, Ethnography

1. INTRODUCTION

Robots are increasingly being integrated into the workplace. While their projected benefits are promising, little is known about their impact on organizations, work processes, and the products and services created by organizations. Their introduction also poses significant design challenges due to the complex social dynamics of the organizations.

HRI'08, March 12–15, 2008, Amsterdam, The Netherlands.

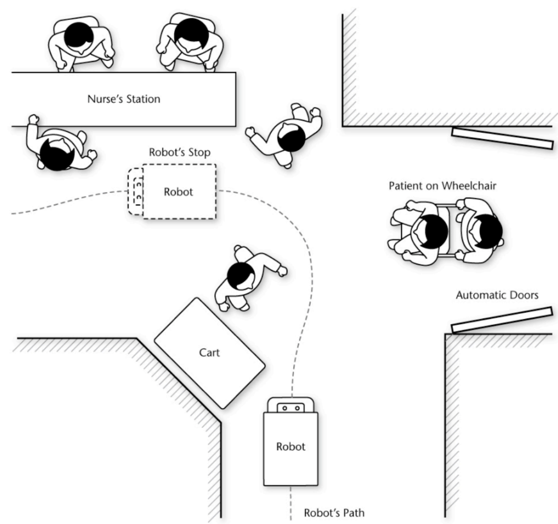

Figure 1. An abstract illustration of the hospital environment as the delivery robot navigates through units.

While the impact and the design of other types of organizational technology have been well studied [1,5,12,14,17,20], only a few studies have examined how robotic technology might impact organizations and how the design of robotic technology could improve group work practices while supporting social dynamics, and the goals and values of the members of the organization [21].

To better understand how robotic technology might situate in organizations, we conducted a 15-month *ethnographic* study of an autonomous delivery robot, Aethon's TUG. Our study took place in two sites and involved qualitative observations and open-ended interviews. We systematically analyzed our data using *grounded theory* following the methodology described in [10,22]. Figure 1 is an abstract illustration of the context of our second site.

Our analysis revealed substantial differences between two types of units at a hospital in how the robot affected the workflow and people's use and perceptions of and interactions with the robot. We found that aspects of workflow and social context affect groups' readiness to integrate the robot into their workplace. When the cost of using the robot outweighs the benefits provided by its adoption to the workflow, people are less willing to use the robot. We also found that differences in the goals and interests of two types of units within the hospital led to differences in the perceptions of the robot. Finally, we found that how the physical environment is used has an impact on people's use and perceptions of the robot.

In the next section, we provide background on related work. We then present a detailed account of our methodology, which is followed by a report of our results. In the last two sections, we provide implications for the design of robotic technology for organizational use and conclude with a summary of our results with suggestions for future work.

2. RELATED WORK

The relationship between technology and organizational structures has been of interest to many organizational researchers. While some have focused on technology's impact on how organizations are formed, how they work, and the products and services they create [17], others have examined how interpretations, social interests, and disciplinary conflicts shape organizations' use of technology [16]. Technology researchers have been interested in organizational impact of technology due to its implications for the design of these technologies. Qualitative studies in the field of Human-Computer Interaction (HCI), and more recently, Human-Robot Interaction (HRI) have developed new theories to explain and predict the impact technology has on organizations and to provide guidelines for the design of technology.

A number of studies in HCI have examined how organizational and psychological factors might shape the design of technology for organizations — that is, technology that facilitates how groups conduct work. Malone proposed the term "organizational interface" to describe computer technology designed to serve a group of users as opposed to a conventional "user interface" that is designed to serve a single user [14]. He argued that designing organizational interfaces requires going beyond traditional cognitive requirements to considering motivational, economic, and political perspectives.

A case-study analysis conducted by Grudin laid out a set of challenges in designing organizational interfaces or "groupware" applications [12]. One of these challenges is the uneven distribution of the benefits of these applications among members of an organization. While these applications are designed to provide a collective benefit to the organization, they require some members of the organization to do more work, which may result in the rejection of these systems. In a related study, Ehrlich looked at how social and psychological factors affected office communication [5]. She discussed the importance of the role of secretaries in maintaining an electronic calendar system. The system greatly benefited managers with secretaries, because their secretaries maintained the system. Maintaining the system created additional work, however, for professionals and managers without secretaries, who were therefore less likely to use the system. Grudin [13] also discussed the social effects of groupware technology. He argued that members of a group might resist groupware if it interferes with the social dynamics of the group. While these aspects of social context are common in groups and organizations, they are rarely explicit, and therefore are not often captured in the design of the technology. When technology is not sensitive to such factors, individuals' experiences with the technology might be negatively affected resulting in resistance to using the use of technology.

Research on the relationship between organizational structures and technology has also focused on how interpretations, social interests, and disciplinary conflicts shape organizations' use of technology [16]. Theories of *structuration* [2,9] and *appropriation* [15] shed light on how people adapt to and incorporate technology into their work practices. Building on these theories, Weick proposed a process called "sensemaking" which plays an important role in technology adaptation [26]. The sensemaking process is triggered when an ongoing organizational process is disrupted, for example by the introduction of new technology. Fieldwork conducted by Orlikowski looked at how the introduction of a groupware application affected work practices and social interaction in a large organization [18]. Her major finding was how the lack of appropriate mental models for collaboration using groupware applications affected people's appreciation and acceptance of these technologies. Additionally, cultural, structural, and workplace norms were found to affect how people perceive technology. Similarly, Barley studied how the introduction of CT scanners in two hospitals led to different departmental structures due to differences in the social context in which they were introduced and the process of technology adaptation at the two hospitals [1].

In an ethnographic study of an autonomous hospital delivery robot, Siino and Hinds extended research on sensemaking to show that the introduction of a robot in a hospital organization triggered a process of sensemaking, even before the arrival of the technology [20]. In this process, different groups in the hospital perceived the projected benefits of the robot differently. Factors such as occupation, hierarchical status, and gender roles in the organization affected hospital workers' sensemaking processes [20,21]. Forlizzi and DiSalvo conducted qualitative interviews with users of a domestic robotic vacuum cleaner [6]. Their results also showed that sensemaking took place before the robot's introduction into the home and during the adaptation period. For example, how people conducted cleaning was influenced by the introduction of the robot. They also found that the physical structure of the home played an important role in how people perceived and used the robot. These results were confirmed in later studies by Forlizzi [7] and Sung et al. [25].

3. METHODOLOGY

Advances in robotic technology have made it possible to integrate robots into organizational contexts. However, organizational, social, and environmental issues around the introduction of such technology have not been extensively studied. Much of the research is only beginning to identify phenomena and set future research agendas for the field. This research is characterized as *nascent theory,* where little or no previous theory exists [3]. Weick highlights the vitality of grounding new theory in the experiences of those living with or creating the phenomenon [27]. These experiences are best captured through the use of qualitative methods such as ethnographies, observations, and interviews and used to build empirically grounded theory [19]. In this process, key constructs are identified and described, the relationships among them are explained, and findings are placed in context for future testing of the theory or informing design decisions [10].

Our long-term goal is to generate substantive, explanatory theory on how organizational, social, and environmental factors affect how people work with and perceive robotic technology. Towards constructing such theory, we utilize *ethnographic data collection* and *grounded theory analysis*. The grounded theory approach is used to identify patterns in relationships between social actors and how the relationships and interactions of these actors actively construct reality [10,24]. In the remainder of this section, we describe our methodology in greater detail.

3.1 Research Context

The research was conducted intermittently over 15 months between May 2006 and August 2007 at two research sites. The study was initiated by a meeting between the manufacturer of the autonomous hospital delivery robot, Aethon Inc., and our research group. The company provided us with the opportunity to be involved in an ongoing development project. This opportunity involved participating in meetings, interviewing personnel from various departments in the company, joining field personnel while installing robots and training users in a local hospital, conducting observations, and interviewing personnel at a hospital that uses the company's robots.

3.1.1 Research Sites

Our study took place in two sites: (1) the headquarters of the manufacturer of the robot and (2) a local hospital that uses the company's robots. The identity of the second site is kept anonymous for purposes of confidentiality. Results presented in this paper are based on data collected *only* at the second site. However, methods used and activities conducted at both sites are explained to maintain unity in the description of the methodology.

The manufacturing company, Aethon Inc.[1], was founded in 2001 as a company focused on healthcare robotics. Their first robots were contracted out to hospitals in 2003. Today, around 200 robots are in use at hospitals throughout the United States. All the robots in use are networked and can be accessed and controlled in real-time over the Internet. The company employs approximately 75 people, consisting mainly of engineering and marketing personnel. While most technical support is centralized and provided remotely, additional support personnel located in local areas provide regular maintenance and support for problems that cannot be resolved remotely.

Our second site was a university hospital for women, the access to which was granted by the hospital. This was the second hospital that purchased the company's robots and they had used them since 2003. They had purchased seven robots, more than many other hospitals that use the company's robots. Nine units throughout the hospital used the robots: four patient-care units (two post-partum units and two medical/surgical/oncology units), pharmacy, laboratory, central processing, kitchen, and laundry. The hospital is considered to be a prestigious healthcare facility and is an early adopter of healthcare technology. The majority of its employees are women.

3.1.2 The Robot

The company's product, TUG, is an autonomous mobile robot that moves from one unit to another within the hospital, delivering, for example, medicine from the pharmacy to patient care units or empty food trays from patient care units to the kitchen. The robot autonomously moves through hallways, doorways, and elevators, controls automatic doors and elevators, stops and circumnavigates obstacles, and makes announcements to inform users of its actions or when it requires the attention of staff. The announcements are made using a pre-recorded female voice. The robot is comprised of a wheeled cart, a computer casing, and a mechanism at the front of the robot that pulls the cart. The carts are four- to five-feet-tall cabinets customized for specific uses such as transporting medicine, lab work, linen, and food trays. The robot uses a precise preset map of the hospital and infrared and ultrasonic sensors for way-finding and detecting and avoiding obstacles. All robots in the hospital, user stations, and control boxes installed on doors and elevators are networked through a wireless area network.

Human interaction with the robot takes place through a web-based computer interface, provided on touch-screen monitors mounted on the wall at base stations or available at nurses' computers, and through two buttons on the computer casing placed in front of the robot. The computer interface allows users to request a robot for an immediate task, send it to other units at pre-set locations, and monitor status (e.g., location of the robot within the hospital). They can also use this interface to see a history of each robot's deliveries through the day. The two buttons on the robot are used to stop the robot momentarily and to resume its motion. The robots are powered by batteries that are charged at base stations when the robots are not in use.

3.2 Data Collection

Our data collection was performed by the first author and spanned 15 months. It followed the methods and techniques of an ethnography consisting of participant observation, fly-on-the-wall observations, and open-ended interviews.

Participant Observations – The goal of *participant observation* is to gain an intimate familiarity with and an in-depth understanding of how social context influences individual behavior and how individual behavior influences the social context [19]. The first author worked closely with the company while improvements were planned for the robot. He joined meetings, conducted interviews at the first site and helped and observed implementation teams install new robots and train users in the field at the second site. Meetings, interviews, and field visits were either audio taped and then transcribed or documented in the form of field notes.

Fly-on-the-wall Observations – These observations involved following the robot from a distance as it made deliveries between two units of the hospital or lingering in the corridor or at a nurse's station without interacting with the robot or hospital personnel. The main goal of this method is to observe the environment, social interactions, and social, political, and workflow structures as they take place in a natural context without influencing the social context being studied. These observations were documented in detailed field notes.

Interviews – Interviews at the first site were entirely open-ended, probing the company's vision, organization, work practices, relationship with clients, etc. Interviews and transcribed meetings at the first site involved nine informants, all of whom were company personnel. More focused, semi-structured interviews were conducted at the second site and involved asking hospital personnel open-ended questions about their experiences with the robots that they used in the hospital. These questions regarded informants':

- Organizational roles, work experiences at the hospital and with the robot,
- Encounters with the robot in the hospital,
- Experiences with the robot and experiences of others that they observe or hear about,

[1] More information on Aethon Inc. and their product, the TUG robot, can be obtained at http://www.aethon.com.

- Perceptions of and attributions made to the robot,
- Evaluations of scenarios about the robot's actions presented to them,
- Suggestions for changes/improvements in the robot.

All interviews at the second site were done at the hospital, in each informant's work environment (i.e. nurse's stations, pharmacy, director's office, etc.). A total of 18 informants (15 female, three male) were interviewed. They consisted of six nurses, five unit secretaries, four pharmacy technicians, two unit directors, a housekeeper, and a central processing technician. Informants had experience in their positions for an average of ten years, and with using the robot for an average of three years. In addition to open-ended questions, interviewees were presented with a set of scenarios that were visual descriptions of stereotypical situations where people encountered the robot, and asked to comment on how they thought the robot would behave in these situations. The purpose of this exercise was to understand how developed people's mental models of the robot's behavior were.

3.3 Data Analysis

With the goal of building substantive theory, we analyzed our ethnographic data using a *grounded theory* approach as described in [10,22]. Our approach included a process of *open coding*, *axial coding*, *model building*, and *comparative analysis*. A detailed description of this process is provided below.

Open Coding – In the first step of our methodology, we conducted open coding, where we identified and coded concepts that are significant in the data as abstract representations of events, objects, relationships, interactions, etc. [22]. In the example below, an informant explains how she "kicked" the robot when it was first implemented. This response is coded as "abusing the robot" due to a negative emotion towards, or frustration or annoyance with the robot.

> I kicked it before **["abusing the robot"]**, and I was told not to…[laughs]…when it first came.

The open coding process created a total of 116 loosely connected concepts with descriptions and dimensions for each concept.

Reliability Analysis – We conducted an inter-coder reliability analysis to ensure the objectivity of our open coding process. The reliability coder received half an hour of training and coded 10% of the full sample using 10% of the codes. Cohen's Kappa was calculated to measure the agreement between the two raters. The reliability was sufficiently high (κ = 0.88). Disagreements were resolved through discussion.

Axial Coding – In the second step of our analysis, we categorized the concepts created by open coding into explanations of arising *phenomena* using axial coding. Phenomena in the context of grounded theory analysis refer to repeated patterns of events, happenings, actions, and interactions that represent people's responses to the problems and situations, which they encounter in the social context [22]. "Negative treatments of the robot," for instance, is a phenomenon as it represents a pattern of behavior shown by the hospital personnel when they are frustrated with the robot. The outcome of our axial coding was a total of sixteen categories.

Selective Coding/Model Building – In this last step of coding, we followed the *selective coding* process to integrate our categories into a central *paradigm*. The goal of this step is to assemble a "big picture" of the findings through building relationships across categories and outlining a theoretical model where a phenomenon is contextualized in the data. While several methods can be used to facilitate this integration, we employed diagramming.

Comparative Analysis – The central phenomenon that arose from our data was that people's perceptions of and interactions with the robot were strongly influenced by workflow, social, and environmental factors. In order to understand "how" these factors influenced people's experiences, we conducted a *comparative analysis* of the data using our final model. We looked at how the robot affected workflow, social relationships, and use of the physical environment in two groups of organizational units. These two groups consisted of medical/surgical/oncology units and post-partum units. For instance, a comparative analysis of the two groups in terms of "treatments of the robot" showed that negative treatment of the robot was more common in the medical units than in the post-partum units.

4. FINDINGS

In our analysis, we distinguished among three main groups: **medical units** (e.g. surgical and oncology units), **post-partum units**, and **support units** (e.g., pharmacy, kitchen, laundry collection, and central services). We observed strong differences in how these units used the robot, which affected workflow, perceptions of, attributions to, and interactions with the robot, and acceptance of the organizational and workflow changes engendered by the introduction of the robot. Through qualitative, comparative analyses of the data along several axes, we discovered a set of dimensions along which these groups differed. These dimensions were categorized as *workflow*, *political, social/emotional*, and *environmental*, combining emerging themes from our analysis and those suggested by other studies of organizational technology (see, for example, [13,14]).

The differences in how people perceived, used and interacted with the robot between the support units and the other units were expected as these units differ from the others in fundamental organizational aspects such as work definition, organizational structure, and physical location. The more interesting set of differences arose between the medical and post-partum units. These units were similar in fundamental aspects and differed only in the type of medical service that they provided. However, this seemingly small difference greatly affected how these two sets of units conducted work, the nature of the social relationships within these groups, and how these groups used their physical environments. These differences also shaped how people used the delivery robot despite the fact that the design of the delivery system assumed equal use of the robots by these two sets of units. In this section, we present how seemingly similar units developed substantially different perceptions and use of the robots due to differences in work practices, social context, and the use of the physical environment.

We conducted observations and interviews at two medical units and two post-partum units. They had identical floor plans and a similar physical setup of nurse's stations, patient rooms, and supply closets. The two sets of units had an equal number of beds varying from 26 to 28 beds per unit, the same number of nurses, and identical organizational hierarchies. The post-partum units had recently undergone renovations. Similar renovations had just begun at the medical units. The units had no visible signage that described the type of medical service provided at these units and were referred to by their corridor numbers.

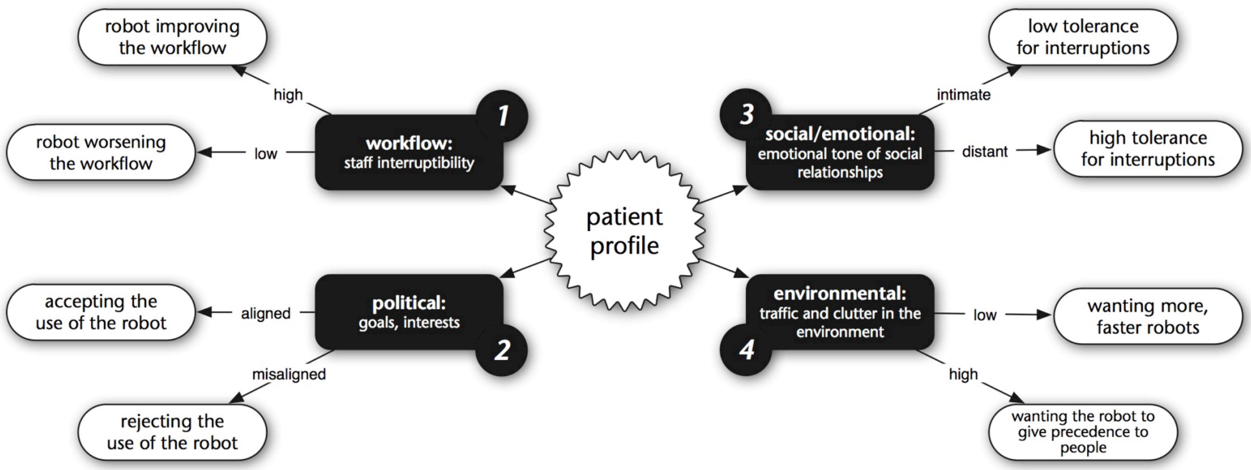

Figure 2. A diagrammatic model of our findings. Patient profile and the kind of healthcare service provided cause differences in units' *workflow*, *goals*, *social/emotional context*, and *use of their physical environment*. (1) When staff interruptibility is low, interruptions by the robot are perceived as worsening the workflow. (2) A misalignment between the goals of the unit and the benefits provided by the robot might cause people to reject the use of the robot. (3) Intimate relationships between caretakers and patients cause a lower tolerance for interruptions. (4) In high traffic and/or cluttered hallways, the robot is perceived as taking precedence over people.

Our observations and interviews uncovered differences in staff workload, emotional tone of the interactions between the two units at nurse's stations, how the physical environment was used, and more. A systematic analysis of the data untangled the relationship between these differences and how people responded to changes engendered by the introduction of a robotic product. In the following paragraphs, we describe the differences in these responses as they relate to how these groups differed in terms of *workflow*, *political*, *social/emotional*, and *environmental* aspects. These relationships are diagrammatically described in Figure 2.

4.1 Workflow

Applications designed to benefit an organization might not provide the same benefits to every member of the organization [13]. Even though the application provides a collective benefit to the organization, some members of the organization have to adjust their workflow to the new application more than others do and might be required to do additional work. In the case of the hospital, the support units greatly benefited from the introduction of the robot, while it created additional work for medical and post-partum units. For example:

> Mostly what I dislike about [the robots] is that it displaced work, you know, put more work here on the unit. And clearly I cannot change that.

An example application where work-shift happened was the collection of linen. With the introduction of the robots, the laundry personnel no longer needed to circle through the medical and post-partum units to collect linen. Every half-hour, the robots visited these units to collect the linen left in front of patient rooms and brought it to the laundry unit. While assigning this task to the robots saved a significant amount of time for the laundry unit, nurses and housekeepers needed to do additional work because the robot relied on them to load the linen on the carts. The following excerpt from an interview with a director from the medical units illustrates the significance of this shift in workload:

> The package was sold as that it was going to save time and effort. And it has on someone else's end but not from this unit, did not, so yes… Did it save hiring a dietary person to pick up carts? Did it save the linen person to come pick up linen? Yes, it did… Where did that land? It landed with my people. And so while it's a nice thing, nobody gave me more because a person wasn't doing that anymore… Well, it didn't save any for me. It cost me, and I didn't get that to replace it. So, yes, I don't like it for that reason. It's not that I dislike the technology.

Several other informants from medical units described the robot as creating more work rather than relieving them of work. One nurse from the oncology unit, when asked whether she found the robot to be helpful, described her experience as follows:

> I think it's more like staff helping the [robot]. I'm the one loading the trays on to it and loading the linen onto it.

While one might expect that such disparity would cause both the medical and post-partum units to resist to using the robot, only the medical units appeared to perceive the cost of using the robots as outweighing their benefit. Conversely, the robot was perceived to improve the workflow at the post-partum units. In the following excerpt, an informant from the post-partum units describes how they have become dependent on the help provided by the robot:

> It's a big help because when they're shut down, like if something's wrong with it or they're working on it, we're like…. We're used to it and I noticed that… When they're out of commission, if they're working on them it's… They're a big help.

This surprising difference between the perceptions of the utility of the robot by the medical and post-partum units prompted us to conduct follow-up interviews. Data from these interviews uncovered a relationship between the healthcare service delivered by these units and how staff perceived the additional work created by the introduction of the robot. Medical units involved seriously ill patients receiving short or long-term treatment at the hospital or recovering from or preparing for surgery. In contrast, the majority of the patients at the post-partum units were well and were expecting to deliver or had just delivered babies. An informant at a medical unit described their patients as a "sick population" while referring to post-partum care as "happy occurrences":

> It's very different care. There [at post-partum units] you are caring for well people… a happy occurrence. Here [at medical units] you are caring for people of all ages who have a terrible diagnosis and are very sick… Because we're an oncology population our patients have cancer. A lot of them, yeah.

The differences in patient profile reflected not only on the patient care delivered but also caretakers' work description, workload, and interruptibility. For instance, the nurses and housekeepers at the medical units frequently took patients to other units for tests (e.g. x-ray, fMRI, etc.). This additional task interrupted them from their housekeeping activities and required them to leave the unit regularly. Therefore, when the robot arrived at its scheduled time to pick up linen, the housekeepers could not attend to the robot, which meant that the linen was left on the floor until the next time the housekeeper would be available to load the linen on the robot. In the following excerpt, the previous informant describes the differences between the two sets of units in housekeepers' availability to attend to the robot:

> I think the way we deliver care and the work is slightly different. Like, upstairs [at post-partum units] the housekeepers pretty much stay on the unit and are housekeepers. So, for them to pick up trays and put into [robots], they're there. Ours are stopping and starting their work constantly because they also transport. They also do our supplies.

In addition to transports, medical units had more emergencies than post-partum units, which meant that the nurses had to interrupt their ongoing work to take patients to the operation room or attend to urgent tasks in patient rooms.

4.2 Political

Workflow differences between the medical and post-partum units also shaped the goals and interests of these groups, which are known to influence the adaptation and use of organizational technology [14]. Designers of most organizational technologies might assume that a collective goal is sought by all members of the organization and overlook the conflicts of interest that might occur. In the hospital, while the main goal of the management in purchasing the robotic delivery system was to improve efficiency in deliveries and save staff time, the goals expressed by the units centered around the quality of the service they delivered. In the case of the linen application, the robot caused linen at the medical units to stay on the floor for extended periods of time. This change was perceived to degrade the quality of the service delivered by the units. In the following excerpt, a unit director comments on this sacrifice:

> Truthfully, what happens, we get a phone call saying the Department of Health is in house and I run around picking up these bags… Or, even a visitor just seeing the bags… Our [patient satisfaction] scores are relatively high but I'd have to say I've been noticing a trend lately. People are rating us lower on cleanliness in their room. …if you'll notice, I'll always be closing cabinet doors. I think it lends itself to looking messy. Same with the linen bags on the floor...

The negative change engendered by the introduction of the robot also created a conflict of interest between the hospital management and the medical units, which resulted in resistance to using the robot, notwithstanding pressure from hospital management. The following excerpt illustrates a manager's attitude towards using the robot:

> I would almost blame it on the management… I saw it as adding work onto our unit… And there's linen on the floor… I felt like I pushed the staff to as much to take on [using the robot] as they could and while I don't stop anybody from using that avenue, I'm not making them either… I have never told them they had to do that because I kind of drew my line on that and I said no, I don't have adequate help to do that.

This resistance did not appear at the post-partum units. On the contrary, informants at these units expressed the need for more frequent use of the robots. They repeatedly expressed dependency on the robot for day-to-day work.

4.3 Social/Emotional

Another dimension differing between the medical and post-partum units was the emotional characteristics of the social context in these units, which manifested themselves in the quality of the social relationships between caregivers and patients, the stress levels of caregivers, and their emotional responses to the robot. These differences again were mainly due to the differences in the healthcare delivered by these units and their patient profiles. In the excerpt below, an informant from the oncology unit describes their relationship with the patients:

> Oncology nurses are so in tune to their patients, both their spoken and unspoken words because you're talking with either terminal, or seriously ill, or life threatening diagnosis.

These patients' need for special care required the caregivers to spend more time with their patients and keep a closer eye on their constantly changing conditions. Therefore, these caregivers had higher levels of stress and less tolerance for interruptions. When the robot made a delivery and they couldn't stop their work to attend to the robot, it repeatedly demanded their attention, which caused the staff to perceive the robot as "annoying." For example:

> It does tend to be annoying when you're on the telephone or 15 things are going on. It's here for delivery, and it just keeps repeating. And from the perspective of being at the desk… there is so much noise, from so many different directions, that, yes, that, in itself, is enough to put you over the top, for it to keep repeating.

This negative affect also manifested itself in impersonations of the robot. In the excerpt below, a unit secretary illustrates how she responds to the robot when the robot gets to be annoying:

> It's when you're sitting here on the phone and there's nobody here to get it, then it's like, "[robot] has arrived." It's like, "Shut up, I'm on the phone, I'll get you, shut up." [Laughing] …Like "Shut the hell up. I'm on the phone." …I called them nasty names and told them, "Would you shut the hell up? Can't you see I'm on the phone? I'll get to you. If you say, '[robot] has arrived,' one more time, I'm about to kick you in your camera."

Additionally, medical unit staff described physically abusing the robot. Several informants reported having kicked the robot or wanting to damage the robot. Informants often used derogatory terms to refer to the robot during interviews.

While the robot was programmed with identical behavior at both the medical and post-partum units, the responses to the robot at the post-partum units were quite different from those described above. Almost all informants interviewed at the post-partum units described the robot in positive terms:

> I think [the robot] is a delight. I think it works fine, as it is.

> [The robot] is my buddy. I like him. Picks up the day chores wonderful. It never speaks back and says, "Thank you." I like him. I like him a lot.

> I think it's fine as it is. It's one of our least bothersome or least—yes. [The robot] is my favorite. "Good morning, [informant's name]. How are you today? I am your nursebot."

4.4 Environmental

While the physical layouts of the two sets of units were similar, the differences in their workflow led to different uses of their physical environments. The frequent transfers and emergencies at the medical units caused heavy traffic in the hallways and a hectic work environment at the nurse's stations. Often beds and wheelchairs were left in the hallways due to frequent use of such equipment. These activities created obstacles for the robot, and caused it to occasionally collide with equipment and staff, patients, and visitors. Such occurrences were less common at the post-partum units. The hallway traffic was relatively low in these units and unused equipment was rarely left in the robot's path.

Most informants in the medical units had first-hand stories about how the robot collided with them or others. These stories involved descriptions of physical pain and feelings of mistreatment. In the following excerpt, an informant describes her feelings after the robot collided with her:

> Well, it almost ran me over… I wasn't scared… I was just mad… I've already been clipped by it. It does hurt.

Informants from medical units also felt "disrespected" by the robot as the robot took precedence in the hallways. These feelings manifested themselves in informants' evaluating the robot through human social norms, and asking for robots with more manners. For example:

> It doesn't have the manners that we teach our children and it takes precedence over people most of the time… You know, we grew up learning your elders go first… It doesn't participate in any of those things like you learn. So I sort of find it insulting that I stand out of the way for patients or a gurney or a wheelchair coming through, but [the robot]—just barrels right on… You need get out of the way.

Negative feelings about the robot were not limited to personal use. Due to heavy traffic and many obstacles, the robot frequently stopped in the hallways for several minutes trying to resolve how to avoid the obstacle or requiring remote or physical help to get back on its path. Informants described these situations as "the robot getting stuck." These situations made most staff at the medical units anxious about the robot getting in the way of an emergency. In the following excerpt, an informant describes her experience when the robot hit her:

> What a concern is if there's an emergency and we have someone on the cart that we have to rush to the delivery room or [operation room] and it's stuck there…?

While people at the medical units attributed these breakdowns to the limitations of the robot, informants at the post-partum units attributed delays and failures in deliveries to the support units. For example:

> Yeah, I mean, we call them for drugs and we wait and wait and wait and wait. And it's like, they'll say something's coming over. I'm like, I wish they'd just put them on [the robot] and get them here. But I don't know what's going on at their end, why they didn't choose or, you know, what the situation is. I really can't say.

5. DESIGN IMPLICATIONS

Our results illustrate how differences in work practices and social relationships have a substantial impact on how people use robots and respond to the organizational change engendered by them. These observations pose several design challenges and require designers to seek a deeper understanding of the factors that affect the organizational use of robots. Here, we provide two illustrations of how our findings could guide designers in addressing these challenges.

Our theoretical model suggests that interruptibility plays a key role in people's perceptions of a robot's impact on their work and social relationships. For instance, nurses at the medical units, who had low tolerance for interruptibility, found the robot to be a nuisance when they had to attend to the robot while they were engaged in "life-or-death" situations. Informants at these units "wanted to be left alone" by the robot. On the other hand, nurses at the post-partum units, whose interruptibility was high, paid attention to the social characteristics of the robot and perceived it be "delightful." During the interviews, informants at these units requested customizations in the robot's social behavior to better adapt the social environment (e.g. using a favorite singer's voice on the robot). To satisfy the task demands and social needs of these groups, the design of the robot must account for the time-critical characteristics of the work at the medical units while supporting the social characteristics of the staff at the post-partum units. For instance, interruptions at the medical units could be minimized through adjusting the robot's announcements at these units to be more subtle using ambient visual signals while allowing the staff at the post-partum units to customize the robot's voice to support the social needs of the staff at these units.

Our findings also showed that nursing staff prioritize the personal care relationships developed with their patents, which makes interruptions from the robot more troublesome and less likely to be prioritized. Designing the robot to minimize interruptions might improve the use of the robot at such types of units. However, the design of the robot could, furthermore, support the intimate social relationships at the medical units through integrating social aspects of patient care into the design of the robot. For instance, senders could record a message on the robot along with the delivery (e.g. "Sue, this is Mrs. Brown's new chemotherapy drugs.") that could be played automatically or on demand at the time of delivery. Knowing that the delivery is Mrs. Brown's medicine instead of daily delivery of mail, Sue can judge, based on her interruptibility, how urgently she needs to attend to the robot. More importantly, Sue would know that medicine is for a cancer patient that she cares about and that the medicine was sent by Jenny from the pharmacy, whom she talked to earlier about Mrs. Brown's situation. This simple social aspect of the design might not only reduce interruptions on workflow and social relationships, but also allow the robot to be perceived as a part of the intimate social environment, and therefore alleviate the resistance to use.

These solutions illustrate how our results could guide the design of the hospital robot. In practice, the process of designing robots for organizations would also benefit from the use of work-centered, value-driven, participatory design methods such as those suggested by [8,11,23].

6. CONCLUSION

When technologies such as service robots are adopted by organizations, they have an impact on social dynamics and work practices of many groups. Hence, design challenges posed by robots that work in organizations go beyond conventional concerns of aesthetics and usability. Through an ethnographic study of an autonomous hospital delivery robot, we showed that aspects of workflow, and social/emotional, political, and environmental context influenced how workers at a hospital used, perceived, and interacted with the robot.

We found that aspects of how a group conducts work affect its members' readiness to integrate the robot into their work. In our data, readiness was affected by job definition, workload, and interruptibility. When the cost of using the robot outweighs the benefits provided by its adoption, people are less willing to use the robot. We found, for example, that while the linen department benefited from using the robot, extra work was imposed on the medical units. We also found that when different groups in an organization have different goals, their perceptions of the robot vary accordingly. While hospital management perceived the use of the robot as an instrument for improved efficiency, and therefore supported it, the medical units resisted the use of the robot because they perceived it as decreasing the quality of the healthcare they delivered.

Our findings also showed that aspects of the social context such as the emotional tone of the interactions within a group affect how people perceive the robot. In our study, nurses who treated cancer patients found the robot "annoying" while nurses at the birth units thought the robot was "delightful." Finally, we found that the physical environment that the robot functions in has an impact on use and perceptions of the robot. In busy, cluttered hallways, the robot was mostly perceived as getting in the way of other urgent work and taking precedence over personnel and patients.

While the results presented in this paper are preliminary, they constitute nascent theory suggesting a significant impact of workflow, social, and environmental factors on people's responses to robots that work in organizations. Further work is required to understand to what extent these results generalize to other kinds of situations, organizations, robot designs, and tasks performed by robots.

ACKNOWLEDGEMENTS

This work was supported by NSF grant IIS-0624275. We would like to thank Sara Kiesler for her guidance throughout the study, Selma Sabanovic for conducting our reliability coding, Jessica Hodgins, Rosanne Siino, Leila Takayama, and Lindsay Jacobs for their valuable comments, and Dave Wolfe and others at Aethon Inc. for their help and support in conducting the study.

REFERENCES

[1] Barley, S. R. Technology as an occasion for structuring: Evidence from observations of CT scanners and the social order of radiology departments. *Administrative Science Quarterly*, 31(1): 78-108, 1986.

[2] Bourdieu, P. *Outline for a Theory of Practice*. Cambridge University Press, 1978.

[3] Edmondson, A. C. and McManus, S. E. Methodological fit in management field research. *Academy of Management Review*, 32 (4): 1155-79, 2007.

[4] Ehn, P. *Work-Oriented Design of Computer Artifacts.* Lawrence Erlbaum, 1990.

[5] Ehrlich, S. F. Social and psychological factors influencing the design of office communication systems. In *Proc. of CHI'87,* 1987, 323-9.

[6] Forlizzi, J. and Disalvo, C. "Service robots in the domestic environment: A study of the Roomba vacuum in the home. In *Proc. of HRI'06,* 258-65, 2006.

[7] Forlizzi, J. How robotic products become social products: An ethnographic study of cleaning in the home. In *Proc. HRI'07,* 129-36, 2007.

[8] Friedman, B, and Kahn, P. H., and Borning, A. Value sensitive design: Theory and methods. *University of Washington, Dept. of Computer Science & Eng. Technical Report,* 02-12-01, 2002.

[9] Giddens, A. *Central Problems in Social Theory*. University of California Press, 1979.

[10] Glaser, B. G. and Strauss, A. *The Discovery of Grounded Theory*. Aldine DeGruyter, 1967.

[11] Greenbaum, J. M. and Kyng, M. *Design at Work: Cooperative Design of Computer Systems.* Lawrence Erlbaum: 1991.

[12] Grudin, J. Why CSCW applications fail: Problems in the design and evaluation of organizational interfaces. In *Proc. of CSCW'88*, 1988, 85-93.

[13] Grudin, J. Groupware and Social Dynamics: Eight Challenges for Developers. *Comm. of the ACM,* 37(1): 92-105, 1994.

[14] Malone, T. W. Designing organizational interfaces. In *Proc. of CHI'85,* 1985, 66-71.

[15] Ollman, B. *Alienation: Marx's Conception of Man in Capitalist Society*. Cambridge University Press, 1971.

[16] Orlikowski, W. J. Using technology and constituting structures: A practice lens for studying technology in organizations. *Organization Science*, 11(4): 404-28, 2000.

[17] Orlikowski, W. J. Improvising organizational transformation over time: A situated change perspective. *Information Systems Research*, 7(1): 63-96, 1996.

[18] Orlikowski, W. J. Learning from Notes: Organizational issues in groupware implementation. In *Proc. of CSCW'92*, 1992, 362-9.

[19] Shah, S. K. and Corley, K. G. Building Better Theory by Bridging the Quantitative-Qualitative Divide. *Journal of Management Studies,* 43 (8): 1821-35, 2006.

[20] Siino, R. M. and Hinds, P. J. Making sense of new technology as a lead-in to structuring: The case of an autonomous mobile robot. *Academy of Mgmt. Best Paper Proc.*, OCIS E1-E6, 2004.

[21] Siino, R. M. and Hinds, P. J. Robots, gender & sensemaking: Sex segregation's impact on workers' making sense of a mobile autonomous robot. In *Proc. of ICRA'05*, 2005, 2773-78.

[22] Strauss, A. L. and Corbin, J. *Basics of Qualitative Research*. Sage Publications, 1990.

[23] Suchman, L. A. Office Procedure as Practical Action: Models of Work and System Design. *ACM Trans. on Office Information Systems*, 4 (1): 320-8, 1983.

[24] Suddaby, R. From the editors: what grounded theory is not. *Academy of Management Journal*, 49: 633-42, 2006.

[25] Sung, J-Y., Guo, L., Grinter, R. E., and Christensen, H. I. My Roomba is Rambo: Intimate home appliances. *In Proc. of UbiComp'07*, 2007.

[26] Weick, K. *The Social Psychology of Organizing*, 2nd ed. Addison-Wesley, 1979.

[27] Weick, K. What theory is not, theorizing is. *Administrative Science Quarterly*, 40: 385-90, 1995.