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Hetero-Technic Cooperation with Computing and Non-Computing Technologies: A Study of the Transmodal Capacity of Prosodic Cues to Alleviate Asymmetric Access to Tactile Phenomena

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by

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Hetero-Technic Cooperation with Computing and Non-Computing Technologies: A Study of the Transmodal Capacity of Prosodic Cues to Alleviate Asymmetric Access to Tactile Phenomena

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Abstract: I present a study of hetero-technic cooperative work involving multiple workers, a shared technical goal, role complementation, and the use of a combination of computing and non-computing technologies. Abundant contemporary examples of HTC (C-NC) work can be found, for example, in the discriminative work maintaining and repairing physical materials. As more work becomes computerized, but still demands the transformation of physical materials using non-computing technologies, HTC (C-NC) will remain important.

The access workers have and the necessities of their work point to two seemingly conflicting demands, namely that participants: (1) have different access to their common field of work through the use of their respective computing and non-computing technologies and (2) intimately depend on the complementary use of both technology types in ways that take into account actions performed independently and perceptual phenomena experienced privately. This dissertation focuses on how within this computing and non-computing context, workers cope with differing degrees of access through their senses of touch.

To address this topic I primarily consult the literature concerned with the study of computer supported cooperative work (CSCW) and embodied communication. I first recount how the studies of work and technology have missed work carried out with a combination of computing and non-computing technologies. Then drawing on the CSCW literature, I address the two work practices of awareness and coordination, that are both essential to a cooperative endeavor. I finally layout how scholars concerned with embodied communication have discussed asymmetries in access to phenomena.

I pose the research question: How do workers in HTC (C-NC) orient to asymmetries in access to tactile phenomena? I focus on asymmetries in access to tactile phenomena because touch is important in work on physical objects, yet ultimately as private perceptual experience. Careful work accomplished with deft tactile perception is problematic when the work is interdependent and even more still when computing technologies are involved. In addition, the lack of touch is the most significant limitation in HTC (C-NC) work, a particularly striking fact given the importance of tactile sensing in non-computing work and the need for transmitting the understanding derived from such sensing to operators of computing technology.

To address the topic of asymmetric access to tactile phenomena in the context of technology mediated cooperative work I present findings from a microethnographic study of the ways participants orient to tactile phenomena through talk-in-interaction. Using video and audio recording techniques, this research sheds light on the ways that participants' access, and the known information about their access, is surfaced in the midst of work.

I choose to study minimally invasive cardiac surgery because it is representative of HTC (C-NC) and because the workers in this environment are faced with interesting and complex asymmetries in access to tactile phenomena. In observing these workers, I find that they flexibly adapt to the particular access provided by their work configuration. Doing so, they overcame asymmetries in access to tactile phenomena through two work practices. The first practice serves as a mechanism for coordinating the execution of work with non-computerized technologies. The second practice fostered a greater awareness of the status of a worker's execution of non-computerized tasks.

By investigating work accomplished with a combination of computing and non-computing technologies this dissertation capitalizes on a missed opportunity in studies of work. I adopt analytic methods from studies of embodied communication to understand how workers overcome asymmetries in access to one rich medium, human touch, using another rich medium, the human voice.

In my discussion I draw on theoretical concepts of the "living body" to discuss the work practices of awareness and coordination anew for a CSCW audience. I argue against an instrumental view of communication that easily slips in when scholars allow the role of the felt experience of work to fall from view. This research broadens our appreciation of the ways that participants cope with the private experience of tactile work and the ways that participants make that private experience public as the felt experience is surfaced in talk. In sum, this dissertation supplies important new knowledge about HTC (C-NC) where it otherwise would not have existed.

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Introduction

Two aboriginal men build stone knives with resin handles. The men work in concert, each with a different primitive tool. They can shape the knife handles only after the seed-based resin is heated to its melting point. So, to begin building the knives, the two men build a fire. One man fills the molding-tray with seeds. Then, holding the tray together, the two men lower it onto the flames. After stoking the fire, the men check the resinous substance. They then divide the labor into two tasks. One man molds the resin into balls and rolls the balls back and forth into roughly shaped knife handles, while the other man shapes the pieces of cooling resin into their final handle form and attaches to them the stone knife blades that the men had earlier prepared (Reynolds, 1994, p. 411).

The work described above is an example of hetero-technic cooperation (HTC), a term Reynolds (1994, pp. 422–423) coined to describe a particular configuration of cooperative work in which two or more people pursue a shared technical goal, take complementary roles, and each use a different technology. Reynolds' (1994, pp. 416–417) original definition of HTC was based on pre-industrial examples of cooperative work. Beyond knife-building, he identified historic examples of HTC in published anthropological descriptions of social tool use including Tikopian islanders removing paper-like mulberry bark to make cloth, Indonesian Batek children building pretend "shop houses," Papua New-Guineans preparing for a feast, and Katpati women helping place pots on one another's heads to gather water from the local stream (Endicott & Endicott, 1984; Firth, 1965).

In all of Reynolds' examples, the people performing HTC use a combination of hand tool type technologies. Historic examples of HTC have interested paleo-anthropologists because the situated context in which each party performed work required coordination and, therefore, required communication. Indeed, paleo-anthropologists argue that the circumstances of HTC served as a catalyst for language development (Ingold, 1994; Reynolds, 1994; Stout & Chaminade, 2009), a point which emphasizes the importance of communication in cooperative work with multiple technologies.

Reynolds' definition is out of sync with contemporary circumstances of cooperative work. While his conception of HTC remains helpful, the examples he cites are only loosely comparable with studies of work accomplished with contemporary technologies. To that end, Reynolds' definition of HTC provides an opportunity to look anew at cooperative work that leverages computing technologies. I introduce the term HTC (C-NC) to describe examples of cooperative work accomplished when two or more workers employ a combination of computing (C) and non-computing (NC) technology types to pursue a shared technical goal that demands role complementary action.

Examples of HTC (C-NC) abound, particularly in work involving the repair and maintenance of physical structures. For instance, an example of HTC (C-NC) work is found when examining automotive engine repair (Landrover Toolbox Videos, 2014). In such cases, mechanics take complementary roles using an endoscopic camera and laptop to inspect a hidden part of a car engine. The camera and laptop enable the mechanics to diagnose problems before removing obstructing parts to make necessary repairs. In some cases, the mechanics work together using computing technologies first and non-computing technologies second to achieve their goal. In other cases, the mechanics' cooperation is magnified because one set of hands and eyes is not enough to operate both types of technologies when the task requires their simultaneous use. Thus, the number of mechanics involved (one or two) appears to be determined in part by whether or not simultaneous technology use is needed.

In other instances, workers perform tasks that would not be possible with a single type of technology or a single worker. A good example occurred in what NASA termed "extravehicular activity twenty-four (EVA-24)" when astronauts and engineers on the ground replaced a malfunctioning ammonia pump attached to a truss of the International Space Station (Bergen, 2010). To replace the pump, astronauts and NASA engineers needed a particular combination of computing technologies (which provided critical digital representations of physical objects) and non-computing technologies (the objects themselves). Transcripts and recordings of EVA-24 depicted astronauts in close communication with engineers in a control room nearly two-hundred and fifty miles below. The astronauts depended on engineers to navigate and annotate the computer models of the space station in real time. The engineers could then instruct the astronauts where to locate the particular ammonia pump that was not functioning and how to travel to it. The engineers likewise depended on the astronauts to operate specially designed hand and power tools to detach the malfunctioning pump and attach its replacement.

Beyond the repair of automotive vehicles and space stations, we see modern-day examples of HTC (C-NC) in a diversity of settings, including scuba search and rescue, veterinary, and obstetrics. Moreover, it seems unlikely that non-computing technologies will disappear from the work equation any time soon. As many of these examples illustrate, if the object of work is itself physical (e.g., a truck, a space station, an air regulator, a dog, a pregnant woman), then most likely operations upon it will require physical technologies (e.g., a wrench, a drill, a valve wrench, a syringe, a pair of forceps). Yet, computing technologies increasingly provide information that guides the use of these physical technologies. Hence HTC (C-NC) work is not only prevalent today, but quite likely to persist. The growing accessibility of augmented reality hardware, which is now used in technical maintenance and repair work alongside traditional hand tools, also hints that HTC (C-NC) will continue (Azuma et al., 2001; Henderson & Feiner, 2009, 2011).

Examples of HTC (C-NC) emphasize the differences in computing and non-computing technologies. Importantly computing and non-computing technologies supply different information to the workers and the workers have different experiences of work. Nowhere are the differences between computerized and non-computerized work evidenced more strongly than in studies of the introduction of computing technologies to previously non-computerized work. The history of studies of work and technology suggests that computing technologies spurred significant changes to work in industrial machining (Noble, 1986), paper milling (Zuboff, 1988), fast food services (Garson, 1988), stock exchanges (Zaloom, 2006), commercial banking (Leblanc, 1986; Morisi, 1996), and travel agencies (Campbell-Kelly, 2003), inter alia. Computer use in these and other industries has increased productivity (Lovelock & Young, 1979), reduced production and service costs (Levitt, 1972), altered workplace demographics (Burris, 1998), and changed or usurped workers' roles (Barley, 1986; Bills, 1995; Bluden, Crane, & Clarke, 1988; Mittelstaedt, 1985; Mumford, 1970; Penn, Rose, & Rubery, 1994).

Perhaps most intriguing of all, computerization has affected the felt experience of work. Zuboff (1988, p. 60), in a prolonged ethnographic study of pulp and paper mill operations in five industrial plants, found the introduction of computing technologies brought significant changes to the role of the sentient body in work:

> Technology change did not mean simply trading one form of instrumentation for another. Because the traditional basis of competence, like skilled work in most industries, was still heavily dependent upon sentient involvement, information technology was experienced as a radical departure from the taken-for-granted approach to daily work.

Zuboff noted that before computerization, evaluation of a worker's competence was based on his skilled use of his body in direct interaction with physical processes. Describing such competencies, Zuboff (1988, p. 58) writes how plant workers:

> [Plant workers] judged the condition of paper coming off a dry roller by the sensitivity of his hair to electricity in the atmosphere around the machine. Another could judge the moisture content of a roll of pulp by a quick slap of his hand.

After computerization, with workers removed from the mill floor and relocated to a computer workroom, a worker's competence was based on his ability to work with data interfaces that indirectly controlled now-distant physical processes. Workers experienced changes to their roles firsthand; in addition, changes in work technologies brought changes to workers' felt experiences of work. As scholars such as Barley (1990) similarly noted in other contexts of work, following computerization, workers lost touch with their prior sentient competencies as they needed to handle representations of their previous objects of work in the form of numbers, symbols, and icons, and not the objects themselves.

As workers came to grapple with data rather than dials, scholarly interest shifted towards computerized work and the computerization of work. Since the first efforts to computerize work, and as a consequence of these shifts, scholars from an array of fields left work with non-computing technologies largely unexamined. In retrospective examinations of the study of work and technology, Bailey and Barley (2005) and Barley and Kunda (2001) identified in the wake of computerization broad changes to the analytic and methodological traditions that previously defined the study of work practice. Indeed, I found little treatment of non-computerized work since the beginnings of the computerization of the workplace, and, not surprisingly, little treatment of cooperative work accomplished with a combination of computing and non-computing technologies.

As a consequence of the broad scholarly interest in computerized work and the computerization of work, many disciplines devoted to the study of work and technology missed or lost touch with the role of the body and sensory perception in work. Zuboff's (1988, pp. 5–6) characterization of the significance of the introduction of computing technologies to work could aptly apply to the scholarship on work and technology:

> [Computerization] means more than simply contemplating the implications or consequences of a new technology. [...] [the computer] fundamentally reorganizes the infrastructure of our material world. It eliminates former alternatives. It creates new possibilities. It necessitates fresh choices.

Zuboff's comment evokes something borne out in the history of studies of work and technology, namely that scholars have largely treated the rise of computing technologies as a tectonic shift in the way work is accomplished and evidently studied. As a consequence of this shift in scholarly focus, we know little about the felt experience of modern work, how workers use their bodies to perform HTC (C-NC) work, and, in particular, how they communicate information they independently gain from their hands and eyes.

The lack of such information has real consequences. For example, Bailey, Leonardi, and Barley (2012, pp. 1497–1499), in their study of automotive simulation engineers who worked to create digital representations that could faithfully (and virtually) represent physical reality, described the importance of the felt experience in the context of car crash tests. The authors reported the struggles of engineers in India who, tasked with digitally modeling car components for simulated physical crash tests, lacked physical access to the car components either before or after a physical crash at the U.S. facility. In contrast with their American counterparts, Indian engineers at the firm could not visit auto crash "tear down" facilities to see and touch crushed vehicle parts and the impacts which marred, tore, and otherwise displaced part material. As Indian engineers struggled to do without essential tactile information, the physical fidelity of their models suffered as a consequence. Lacking tactile access, Indian engineers relied on videos of physical crash tests and photos of crashed parts, although these representations were poor substitutes, and talked with their American colleagues.

The Indian and American engineers in this example of simulated auto crashes unavoidably experienced asymmetries in their perceptual access to work-relevant information, and those asymmetries in access proved consequential for their work's success. By "asymmetries in access" I mean that each group of engineers had greater or less access relative to the other group. In the case of auto crash simulation, the Indian engineers lacked touch, a crucial form of access, because they worked on a distributed team distant from physical car parts and testing facilities. In an effort to regain the information beyond their reach, the Indian engineers and their American counterparts communicated, albeit imperfectly. In part because of the distributed nature of this work there was insufficient awareness about the Indian engineers' need for physical access to crash test parts.

One of the more pernicious asymmetries workers in HTC (C-NC) face is a lack of shared information about the tactile experience of using non-computing technologies. Consider the example of NASA's EVA-24 pump replacement. The aerospace engineers in the NASA control room depended on the astronauts to operate the hand tools on the space station, not only because of their locations relative to the malfunctioning pump, but also because the hand and power tools used to install the pump were designed for one operator only. Said differently, even if the engineers and astronauts could have worked near one another, whoever operated the pump and drill would have had appreciation of the work that his counterparts would not have had. As a consequence, when difficulties arose in installing the pump, the engineers in the control room depended on the astronauts to relay relevant information verbally.

This dissertation examines workers' coordination and awareness of skilled manual action in HTC (C-NC). Specifically, I discuss how workers orient to tactile phenomena wherein they have asymmetric access. As such, my study falls within the realm of studies of work and technology. By investigating work accomplished with a combination of computing and non-computing technologies, this dissertation capitalizes on a missed opportunity in studies of work.

Literature Review

INTRODUCTION

HTC C-NC is a complex form of cooperative work with deep ties to the history of human development and at the same time an important if sometimes overlooked role in the future of work. This dissertation builds upon existing scholarship with a comparable scope. First, I draw on historical analyses of studies of work and technology to explore why HTC (C-NC) has thus far been overlooked. Second, I turn to studies of computer supported cooperative work (CSCW) and embodied communication, which provide important concepts crucial to my analysis of HTC (C-NC) work. I note that, although these literatures lend my inquiry valuable concepts, they, like studies of work and technology more broadly, did not investigate them in the context of HTC (C-NC) work. Third, and lastly, I present a research question that guided my analysis of this form of cooperative work.

LOSING THE BODY, UNINTENDED EFFECTS OF COMPUTERIZATION

Scholars have long been intrigued by the interaction of work and technology. Taylor (1915), Gilbreth (1911), and Scientific Management and "motion and time" devotees delved into the relation between workers and their technology and paid close attention to the physical details of that interaction, especially the worker's use of his body in interaction with non-computing technologies. Such studies prefigure a description of humans as cogs in the machine of industrial production. New technologies, such as the assembly line, occasion dramatic changes in work that in turn lead to new forms of work which prompt additional technological innovation. The assembly line changed not just the organization of work— from small groups of workers cooperating in joint, holistic tasks to long lines of workers carrying out small, coordinated, rationalized tasks—but also men's enjoyment of work, life aspirations, and required skills and knowledge (Chinoy, 1952; Hounshell, 1985; Roessner, 1985; Trist & Bamforth, 1951).

Arguably some of the most dramatic changes to work have come with the introduction of computing technologies to workplaces around the middle of the 20th century, as suggested by the history of studies of work and technology. These changes included but were not limited to industry, productivity, labor costs, workplace demographics and workers' roles. Not only did workers' roles change, but also their felt experience of work changed. Something somatic was lost with the turn to fully computerized work, as Zuboff (1988, pp. 8–9) describes: "As more tasks must be accomplished through [...] computer-mediated work, the sentient body loses its salience as a source of knowledge, resulting in profound disorientation and loss of meaning." For many scholars, such dimensions of work no longer had meaning because computers made them unnecessary. Yet, if we recognize that non-computerized technology is still in play in many work environments, these dimensions retain their importance, and, as such, are likely to be critical to our understanding of HTC (C-NC).

As computing technologies became increasingly ubiquitous to workplaces, scholars of work and technology shifted focus to computing technologies at the expense of continued investigation into non-computerized work. This shift is demonstrated in the number of fields that oriented to work with computing technologies, including Organization Science, Industrial Engineering, Human Factors, Ergonomics, Cognitive Science, Anthropology, and Sociology (Bailey and Barley, 2005a). Additionally, technical and artistic disciplines such as Computer Science and Industrial Design contributed to the design of computing technologies in the fields of Human Computer Interaction (HCI) and Computer Supported Cooperative Work (CSCW) (Heath & Luff, 2000, pp. 12–13; Luff, Hindmarsh, & Heath, 2000, p. 300). The breadth as well as quantity of fields that oriented to computing technologies is notable. The list above includes fields with long-standing inquiries into work, established fields that previously had not studied work, and fields that emerged for the purpose of imbuing work with specially designed computing technologies.

Within this new analytic focus on studies of work and technology, I note that a complement of shifts in the methodological approaches to the study of work not only emerged around the time of computerization but were also spurred on by computerization. Accompanying the shift in the fields that became concerned with work and its computerization, historical analyses of studies of work and technology suggest a complement of changes in *how* work was studied and *which* analytic lenses were employed. As detailed in Bailey and Barley's (2005) field retrospective, scholarship on work in the field of Industrial Engineering re-orientated analytically and methodologically to embrace computerized work. In the 1920s Industrial Engineering emerged as a field centered on "the grounded study of work practices" on the shop floor. Accordingly, the earliest curricula offered engineers-in-training "actual techniques for converting raw materials into products: forging, welding, cutting, stamping, sawing, milling, grinding, polishing, pulverizing, pattern making, jig making and so on" (Bailey & Barley, 2005, p. 740). Industrial Engineering research and curricula maintained this analytic and methodological orientation until after the Second World War, after which one finds a marked "decline [in] work studies" as "industrial engineers turned their attention to more quantitative and analytical endeavors" and developed new orientations to topics "that could be investigated more rigorously in a laboratory than on the factory floor" (Bailey & Barley, 2005, p. 739).

However, consideration of individual fields alone does not convey the extent of the shifts across disciplines or the significance of these shifts to the study of work in general. Looking broadly, Barley and Kunda (2001, pp. 78–79) also note shifts in the analytic and methodological traditions that previously defined organizational studies of work. Initially organizational scholars carried out detailed studies of physical labor in naturalistic settings using observational methods and often presented their studies as situated accounts of work practice. After a shift in the 1960s and 1970s, many organizational scholars "ceased writing about work practices and focused instead on elaborating abstract frameworks" and "turned their attention to formalizing abstract concepts that could be used across settings" (Barley & Kunda, 2001, p. 81). As part of their retrospective analyses, Bailey and Barley (2005) and Barley and Kunda (2001) each call for a return to observational studies of work practice in the fields of Organization Science and Industrial Engineering, a call echoed by others (Heath & Luff, 2000; Luff et al., 2000; Orr, 1996, pp. xii–xiii).

An appreciation of the basic research that underlines technology development slipped away from these fields. To address the heterogeneous technological landscape of contemporary work requires a return to work practice. Similar directives are recurrent in studies of work and technology, as seen in organization science literature and literature of workplace studies: Orr (1996, pp. xii–xiii), Bailey and Barley (2005), Barley and Kunda (2001), Luff, Hindmarsh, and Heath's (2000), and finally Heath and Luff (2000).

In addition to shifts in fields with long-standing inquiries into work, new fields emerged oriented to computer use in work. In the 1980's and 1990's scholars with a history of studying work and technology, and those with a newly acquired interest in computing technologies, formed two interdisciplinary fields: HCI and CSCW. Both fields sought to study and understand computer use and to apply their findings to the design of computing technologies (Grudin, 2008; Grudin & Grinter, 1994; Luff et al., 2000).

However, CSCW scholars were more interested in the computerization of work and the study of non-computerized work with respect to its computerization. Incidentally, CSCW's methodological and analytic orientation is more sensitive to social dimensions of computer use, whereas HCI is known for a more cognitivist approach (Luff et al., 2000). As a consequence, CSCW scholars focused on situated studies of work practices of groups within organizations and workplaces, often employing an ethnographic approach to the studies of cooperative work.

CSCW scholars applied their knowledge of work practices to the design of computing technologies created for groups to collaborate, cooperate, and coordinate (Luff et al., 2000, pp. 9–10). Retrospective accounts of CSCW's design efforts to introduce computing technologies to work suggest that computerization was, in fact, slow, stepwise, and incomplete. Despite several fields seeking to further the computerization of work, CSCW studies of technology use and adoption in a variety of workplaces show that sometimes workplaces abandoned computing technologies for existing non-computerized alternatives (Grudin, 1988; MacKay, 1999). Such trends suggest that non-computing technologies remained valuable in cooperative work. Said another way, in making this shift, scholars missed opportunities to study work accomplished with a combination of computing and non-computing technologies.

For example, describing the incremental adoption of computers in a Paris transportation control room, Theureau and Filippi (2000, p. 68) say that the equipment "was not designed as an integral system," but instead was "extended on a piecemeal basis, in line with traffic growth." As a result, computerization of this work place grew incrementally owing to the continued utility of telephones and radios. The authors found that operators used existing information systems in combination with computing information systems, such as the "printed fixed-line diagram" of the Paris Metro and a computer terminal displaying the information on the printed diagram in more detail (Theureau & Filippi, 2000, pp. 70–71).

Even with the incremental addition of computing technologies into workplaces, these new technologies did not always fulfill the basic functions of the non-computing technologies they were designed to replace. Describing the implementation of an automated, computerized system developed for the London Ambulance Service, Heath and Luff (2000, pp. 1–2) report the new system did not work as intended. Instead, the system notified employees late, multiple times, or not at all. Quickly appreciating the severity of these problems, the organization returned to the previous non-computing information system (Whalen, 1995; Zimmerman, 1992). These and other reports of new information systems indicate that the appearance of computing technologies in the workplace did not precipitate a clean break from traditional ways of doing work.

Additional studies in this field suggest that unforeseen difficulties in computerizing work contributed to these trends in adoption because designers and engineers underestimated the complexity of non-computerized work. In investigations of clerical work, Suchman (1984, p. 4) found that the formal procedures of document handling were easy to implement in computer systems. But, clerical work practices for document handling are often informal and not part of the official workflow. Ultimately, informal work practices were not easy to implement compared to the formal rules the computer information system was designed to follow (Payne & Green, 1986). In sum, clerical staff applied informal practices with more flexibility and discretion than computing system engineers could understand or re-create (Blomberg, Suchman, & Trigg, 1994; Suchman, 1995, 1996).

Reflecting on these and related studies of paralegal work performed a decade earlier, Blomberg, Suchman, and Trigg (1994, p. 250) remark that law firm executives prematurely decided to outsource and automate the firm's clerical work largely because they were unaware of the complexity of their paralegals' work with non-computing information systems. As Blomberg, Suchman, and Trigg (1994, p. 249) found, and as Suchman's (1984) and Suchman and Wynn's (1984) studies show, paralegals created computer databases to provide access to paper documents to support on-going litigation. In addition, paralegals devised formal and informal office procedures to bridge the information systems to ensure they maintained correct information in both document formats. Paralegal work was "invisible" to law firm executives who did not understand the constraints of the computing systems developed to replace their staff (Blomberg et al., 1994, pp. 251–253). Executives, lawyers, and the firm as a whole unknowingly relied on their paralegals' work to overcome the constraints of new inflexible information systems and facilitate the new system's use. Paralegals bridged the new electronic information system with the paper-based information systems that they developed in-house.[1] As a consequence of these missteps, the firm encountered many unforeseen difficulties in their attempts to computerize hidden details of paralegals' work to coordinate subsequent interdependent actions.

Despite the introduction of computerized technologies, non-computerized work not only persisted but remained valuable. And examples like the ones I just outlined show that system designers struggled to understand work with non-computing technologies and its value as demonstrated by the partial adoption of paper-less information systems (Harper & Sellen, 2003).

It is through examples like the partial adoption of a paperless information system (Sellen and Harper, 2003) that we come to appreciate the difficulty of understanding

[1] Strauss (1985) coined the term "articulation work" to refer to the kinds of work practices that support explict coordination between interdependent workers.

work with non-computing technologies only with respect to its computerization. The studies of slow, stepwise, and incomplete adoption give credence to a fact appreciable from even a cursory look at work in a heterogeneous technological landscape. I note this incongruity between the disposition of studies of work and the realities of work to bring attention to the need for researchers to ensure that their theories fit with the actual work carried out by skilled and effortful bodies. It is unwise to study work organized into technological eras because the new technologies that are "revolutionizing" work change constantly.

Critical histories of the computerization of work highlight scholarly dramatization of the changes in social processes with technological change. For example, Kling (1991) highlights Toffler's (1981) presentation of the computerization of non-computerized work. The dramatization of technology change distracts researchers from examining how work continues to be accomplished with a combination of existing technologies with the help of newly introduced technologies. Barley and Kunda (2001) raise related concerns when they argue that there is a pre-mature hastiness to link new technologies, such as the computer, to new organizational forms. Instead, studies of work could opt for a more considered and less reactionary approach to the introduction of new technologies. New possibilities arise when scholars embrace and treat with equal attention the work accomplished with different technologies, and we are more likely able to accurately speak to the ways incremental changes in technologies happen on the small scale that affect our everyday working lives.

In this section, I showed evidence that indicates that the process of computerization was slow, stepwise, and incomplete. Yet, studies of work and technology have treated the development of computing technologies as a tectonic shift. As a result, studies of work have neglected the treatment of cooperative work accomplished with a combination of computing and non-computing technologies. I noted that established and newly founded fields alike have shifted towards the study of computing work and the computerization of non-computerized work. The positioning of the computer as an analytic technology has further de-emphasized somatic involvement in work. For this reason, I approach my study of HTC (C-NC) as a study grounded in the felt experience of work. I turn to studies of CSCW and embodied communication for concepts that will help us to regain an analytical lens on the role of the body and sensory perception.

CONCEPTUAL EQUIPMENT FOR HTC (C-NC)

I have already introduced the field of CSCW, but I have not introduced embodied communication. Embodied communication is not a discipline *per se* but a loosely organized community of scholars with a shared interest in social interaction and its study through microethnographic analysis of video recordings.

Both embodied communication and CSCW investigate social interactions involving groups of people. CSCW focuses on cooperative work, while embodied communication focuses primarily on communication. Consider how cooperative work is typified by workers' concerted actions as participants in an ongoing social interaction through which their efforts are applied to a shared goal. Communication can be understood to have corollary goals. As Harper, Hughes, and Shapiro (1989b, pp. 84–85) counsel a work is cooperative in the "same fundamental sense that conversation, a row, a disagreement is cooperative." In addition to the general affinity between cooperation and communication, several parallels exist between the features of CSCW and those of embodied communication, and in many cases I cite work by researchers who publish in both fields. For the purposes of this review, I turn to the community of scholars concerned with embodied communication in addition to those concerned with CSCW for two reasons.

First, embodied communication and CSCW researchers employ complementary analytic and methodological approaches to communication and cooperation. Both domains of scholarship are informed by phenomenology, which examines structures of consciousness as experienced from the first-person point of view (Robertson, 1997, 2002), and ethnomethodology, which holds that social order is epiphenomenal to social action and interaction (Garfinkel, 1967; Sacks, 1992). Both fields derive their findings through induction, maintaining a healthy caution with respect to the use of established categories. Both are sympathetic to an ethnographic approach to situated social practices of groups in organizations and workplaces or beyond. In addition, CSCW studies are loosely complementary to the use of conversation analytic methods favored by scholars of embodied communication.

Second, and building on my last point, I draw on concepts from CSCW and embodied communication because, to some degree, each field treats the body and the material environment as salient in their analyses of communication and cooperation. As such, these fields place emphasis on bodies and practical action. The role of the body is primary in studies of embodied communication as demonstrated by its analytic traditions, its preferred methodological approach, and especially its popular treatment of gestures in everyday conversation (Mirivel, 2011; Mortensen & Hazel, 2014; Streeck, 2009; Streeck, Goodwin, & Lebaron, 2011). By contrast, CSCW treats the body in a less substantial way, but the body is somewhat salient in early descriptions of work practice (Bennerstedt & Ivarsson, 2010; Koschmann, LeBaron, Goodwin, & Feltovich, 2006; Sharma, Pavlovic, & Huang, 1998).

The material environment is in some ways central to CSCW studies in particular because CSCW focuses on the use of technologies with respect to improving technology design, though few scholars use this term (Heath, Knoblauch, & Luff, 2000a; Koschmann et al., 2006; Schmidt, 2011; Svensson, Heath, & Luff, 2007). For instance, Schmidt (2002, p. 286) raises central questions regarding the support of cooperative work, writing,"How should computational environments and material environments interface and interact? How can computational environments facilitate embodied action and interaction?" The role of the material environment has gained prominence in embodied communication following the multimodal turn in studies of social interaction (Deppermann, 2013; Keating, 2011; Mondada, 2006a). The topic of multimodality in studies of embodied communication is part of the expanding scope of ethnomethodological research that examines computer-mediated communication (Broth & Mondada, 2013; M. H. Goodwin, 1996; Kirk, 2007; Mondada, 2006b; Sakr, Jewitt, & Price, 2014; Wolff, Roberts, Steed, & Otto, 2007). At issue is the opportunity to reconcile the existing understanding of face-to-face interactions with nascent analyses of interactions enabled, and mediated by, computing technologies. In what follows I draw on these combined literatures to identify several concepts that should prove useful in a study of HTC (C-NC). To begin I focus on two work practices common to many if not all forms of cooperative work: coordination and awareness.

LESSONS OF COORDINATION AND AWARENESS IN CONTROL ROOMS

From the history of studies of work recounted earlier in this review, we learn that working in a distributed fashion emphasized the need to understand and support key practices in cooperative work. The computerization of work enhanced the need for coordination and awareness and complicated efforts to coordinate and maintain awareness as work became distributed. Indeed these concepts are exceptionally central to the CSCW literature because coordination and awareness are both necessary for a successful cooperative effort. Specifically, workers' awareness enables coordination, and coordination breaks down when workers are unaware of one another's actions.

CSCW as a community has identified and nominalized coordination and awareness as crucial components in cooperative work through numerous field studies carried out in rich technological environments (Dourish & Bellotti, 1992; Gutwin & Greenberg, 1998, 2002; McDaniel & Brinck, 1997; Rodden, 1996). The field based literature reviews written on coordination and awareness provide extensive terminological debate on the meaning of these terms (Malone & Crowston, 1994; Schmidt, 2002). For the purposes of my review I begin with particular uses of each term.

Coordination involves workers "managing dependencies between [their] activities" (Malone & Crowston, 1994, p. 90) and awareness in cooperative work is the product of a worker "taking heed" of the current context of a shared endeavor (Bly, Harrison, & Irwin, 1993, p. 33; Dourish & Bellotti, 1992). For simplicity's sake one could say that coordination is a kind of action *dealing with* interdependence in a cooperative endeavor and awareness is a kind of situated *knowing* about a cooperative endeavor. Under these terms each worker's awareness and ability to effectively coordinate are crucial for success.

Appreciating the importance of coordination and awareness, and aiming to not only understand but also contribute to the support of cooperative work, CSCW's treatment of coordination and awareness in control room settings is true to the field's Janus faced tendencies to investigate work practices in the wild and design for them. One finds extensive literature promoting the speculative process of designing systems to support cooperative work, as well as many articles reflecting on the pitfalls of interventional social science (Anderson, 1994; Bentley et al., 1992; Blomberg et al., 1994; Plowman, Rogers, & Ramage, 1995, p. 313). For the narrow purposes of this review I do not explore both faces of the coin, but instead focus on ethnographic investigations of these two essential cooperative work practices.

In particular, I circumscribe my treatment of coordination and awareness to those studies germane to the nature of HTC (C-NC) work. I focus on ethnographic studies involving the use of computing and non-computing technologies as support in processes of physical transformation. I reflect on the often mediated nature of communication in contemporary work environments, but firmly situate my treatment of coordination and awareness in the physical realm of cooperative work carried out in purposively designed workplaces. In effect, my choices serve to narrow my treatment of coordination and awareness in work environments similar to those listed in the examples of HTC (C-NC) provided earlier. Specifically, I primarily focus on studies of coordination and awareness in control rooms, sometimes referred to as "centers of coordination" in comprehensive reviews (Suchman, 1997).

Developed in the 1920s, control rooms are older than modern computing technologies. Nevertheless, even the earliest control rooms built for the supervision of factory work carried a computational bent (Bennett, 1993). A control room is a setting in which the context of action dynamically shifts according to changes in individual elements. Control rooms as a particular kind of work environment require multiple workers to maintain awareness of a changing context of work so as to coordinate disparate efforts towards a shared endeavor (Berndtsson & Normark, 1999; Broth, 2009; Filippi & Theureau, 1993; Heath & Luff, 1991, 1992a; Hughes, King, Rodden, & Andersen, 1994). As a physical work environment, a control room serves as a central space from which activities carried out in a larger facility can be monitored and managed.

The activities monitored, whether they be the launch of a space shuttle or the production of consumer goods, often involve physical transformation through a technology rich process. The combination of people, the need for computational thinking, and the close relationship with physical transformation represented in the work of control rooms make this work environment an especially suitable setting from which to glean insights on the topics of coordination and awareness for my investigation of HTC (C-NC) work.

To begin, I address coordination and awareness in the demanding work environment of transportation control rooms wherein physical transformation involves the coordinated movement of vehicles through the help of numerous technologies that support workers' efforts to schedule incoming and outgoing traffic. Studies of British and Danish air traffic control rooms and the London Underground serve as foundational field work in CSCW's understanding of coordination and awareness work practices (Berndtsson & Normark, 1999 cf; Harper, Hughes, & Shapiro, 1989a; Harper et al., 1989b; Heath & Luff, 1992a).

Appreciating coordination and awareness work practices depends on understanding four key traits in the work of transportation control. First, the ultimate goal of such cooperative efforts is to ensure a safe and efficient flow of traffic. As goals, safety and efficiency are at odds, requiring teams working in a transportation control room environment to make constant trade-offs between skirting danger and running behind. Second, and relatedly, much of the work carried out in a transportation control room involves managing geographic and temporal resources to optimize for efficient use while ensuring safety. Third, and as a consequence of these first and second traits, the activities in transportation are bifurcated: essentially efforts are split between strategic work functions like creating a schedule and tactical work functions like adjusting the schedule and other resources to handle unforeseen contingencies. Fourth, there is a layer of articulation work implicit in the work of transportation control management of human and technical resources that support operations. It should come as little surprise that transportation control environment staff representing a variety of roles use a combination of technologies, some computerized and some not, to distribute and divide decision making responsibilities while managing the broad and deep interdependencies in their work.

Even with a high-level overview of the work of transportation control rooms, it is easy to appreciate that this work is interactional at every level. Some have described these work environments in terms of distributed cognition (Broth, 2009; Luff et al., 2000; Suchman, 1997), a descriptor that invites metaphoric conceptualization of transportation control as a living organism. Out of the wealth of critical discussions in transportation control rooms, I want to focus on a pair of themes related to coordination and awareness.

The first theme addresses work practice of awareness. Scholars highlight the importance of the situated use of artifacts and technologies in the representation and transformation of information in support of awareness among workers (Benford, Bowers, Fahlén, & Greenhalgh, 1994; Heath, Svensson, Hindmarsh, Luff, & Vom Lehn, 2002). The lesson gained from this first theme regarding awareness is that an artifact or technology is not important on its own, rather what is important to understand are the details of its use. Furthermore, the use of an artifact or technology can serve to prioritize certain information that workers take heed of when orientating to their current activities.

To illustrate this theme I draw on an example of the use of paper flight strips in air traffic control to support awareness (Berndtsson & Normark, 1999). Flight strips are paper artifacts that contain information about a scheduled arrival or departure. The information printed on each flight strip is standardized as is the hand off and distribution of flight information using strips. However, while air traffic controllers use the flight strips, they also inscribe the strips with new information indicating updates to the schedule, based on unfolding and often unexpected events such as bad weather. The authors showed that the situated representation of flight information and transformation of information for different groups of workers, at different consequential moments in the course of a plane's arrival or departure, served to help the team maintain awareness about the status of the flight. This was especially the case even as the originally printed and electronically schedule flight plan decayed and fell out of date. Observing the inscription of a flight strip served to alert air traffic controllers of changes to the flight schedule, thus making the observability of inscriptions its own means of awareness in addition to the information inscribed.

The use of public announcement systems in the London Underground offers a second illustration of how information is cast and recast to create and maintain awareness of highlighted aspects of unfolding events (Heath & Luff, 2000). In this example the operators working in the control office take telephone calls and read electronic messages that later need to be relayed over the public announcement system. Here the action of gathering information from various sources and redistributing that information offers opportunities for subtle reshaping of the procedural information into a public announcement.

This transformation process benefits workers' and passengers' awareness of events. Notice, too, that information in the example of the London Underground was not circumscribed to a single modality, but rather information could be typed out on screen or voiced in with a range of emotions. The choice of format of information was flexible, bent to the purposes of the next action. In short, representation and transformation of information greatly benefit awareness.

The second theme addresses work practice of coordination. Scholarship introduces a critical perspective on procedures, task assignments, and other formalized organizational features that need to be appreciated with respect to workers' coordination as they respond to unfolding events, shape next actions, and make sense out of others' efforts to do the same (Heath & Luff, 2000, p. 25). The lesson we gain from the second theme is that coordination is accomplished *in situ*: it is poorly articulated as a formalized set of tasks or procedures, and better described as "coordinated conduct" (Heath & Luff, 1992a, 2000, p. 91; Nevile, 2004; Robinson & Stivers, 2001). Dealing with interdependencies can be an improvisational achievement of a cooperating pair wherein roles, task assignments, and standards inform but do not determine the next action. Rather, next action is a situated social achievement.

Within this discussion of the work practices supporting coordination and awareness in transportation control I found little analysis of the worker's body, an element that remains particularly important to cooperative work as an effortful achievement. It would appear, based on this narrowly conceived review, that the body is seemingly understood. However, examples drawn from the transportation control rooms, do provide glimpses of the worker's body. In the case of the London Underground we can gather that the qualities of the operator's voice conveyed context clues to the information related over the walkie talkie. In the case of the air traffic control room we gather that the handwritten inscriptions of the flight strips linked particular bodies and their particular styles of handwriting to the information conveyed in the inscription. Each flight strip had a personal history of use. Other examples are found but not focal in discussion of coordination and awareness in cooperative work. In addition, and quite innovatively, controllers would use the flightstrips to also post status information. For instance, Berndtsson and Normack (1999, p. 108) describe an example of this practice in which a controller who was going on break inscribed a flight strip with "Long Break" so that his status was broadcast to other controllers using the closed circuit televisions.

CSCW literature reviewed here validates the importance of coordination and awareness in transportation control rooms and provides lessons for the understanding of these practices in HTC (C-NC). However, the latent discussion of the worker's body in relation to these work practices leads me to wonder about the role of bodies in this special form of cooperative work. From the discussion of work in control rooms we know that workers in these (and cognate) environments deal with practical constraints to their perceptual access to one another, as well as relevant artifacts and technologies. It follows that in dealing with limited access workers in HTC (C-NC) would need to find special ways to facilitate the coordination of interdependencies in their work and maintain awareness.

COMMUNICATON IN CIRCUMSTANCES OF ASYMMETRIC ACCESS

Understanding asymmetric access is important to investigation into HTC (C-NC). To maintain awareness in this configuration workers contend with some practical constraints regarding their access via the senses (Gibson, 1966), and the same practical constraints affect workers' ability to coordinate their interdependencies (Gaver, 1992). In some circumstances, workers may have roughly equivalent access to a common set of artifacts and technologies, however often this is not the case. Whether HTC (C-NC) work is carried out face-to-face or accomplished in a distributed fashion, the ability to take heed of the context of work depends on a worker's access via his senses. His ability to coordinate may be equally constrained. In this last section of my review I discuss communication in circumstances of asymmetries in access to phenomena and the multiple and interrelated factors that create them. Based on my review I find that people with asymmetric access often find creative and flexible ways to overcome the limitations in their ability to communicate. I also find that in some cases asymmetries are leveraged for communicative effect in much the same fashion as communication symmetry is leveraged.

Appreciation of the literature reviewed next depends on a somewhat technical description of access in a work environment and how access is shaped by, and related to, multiple factors. The topic of asymmetries in access to perceptual phenomena can be difficult to concretely discuss for two reasons. First, a combination of factors contributes to the access workers enjoy and, crucially, the lack of access with which they contend. Second, even though many of the factors that impact workers' access are incredibly familiar, they are often not discussed in technical terms. For the purposes of this review it is only necessary to understand that access to perceptual phenomena is relational, meaning that each worker as a sentient body is uniquely related to his or her work environment (Chemero, 2003).

CSCW researchers have treated the issue of asymmetries in people's ability to maintain awareness within a cooperative work arrangement (Billinghurst, Bee, Bowskill, & Kato, 1999; Kethers, Hargreaves, & Wilkinson, 2004; Kirk, 2007; Voida, Voida, Greenberg, & He, 2008) though the treatment of asymmetries is less prominent than discussions of awareness or coordination. The field's interest in access arose when members of the research community developed technologies for distributed cooperative work. Through the process of system evaluation, researchers began to articulate differences in workers' perceptual access and ultimately tried to correct these asymmetries in distributed communication to regain the understood ease of collocated work. At times one finds design properties of computing technologies promoted as solutions to resolve limitations of non-computerized work within the CSCW literature, but closer examination of technology use quickly refutes this simplified view. In this portion of the literature review I explore how and in which ways computing technologies resolve, but also introduce limitations in access to work-relevant phenomena.

Perhaps one of the most influential design projects in the CSCW literature is MediaSpace, a video-conferencing software used to support awareness and impromptu socialization among distributed office workers (Bly et al., 1993; Fish, Kraut, Root, & Rice, 1992; Gaver, 1992; Heath & Luff, 1992b; Mantei et al., 1991; Sellen, 1992; Sellen, Gaver, Heath, & Luff, 1993; Voida et al., 2008). As Smith and Hudson (1995, p. 1) enthusiastically summarize: "Media spaces are systems designed to use audio, video, and other media to create shared 'spaces' in which distributed work groups can operate smoothly and conveniently." The design of MediaSpace as a computing technology was not as neutral as Smith and Hudson represent it to be; instead some scholars discuss the ways that people using such virtual collaboration system discovered and leveraged their access through social interaction (Gaver, 1992; Keating, 2008).

Computing technologies are not unique in their ability to form so called spaces. Non-computing technologies and other kinds of objects, like paper printouts, also circumscribe space for social interaction (C. Goodwin, 2007; K Schmidt & Wagner, 2003; Weilenmann & Lymer, 2014). The flexibility as well as the complexity of these new spaces for interaction is due to properties that enhance participants' perceptual ability and access to resources as part of an unfolding interaction.

In sum, the technologies used in work configurations are impactful insofar as they can create new spaces for interaction and amplify workers' ability to perceive and act (Keating, 2008). These technologies enable workers to gain capabilities they would not have in traditional face-to-face interactions by virtue of the features of the technologies and their new spaces.

Although computing technologies did ease some asymmetries experienced prior to computerization, computing technologies should not be treated as a cure all for all difficulties created by asymmetric access. In their studies on computer-mediated communication, Keating (2008) and Gaver (1992) unavoidably highlight that these technologies created asymmetries in access to other relevant phenomena in the work environment. Computing technologies such as the MediaSpaces program resolved some issues that the participants' experience, but in changing the work environment computing technologies added additional dimensions and complications to their interactions. Computing technologies contributed to asymmetries in access that workers leveraged for communicative effect.

For instance, Keating (2008; 2011) noted that new spaces and the different properties of objects within them can create asymmetries in access to information. Writing for both an embodied communication and a CSCW audience, Heath and Luff (1993) present an observational study of work in newsrooms in which they noticed that technologies and their layout in the work environment created asymmetries in access to information that workers used to dynamically highlight or obscure the status of one's work for others nearby. Similar, if not identical remarks are made about video-conferencing tools used to support awareness and impromptu socialization among distributed office workers (Gaver, 1992; Heath & Luff, 1993).

CSCW research tended to approach asymmetries as a problem to solve, in a sense seeking to rebalance human ability through design of computing technologies. Accordingly discussion of perceptual access in CSCW centers around a single topic: the design of computing technologies. The relational qualities of perceptual access are appreciable in embodied communication scholarship informed by Gibson's (1966, 1979) writings on ecological psychology. With an appreciation of the relational nature of human perception, I look beyond CSCW to understand the limitations on access imposed by technology. The studies that follow provide a broader context for discussing asymmetries in access as these studies take into account the difference in human ability and consequential complexity in the body's relation to the material environment. Put another way, asymmetries in perceptual access are not a technological problem to be solved, or not only so, because such perceptual asymmetries exist a priori the distribution of work.

The literature of embodied communication offers insight into an array of other communication asymmetries. The studies described next address communication outside of cooperative work. The interactions documented were nonetheless cooperative in a fundamental way as the participants involved depended on their partner to successfully communicate. I describe communication asymmetries in three contexts. Examples taken from these three contexts emphasize the flexible ways that participants overcame communication asymmetries.

By and large the participants described in these examples relied on a communication resource held in common to cope with their communication asymmetries. The first example is based on a group of studies documenting how a person's access is shaped by his or her sensory composition. The second example is based on a group of studies documenting how a person's prior knowledge and experience shape their ability to understand work-relevant phenomena. The third example is based on a group of studies documenting a familiar factor in communication asymmetries, namely how a participant's access is affected by their location relative to work-relevant phenomena. I discuss the first example in the greatest detail because it describes a rather profound communication asymmetry.

Studies on the composition of sensory apparatus in communication greatly inform our understanding of the ways that participants in a cooperative effort can be differently afforded or constrained by their bodily or cognitive capacities in terms of the use of their perceptual apparatus. Examples of asymmetries in perceptual apparatus demonstrate a profound human ability to adapt to communication with quite limited resources.

In an exemplary case of communication asymmetries, Goodwin (1995, 2000) describes the communication practices of an aphasic man who lost the ability to speak all but three words ("yes," "no," and "and") after a major stroke. Even with a limited vocabulary the aphasic man and his conversational partners are able to cooperatively resolve practical issues, such as getting help adjusting an article of clothing or choosing what type of bread to have and what it should be dressed with. Goodwin's observations show that conversational partners are even able to accomplish commonplace social customs like having the aphasic man recount a story. The conversational partners and the aphasic man are together able to accomplish mundane communication tasks despite working with a skewed set of verbal resources. These studies show significant adaptation of conservational practices to the constraints of a three-word vocabulary.

People who encounter asymmetries due to differences in perceptual apparati cope with differences in their access and abilities by translating inaccessible phenomena into an accessible modality. This is the observation of Keating and Haddar's (2010) review of ethnographically oriented anthropological studies of sensory impairment. Their review encompassed a breadth of asymmetries due to differences in perceptual apparatus. What is clear from their review is that there is an exquisitely adaptive quality of talk-in-interaction whatever the sensory context.

In a cognate vein of research, Keating and Mirus' (2004; Keating, Hadder, & Mirus, 2004) study of computer mediated conversations of deaf participants explores the new opportunities for interaction enabled by computer mediated communication platforms. The deaf participants demonstrate a similar degree of adaptability in their efforts to visually organize web camera softwares to enable the display of signed conversation. From this research we gain a greater appreciation for the ways that participants with non-standard perceptual apparatus nevertheless accomplish mundane communication work by adapting and substituting communication practices to the particulars of their situation. In particular in this vein of research we learn, the communication practices adapted were geared to the use of indexical references, and the coping mechanisms diminished the impact of differences in perceptual apparatus.

An additional study by Goodwin (1994) describes how prior knowledge and experience shape a participant's ability to understand work relevant phenomena. Based on his observations and analysis of the recordings of archeologists making maps in a field school, Goodwin's (1994) study offers an appreciation of the importance of asymmetries that differentiate experts' and novices' access along their levels of professional membership. Goodwin's study makes clear that a novice is not naturally endowed with the necessary perceptual abilities for work in a chosen occupation. Instead, the novice must acquire such "professional vision," meaning "socially organized ways of seeing and understanding events that are answerable to the distinctive interests of a particular social group" (Goodwin, 1994, p. 606), with the help of an expert and highly experienced archeologist. Goodwin's report focuses on the expert archeologist's techniques for shepherding the novice into a particular visual orientation so that the novice achieves functionally equivalent perceptions of subtle features of an excavation site through situated social interaction.

From Goodwin's study we learn that prior knowledge and experience, the kind required for professional membership, informs a participant's access to perceptual phenomena and ability to appreciate the relevance of phenomena to the task at hand. Echoing what the prior examples showed us, Goodwin notes that despite differences in their access to the relevance of perceptual phenomena, a novice and apprentice can overcome their asymmetric access. To this end, Goodwin identifies techniques that professionals use to cope with asymmetries in access to perceptual phenomena experienced by junior more novice members of the team. These coping techniques allow us to appreciate that symmetric access is not solely determined by proximity to the relevant phenomena, but that the participant's ability to detect relevant phenomena is also dependent on his knowledge and experience. These examples help us appreciate how complex and unique circumstances of asymmetric access can be.

Nonetheless, location certainly can play a role in generating asymmetry. In a final example, I discuss a commonplace instance in which two workers deal with asymmetries in access due to their location. Communication asymmetries are inescapable and regularly resolved by conversation partners. One factor that often influences communication in cooperative work is differences in each worker's location relative to work relevant phenomena. Sakai, Korenaga, Mizukawa, and Igarashi (2014, pp. 510–511) provide an example of mundane cooperative work of a plumber and a plumbing manager who often worked in different locations and at different times of day. The plumber and the manager met to discuss progress on the renovation of an old home. The pair negotiated their qualifications for making decisions for the remodel based on the access each had to work relevant phenomena. Specifically, the plumber was expected to follow the formal plans for the remodel as the plumbing manager prescribed them, but the plumber had a greater degree of access to the project as he, and not his manager, had seen the layout at the job site.

Sakai et al. (2014) describe the ways in which the plumber and the manager discovered the relevance that their different levels of access played in negotiating changes to the formal plans of the remodeling job. From Sakai et al.'s (2014) study we can appreciate that the circumstance of asymmetries in access as a consequence of the workers' spatiotemporal location led to the need for substitution of a representation (hand-drawn annotations to a blueprint) in lieu of the missing phenomena (the job site itself), enabling them to move forward with their shared goal of completing the renovation. Specifically, the plumbing manager and the plumber creatively and flexibly adapted to overcome their asymmetries in access to information through the use of shared resources: the formal blueprints and pencils they used to augment the blueprints with the missing information.

Revisiting an example in the introduction clarifies how access is impacted in HTC (C-NC) by multiple factors. The first factor will be obvious: location affects workers' access. The second factor will be easier to overlook: perceptual access is relational in multiple ways at once, all of which affect workers' access. Other factors can include the organization of cooperative work, for instance the division of labor that informs which worker(s) are assigned which tasks.

In a prior case I discussed, NASA control room engineers lacked access to the leaking ammonia pump located on the International Space Station. Accordingly, the mission control operator needed to rely on the astronaut's "feel" of a bolt tightness or looseness. No video-link alone could substitute for the operator's lack of tactile access to the technologies and materials needed to make repairs to the craft two hundred and fifty miles above. Similarly, the Indian automotive engineers were unable to touch the physical crushed car parts located in the distant American teardown facility. In both these examples, the cooperating pairs dealt with asymmetric access to tactile phenomena relevant to their cooperative endeavor using conversation. In work environments where non-computing technologies remain in use the scheme of technology input and output also become salient. For instance, in the example of the International Space Station only one astronaut alone could use the wrench because this non-computing technology was designed for one-handed operation. Hence at least two factors – location and technology design – impacted access in the example of replacement of the leaking ammonia pump.

Broadly this section examined how asymmetric access to perceptual phenomena impacts how people communicate and cooperate. The literature in and beyond studies of embodied communication indicates that limitations of access do not prevent communication but instead shape how communication is carried out. Together the examples provided in this section of the review emphasize the flexible ways that people cope with asymmetries that are appropriate to their shared goals. Examination of the topic of communication in spite of asymmetric access disposes me to question how workers in the context of HTC (C-NC) handle asymmetries in access to tactile phenomena.

RESEARCH QUESTION

The spaces involved in HTC (C-NC) work are more complex than everyday conversational settings. Naturally then, each worker's access, and consequently their awareness in a cooperative work arrangement, differs due to the variety of ways their access is shaped by their context of work. Put another way, access and the ability to maintain awareness is a relative byproduct of a number of factors in a cooperative work arrangement including but not limited to differences in worker's technologies, roles, experience, and abilities. In such circumstances workers experience asymmetries in their access to the people, objects, and events that occur within a cooperative work arrangement, and which as a composite whole comprise the context of cooperative efforts as these elements dynamically interact.

HTC (C-NC) places two seemingly conflicting demands on workers, namely that participants (1) have different access to their common field of work through the use of their respective computing and non-computing technologies and (2) intimately depend on the complementary use of both technology types in ways that take into account actions performed independently and perceptual phenomena experienced privately. Based on my review and with appreciation of the concepts just highlighted, I suggest that a worthwhile place to begin investigation into HTC (C-NC) is understanding work practices that allow workers to cope with asymmetric access to tactile phenomena. I seek to appreciate the ways that participants treat that private experience of work and make that experience public. I am particularly interested in the ways that felt experience is surfaced in talk. Specifically, this dissertation addresses the research question: **how do workers in HTC (C-NC) orient to asymmetries in access to tactile phenomena?**

Addressing this research question, I seek to fill a gap in the existing scholarship concerning coordination and awareness in HTC (C-NC) and the asymmetries in access that can be implicit in and amplified by technology-mediated communication. There are three key terms in my research question. The phrase "tactile phenomena" can be understood in this case to designate the productive activities of hands and a person's manual operation of technologies as these technologies are situated within the built environments designed for HTC (C-NC). Tactile phenomena are important to this inquiry because, as past studies have shown, touch is an important way we know and interact with the world (Katz, 2013; Lebaron, 1998; Mingers, 1996). The phrase "talk-in-interaction" designates the importance of talk and emphasizes the analysis of verbal communication in my study of technology-mediated communication (C. Goodwin, 2002;

Harrison & Williams, 1994; Heath, Knoblauch, & Luff, 2000b; Maynard & Clayman, 2008). At the same time, this phrase also encompasses a diversity of interactional material including, but not limited to, the use of gesture, such as tool-tip deictics (pointing), and vocal performance qualities, such as prosody (i.e., the patterns and stresses in the tone of spoken language). Studies of embodied communication in particular have demonstrated the importance of talk-in-interaction for understanding a range of communication resources in television control rooms (Broth, 2008, 2009), auto repair shops (Streeck, 2010, 2016), computer support desks (Harrison & Williams, 1994), and archeological digs (C. Goodwin, 1994). Lastly the phrase "orient to" designates a broad class of attentional shifts to phenomena as evidenced in a gesture, utterance, or some other embodied action that references tactile phenomena. Such orientation has been of interest to embodied communication scholars (Broth & Mondada, 2013; C. Goodwin, 2004; Suchman, 1997; Zellers & Ogden, 2014) because the term encompasses a myriad of ways that people react, and for those same reasons it should be of great concern to an inquiry of HTC (C-NC).

Methods

Introduction

CSCW scholars recognize a strong tradition of ethnographic research (Anderson, 1994; Harper, 2000; J. F. Hughes, O'Brien, Rodden, & Rouncefield, 2000; J. Hughes, King, Rodden, & Andersen, 1994) that extends into studies of awareness and coordination in cooperative work (Filippi & Theureau, 1993; C. Goodwin & Goodwin, 1996; Harper, Hughes, & Shapiro, 1989; Heath & Luff, 1992, 1996; Suchman, 1997). The use of ethnographic methods in CSCW, within and beyond studies of awareness and coordination, provides an appreciation of the easily overlooked social context of technology use through attention to the small details of members' speech and behavior. An alternative naturalistic approach to research, called "microethnography" (Streeck & Mehus, 2005, p. 381) or alternatively "ethnographic microanalysis" (Erickson, 1982), provides an even closer look at naturally occurring human activities and interactions.

As a well-established methodological approach used in studies of embodied communication (Mortensen & Hazel, 2014; Streeck, 2009, 2013; Streeck & Mehus, 2005), microethnography concerns itself with the social practices by which members pursue their interests. Taking an ethnomethodological perspective, researchers begin with a basic question facing the members being studied, namely, "What is going on here?" (Agar, 1975, p. 46). A microethnographic analysis then proceeds according to a basic assumption that the answer to that question can be presumed by "the way the individuals [under study] proceed to get on with the affairs at hand" (Goffman, 1974, p. 8).

Microethnographic analysis of embodied communication bears a strong affinity with CSCW-styled ethnographic investigation of cooperative work practice as each have taken an ethnomethodologically-based stance towards documentation of social practices (Büscher, Gill, Mogensen, & Shapiro, 2001; Dourish & Button, 1998; Rooksby, Rouncefield, & Sommerville, 2009). Foundational studies of cooperative work (e.g., M. H. Goodwin, 1996; Heath & Luff, 1992; J. Hughes et al., 1994) make clear that microethnography is impressively well-suited to understanding HTC (C-NC) work practices because they are cooperatively built and made anew through recognized social action.

To describe the microethnographic study that I conducted, I first detail the ethical considerations of my study and proceed from there to explain the rationale behind my choice of the research setting of Minimally Invasive Cardiac Surgery (MICS). I explicate my reasoning by describing the participants, activities, and physical and digital infrastructure of the setting. I next describe the data collection process, which involved making observations and video recordings with ethnographic techniques of observational fieldwork. At the close of this chapter I detail my procedures for carrying out a multimedia microethnographic analysis of MICS operations including the conversation analytic technique of transcription and the annotation of extra-linguistic features of prosody. In combination, these analyses enabled me to address my research question: How do workers in HTC (C-NC) orient to asymmetries in access to tactile phenomena through talk-in-interaction?

Research with Human Subjects, Ethics, and Other Considerations

The University of Texas Institutional Review Board (IRB) does not consider the research design for this project to be human subjects research. I originally received this determination in 2012. At that time the IRB provided feedback on study designs via email. Following the successful defense of my dissertation proposal in 2016, I contacted the IRB to update them with changes to my study design to ensure I had satisfied all of my ethical obligations. In early December I received a formal letter from the IRB stating that, even with my current study design, they do not deem this dissertation human subjects research. The primary considerations in the IRB's determination involved my choice not to interview participants. The IRB deemed my work an investigation into a work process, and not individuals at work per se. Formal documentation of the IRB's decision and my application to the IRB is included in Appendix A.

Though my research operates outside of the IRB's purview, I remained sensitive to my participants' privacy and confidentiality concerns. To maintain the anonymity of the people involved I used pseudonyms for medical personnel, patients, and the hospital(s) where I collected data. I took precautions to prevent the recording or unwitting distribution of patients' personally identifiable information and health history. Accordingly, on data collection trips I gained consent from all study participants, excluding the patients, with whom I did not interact as they were typically under anesthesia. The informed consent described the parameters of my data use. These parameters included the use of images and video data for research purposes. As part of the study design, I put limits on data reuse and distribution. Where needed, I used line drawings in lieu of video still images so as to further protect the anonymity of the patients and medical team. Specifically, I did not distribute the data electronically without request and receipt of written consent from the participants depicted. I gained consent for limited distribution of excerpts of my research data as part of the microethnographic practice of data sessions. In these sessions, other researchers jointly reviewed video material and work with transcripts that closely and systematically represented the phenomena of talk-in-interaction.

SETTING: A CASE OF HTC (C-NC)

HTC (C-NC) can be investigated in many contexts. For example, the work configurations typical in international space station repairs provide ample instances in which the astronauts in space and the engineers at mission control cooperate to solve the practical demands of repairing, maintaining, and upgrading that durable craft (Duarte, Cardoso, & Lamounier, 2005; Dünser, Steinbügl, Kaufmann, & Glück, 2006; Fjeld & Voegtli, 2002). For the purposes of this dissertation, I chose a particular research setting that satisfies all of the requirements of HTC (C-NC): MICS. In this section I situate my research setting within a wider context of MICS as a particular genre of minimally invasive surgery. As part of the contextual description of the research setting, I also demonstrate that cardiac electrophysiology (cardiac EP) is a kind of MICS that serves as a complete example of HTC (C-NC) work with real world complexity and significance. Therefore, I identify MICS, and in particular cardiac EP, as an ideal setting to investigate my research question. I provide a description of the activities central to MICS, the professional roles of the participants in these procedures, the technologies principally used, and physical and digital infrastructures that support this kind of cooperative work. To conclude this demonstration, I describe several high-level activities and features essential to cardiac EP as a kind of MICS.

The Context of MICS

I base this description of the research setting on fieldwork I conducted primarily in a single research-oriented hospital located in the Northeastern portion of the United States. As I will detail elsewhere, I conducted this fieldwork with the permission of the university and the hospital. Originally I gained access to the Northeastern hospital as a research site through a personal connection: the central participants, a cardiologist and a surgical nurse, were at one time my mother’s co-workers. In 2013, I sought permission to initially observe, and later record, cardiac EP procedures conducted at the hospital based on an interest in technology-mediated cooperative work and with the intention to identify a dissertation topic.

Medical teams conduct cardiac EP procedures in roughly two thousand hospitals across the United States and an equal number worldwide. Cardiac EP procedures share a number of characteristics with other minimally invasive surgeries in cardiology as well as those beyond. To begin, cardiac EP procedures, like other MICS procedures and minimally invasive procedures broadly conceived, involve surgical teams that reflect a combination of professional roles. In addition, these teams conduct cardiac EP procedures in purpose-built multi-room environments that protect against hazards such as radiation exposure and asepsis. Importantly, the teams accomplish cardiac EP procedures with a combination of computing and non-computing technology types. As in all minimally invasive surgeries, these technologies provide essential features in the diagnosis and treatment of pathologies, and operating them requires the cooperative efforts of professionals representing various professional roles. In the particular case of cardiac EP, members of the teams rely on one another and must coordinate the use of multiple technologies to find, diagnose, and treat cardiac pathologies in real time and in close communication.

Activities for Finding, Diagnosing, and Treating Cardiac Pathologies

Cardiac EP procedures are lengthy, often lasting three to four hours. In this time, the medical team's purpose in a cardiac EP procedure is to find, diagnose, and treat the source of a problem in the way a patient's heart conducts electricity (a problem with cardiac electrophysiology called an arrhythmia, or abnormal heart rhythm). I summarize each activity.

The work of finding cardiac arrhythmias involves a commingled set of physical and digital maneuvers. In terms of physical maneuvers, the procedure involves inserting intravenous medical instruments into the patient's groin, guiding them to the heart, and manipulating them to map the heart and eventually deliver therapy. In terms of digital maneuvers, locating the problem requires the medical team to take various recordings of the patient's heart rhythms. In order to relate the recordings to the heart's anatomical features, the team uses a map of the patient's cardiac anatomy. Software systems can generate an initial map, but not one complete or accurate enough to diagnose and treat arrhythmias. As a consequence, much of the work of a cardiac EP procedure involves correcting, re-mapping, and updating the map of the patient's heart. The re-mapping aspect of the procedure in particular involves expert instrument manipulation because the map cannot visually guide the catheter operator; instead, the operator relies on his or her memory of cardiac anatomy and the feel of the catheter in his hand.

Diagnosing occurs between the finding and treatment activities of a cardiac EP procedure. In terms of physical maneuvers, the team member manipulating the instrument must wait until a diagnosis is established to treat the patient, but while waiting may fine-tune instrument placement as the need arises. In terms of digital maneuvers, diagnosis as an activity begins once the medical team has a sufficient map to make decisions. Diagnostic decisions are based on measurements of cardiac rhythms using electrocardiograms. Based on these diagnostic decisions, the head of the medical team will decide on a therapy and treatment.

As in finding activities, treatment activities of cardiac EP consist of physical and digital maneuvers. In this type of procedure, treatment equates to the delivery of ablation therapy, which involves the intentional destruction of heart tissue that the medical team determines is contributing to the arrhythmia (Spector, 2016). In terms of physical maneuvers, a medical team member performs ablation therapy by delivering a radiofrequency current to the heart via intravenous medical instruments. The decision to apply ablation therapy depends on essential additional digital maneuvers involving the adequate completion of cardiac mapping and measurement of cardiac rhythms.

Medical Team and Roles

One encounters a large team of medical professionals with diverse training in the midst of the finding, diagnosing, and treatment activities. At a research-oriented hospital such as the one in my study, teams are composed of one (or sometimes two) cardiologists (one of whom holds the role of the attending physician), one cardiac EP nurse, an anesthesiologist, and up to three circulating nurses, as well as medical device representatives who are occasionally present. Additionally, in a research-oriented hospital, a cardiologist on fellowship with the attending physician may complete the team. Within such a broad team, a subset of members is focused on the specifics of the procedure. The attending physician usually fills the role of directing the procedure, identifying arrhythmias on the images, and either performing or directing medical instrument manipulation. If another cardiologist is present, including the cardiology fellow, that person can aid in the identification of arrhythmias or simply observe the procedure. The cardiac EP nurse or cardiologist can perform the physical or digital maneuvering that these procedures require as directed by the attending physician. Circulating nurses support the attending physician and the cardiac EP nurse by tracking therapy outcomes in the medical reporting system as well as gathering and preparing surgical supplies. Apart from those members focused on the specifics of the procedure, the remaining members focus on the overall health of the patient. This subset of team members includes the anesthesiologist who monitors and administers drugs to the patient and the circulating nurses who relay information about the patient's condition to the rest of the team. Of these professionals, I limit my description principally to the interactions between the attending physician, cardiac EP nurse, and cardiology fellow, as these three roles are central to the activities of finding, diagnosing, and treating cardiac arrhythmias. I now turn to detailing the associated technologies essential to physical and digital maneuvering.

Technologies for Physical and Digital Maneuvering

Many technologies are represented in the setup of cardiac EP. I describe the technologies that are principally involved in the finding, diagnosing, and treating of cardiac arrhythmias. At a basic level, the technologies principally involved in these three activities can be described as a combination of non-computing and computing technologies. Non-computing technologies are essential to finding and treating activities. As shown in Figure 1, a catheter is a small flexible tube inserted into a blood vessel through a small cut in the patient's groin and fed through the circulatory system to reach the heart ("Biosense Webster Partners to Complete Electrophysiology Labs," 2014; Wang, 2012). The pair of images shows the size of the catheter relative to the nurse's hand (left) and a downscaled representation of the attenuated body of a catheter (right). Multiple catheters may be used in any cardiac EP procedure. One type of catheter maps the heart as a part of the activity of finding cardiac arrhythmias. Another type delivers treatment through radiofrequency ablation.

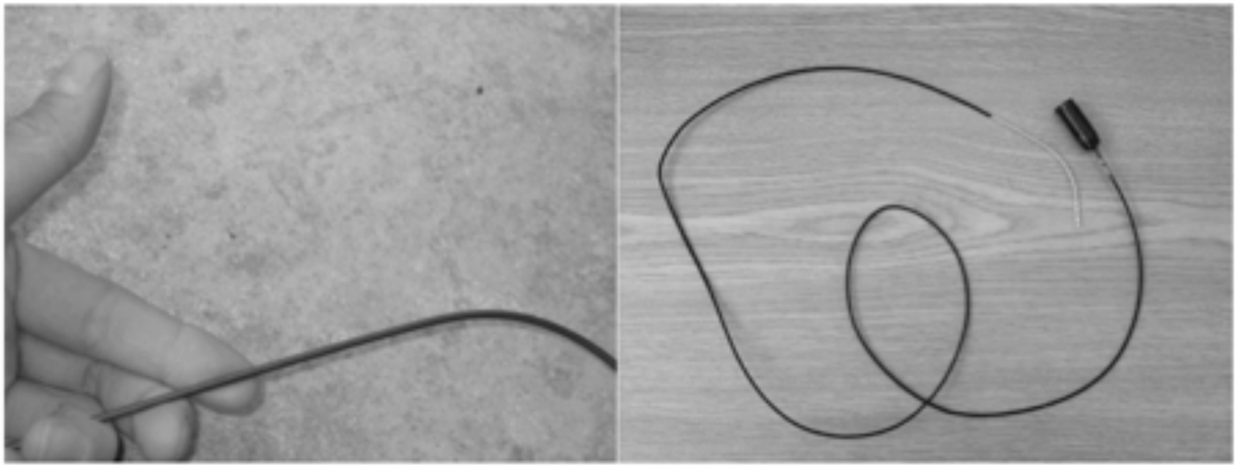

Figure 1: Example of Catheter Size and Dimension

Catheters work as physical tools to conduct cardiac EP, but these tools are connected through digital infrastructure to computing technologies. In terms of the catheter's design, the tip is the portion that is inserted into the patient's vascular system. The back end of the catheter, which carries an electrical wire inserted within the flexible tubing, is connected by an electrical lead to a power source installed beneath the boom, a visual display. The power source includes a set of network attachments that extend from the electrical leads. Network attachments are routed to the imaging workstation. The medical images shown on the board and boom are digital representations of the catheters as they are located in the physical surgery site (i.e., the patient). The catheters enable a myriad of representations through the sensors embedded within them.

In addition to the non-computing technologies, cardiac EP procedures principally rely on the use of computer imaging software systems in the activities of finding, diagnosing, and treating cardiac arrhythmias. Figure 2 illustrates the kinds of digital representations of the heart that these systems yield. This figures shows the initial and final map of the patient's cardiac anatomy: image A shows the initial map, an estimated model of the patient's anatomy, and image B shows a final map, revised to correct the missing anatomical features (namely, the branch-like aorta) ("Biosense Webster Partners to Complete Electrophysiology Labs," 2014).

I limit my description of computer imaging software systems to the essential ones. Therefore, I focus on the setup and use of one of the most important software systems in mapping cardiac anatomy and physiology, called Carto3™, and its connection to catheters, the non-computing technologies that support data acquisition. On occasion, the team works with fluoroscopic images in lieu of mapping and re-mapping with the Carto3 system, but in either case, a cardiac EP procedure requires expert use of a combination of computing and non-computing technologies.

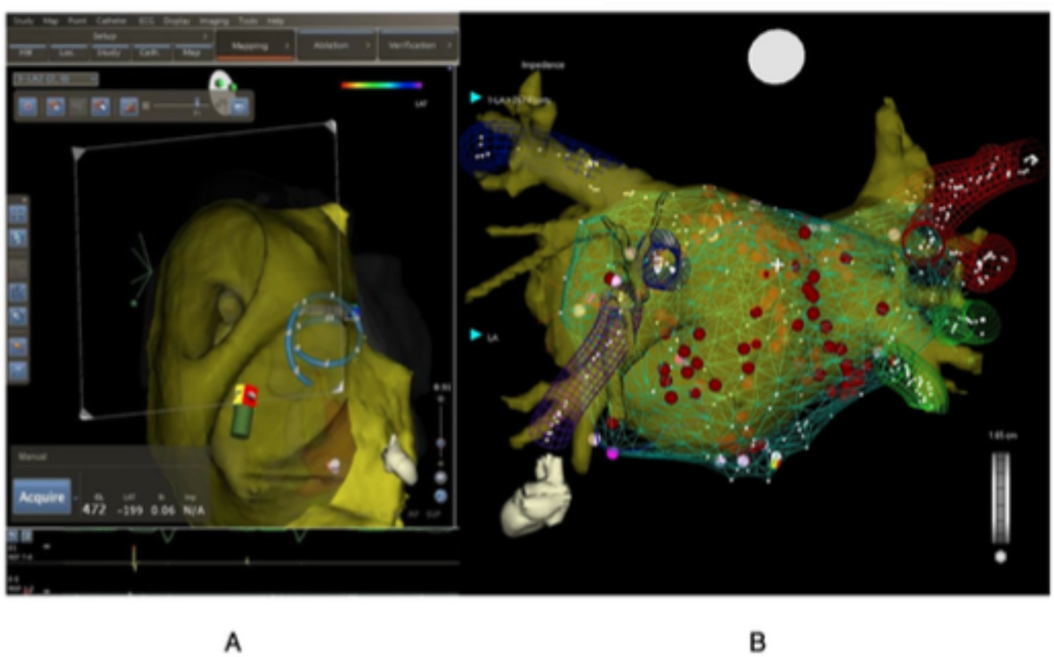

Figure 2: Initial and Final Maps on the Carto3™ System

To support catheter placement before the cardiac mapping activities begin, the attending physician and cardiac EP nurse run fluoro (x-ray imaging) to view images. Using the fluoro imaging as a guide, the cardiac EP nurse inserts the catheters in the patient's groin, setting up the physical surgery site. Once the mapping catheter and the other catheters are in place, the attending physician can use Carto3™ to generate the initial map, and the team need no longer rely on the fluoro images. Importantly, this map is a dynamic three-dimensional (3D) model (unlike the two-dimensional fluoro images) that functions as a virtual surgery site corresponding to the physical surgery site. To generate this initial map, Carto3™ requires the measurement of electrical conduction at different positions in the patient's cardiac anatomy. The electrical conduction measurements are taken from sensors embedded within each catheter tip. These sensors enable the software to create the initial map automatically. But the initial map is not sufficient, thus the attending physician and cardiac EP nurse must manually acquire additional 3D imaging data to make it sufficiently accurate.

To correct the initial 3D map generated by the software imaging system, the attending physician directs the nurse where to navigate the mapping catheter. As the cardiac EP nurse moves the catheter within the patient's physical anatomy, the attending physician corrects the 3D map, logs the catheter movement in this map, and refreshes the map display at regular intervals. Each time the software reloads the image, some cardiac features that were missing in the initial map are added according to the annotations in the attending physician's log, whereas other cardiac features are removed because the mapping catheter has provided sufficient data to eliminate those portions. After repeated iterations of navigation, correction, logging, and refreshing, the team achieves a final map upon which it relies heavily for diagnosis and treatment of one or more cardiac arrhythmias.

The Physical and Technological Layout of Cardiac EP

Although the attending physician, cardiac EP nurse, and cardiology fellow work closely together to generate and correct the cardiac map, the work they perform is actually distributed across two rooms of the cardiac EP surgical environment, referred to as the control room and the procedure room, as Figure 3 shows. Constraints dictate this two-room layout. Chief among these constraints is the need to maintain a sterile surgical site for the use of the catheters inserted into the patient, as indicated by the catheter workstation in Figure 3. The center for digital work of the surgery is located in a non-sterile control room. Although cardiac EP procedures require two separate rooms, they also require access and interconnection between activities occurring between these rooms.[2]

Figure 3 shows a wall with a large window that connects the two rooms. The two rooms are also connected by a gap at the top of the wall that permits sound to pass between them (not shown in the diagram) and an open passageway that allows team members to also pass between them (shown in the diagram). As a whole, the design of the rooms and the way they are interconnected creates a physical infrastructure that supports the work of cardiac EP procedures.

The physical and digital maneuvers required for the activities of finding, diagnosing, and treating cardiac arrhythmias are carried out at two separate workstations: the imaging workstation in the control room and the catheter workstation in the procedure room.[3] Each station centers around a digital display, called the "board" and "boom"

[2] The two rooms are also separated to prevent x-rays used in the procedure room from passing and harming those medical team members working in the control room. As a consequence of the threat of extended x-ray exposure, when team members enter the procedure room, they must wear lead aprons to curb the absorption of x-rays. When in the control room, the medical team is protected by leading embedded in the wall and window separating the control room from the procedure room where the x-ray imaging stations are located.

[3] The control room also houses one workstation for medical reporting carried out by circulating nurses. The

respectively. In the control room, digital maneuvers take place at an imaging workstation in front of the board, which is a bank of computer monitors that can display cardiac medical images. In the procedure room, physical maneuvering takes place at a catheter workstation in front of the boom, another large computer monitor display suspended from the ceiling just near the procedure table. The medical images displayed on the board and booms are identical. This identical view is supplied by network attachments that lead from the boom in the procedure room to a port in the ceiling above the procedure table. The network attachments run along the crawl space in the ceiling, then into the control room through another port in that ceiling, and finally connect to the computer and board.

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procedure room houses a place for the anesthesiologist to work, as well as an instrument table upon which circulating nurses lay out needed medical instruments for the cardiac EP nurse. Work surfaces and cabinetry complete the procedure room.

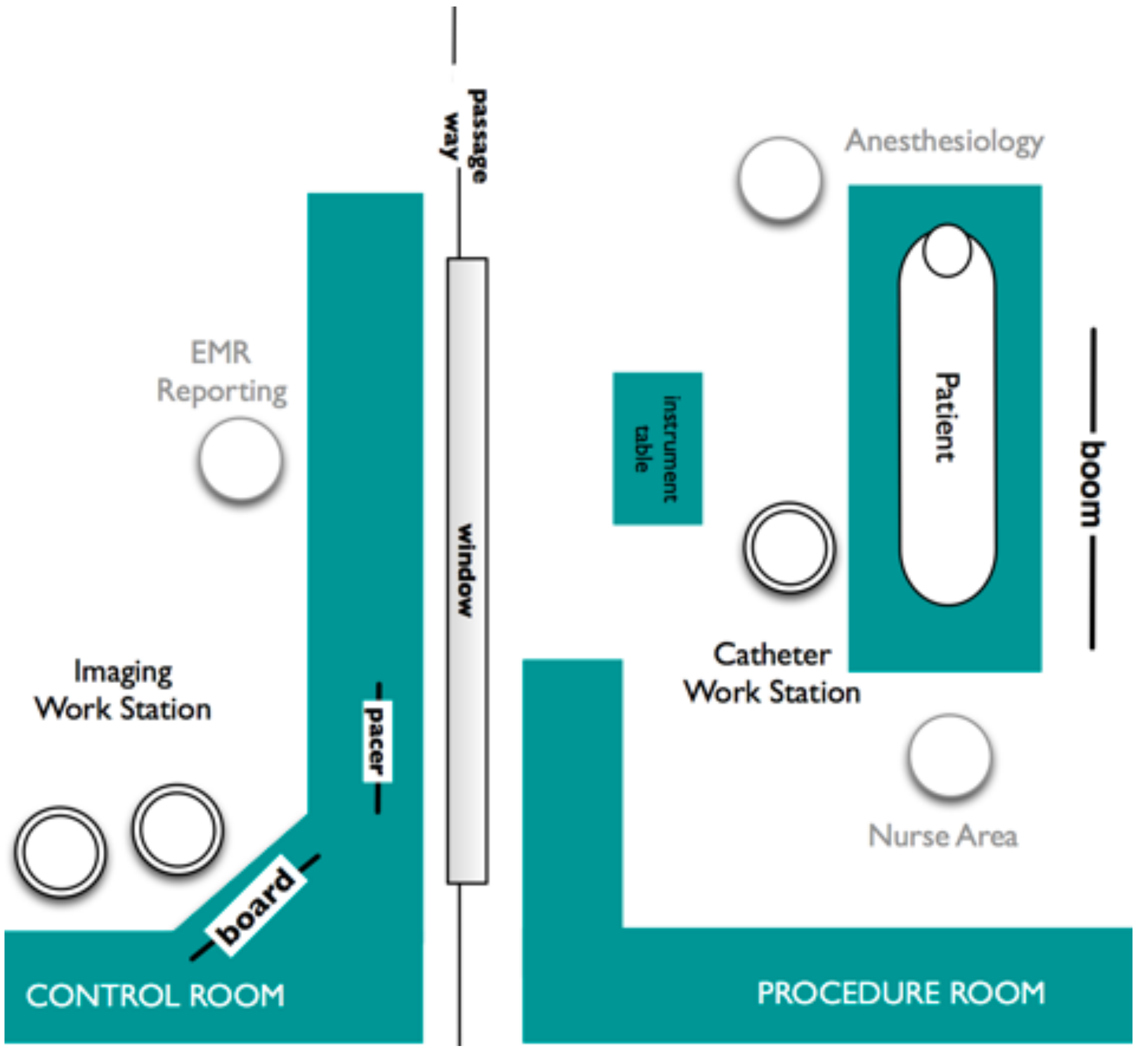

Figure 3: Diagram of Control and Procedure Room of the Cardiac EP Surgery Suite

The setup of the control and procedure rooms and the roles filled by the attending physician, cardiac EP nurse, and cardiology fellow greatly shape each team member's perceptual access to phenomena relevant to the ongoing procedure. As perceptual access is so crucial to my research question, I next identify the asymmetries in access to perceptual phenomena that are typical of cardiac EP procedures, paying particular attention to team members' visual and tactile access.

Asymmetries in Access for Each Workstation

I will describe the circumstances of perceptual access from a seated position in the control room at the computer imaging workstation and from a standing position at the catheter workstation in the procedure room. For the purposes of clarity I do not situate the key participants in a specific workstation because in practice the attending physician, cardiac EP nurse, or cardiology fellow can work at either workstation. As my description will make clear, the person seated at the computer imaging workstation lacks significant forms of visual and tactile access that the person at the catheter workstation possesses.

From his or her vantage in the control room seated at the imaging workstation, a team member is able to touch and operate a variety of computing technologies. The team member is able to see the medical images displayed on the board and can turn to see through the window dividing the control and procedure rooms. Looking through the window the team member can see the catheter workstation and the person operating each catheter from behind. The boom is partially visible from a seated position at the imaging workstation, but the boom is also partially obscured by the catheter operator's head.

As a consequence of having an obscured view into the procedure room, the team member seated at the imaging workstation cannot see much of the patient, nor can this person see the physical surgery site located at the incision in the patient's groin as these points are obscured by the team member standing at the catheter workstation. In addition, the person seated at the imaging workstation cannot see the front of the catheter operator's body or face, including that person's hand or face movements. In terms of touch, the team member seated at the imaging workstation has a limited scope of tactile perception, being unable to use his or her sense of touch to perceive the particularities of the patient's cardiac anatomy through use of the catheters fed through the physical surgery site to the patient's heart.

Whereas the team member at the imaging workstation can neither touch the patient nor interact with the catheters at the physical surgery site, the team member operating the catheters can. And though the team member at the imaging workstation can type and use the mouse at the computer imaging workstation, the catheter operator cannot. The team member at the imaging workstation is also able to get at least a partial view of the procedure room and its contents and activities, but the team member operating the catheters cannot easily view the imaging workstation because he or she is facing away from the window connecting the control and procedure rooms. For the team member who is operating the catheters to be able to see inside the control room, that person would need to turn around away from the boom and patient.

In short, from each workstation team members have different access to phenomena relevant to the work they share. Team members' limited access places them in an interdependent relationship because no one member can both operate the computer imaging workstation and manipulate the catheters in the other room. What is also interesting about the setup of this work environment is that the boom and board provide information in duplicate about the computing work going on, but there are no redundancies for catheters. In such cases the felt experience of the catheter operator in terms of the navigation of those medical instruments is a private tactile experience felt by the catheter operator alone. Even a direct view of work of catheter navigation is not available for the team member(s) in the control room. As a consequence of this setup, the experience of catheter navigation must be related to the control room verbally if at all.

In this section I provided essential details about the circumstances of cardiac EP MICS for two reasons: (1) to introduce the site of my dissertation data collection presented in the next section, and (2) to provide essential context for my findings that appear in a subsequent chapter. The work of cardiac EP MICS has all four necessary components of HTC (C-NC) work as informed by Reynolds (1994): (1) a combination of technologies (in this case, computing and non-computing technologies), (2) two or more workers, (3) a shared technical goal, and (4) a need for workers to maintain complementary roles. The importance of the surgical work accomplished in MICS strengthens my choice of research setting. This example of cardiac EP MICS situates HTC (C-NC) in a worthwhile setting that showcases the work necessary for creating and repairing the physical world, including the repair of bodies, in a particular setting.

DATA COLLECTION

The data collection strategy I employed was in line with microethnography (Streeck & Mehus, 2005). In particular, I employed a video recording method that "attempts to preserve the fluidity and temporality of the events, but also constitutes a reification of these events in a limited record" (Bergmann, 1985, p. 305). Recording helps the analyst to later gain an understanding of "sequentially arranged activity, moment-by-moment, by the participants within the very context of their activity" as they naturally occur (Mondada, 2006b, p. 80; 2012). In this section I describe the benefits of video recording coupled with, and complemented by, the ethnographic technique of observation.

Benefits of Video Recording

To begin, video recording is beneficial because the small details of social interaction are accessible and easy to review using video playback (Barron, 2007, p. 160; Sacks, 1992, p. 622). The details captured in "[video] recordings allow for the study of temporal and embodied details that are difficult, if not impossible, to notice without repeated viewings" (Sacks, 1992, p. 622). Video recording can capture small but important features in social interactions (e.g., head nods) and make these features accessible for close study (Aoki, 2011; Oshima, 2009). In addition, because modern video equipment is small and portable, its use causes minimal disruption to the physical layout of the environment under study further enabling the researcher to capture naturally occurring social interaction (Hindmarsh, Luff, & Heath, 2010, p. 41). The benefits of video recording make this data collection technique the most appropriate choice for my microethnographic research. I next describe the final set of collected data that I used in my analysis and the recording guidelines I developed to structure that data set.

Data Set

Data collection focused on capturing workers' social interaction as it was endogenously organized on the scale of sequences, activities, and practices. Specifically, my data collection enabled me to study the interactions among the attending physician, cardiology fellow, and the cardiac EP nurse on a moment-by-moment basis as these team members negotiated their interaction and progress towards their goal of successfully completing the procedure. Later, claims I make regarding my research question will be made on the scale of utterances, actions, and other embodied signs of participation that I captured in these data.

Before entering doctoral candidacy, and to indulge an interest in technology-mediated cooperative work, I made several visits to a cardiac EP surgery suite to observe procedures conducted in a Midwestern hospital where my mother worked. This site served as my supporting site in that my observations helped me formulate a research agenda. I later formalized my research agenda and gained access to record at a Northeastern hospital, which served as my primary site. During 2014 I videotaped portions of multiple cardiac EP procedures at this second hospital. Unfortunately, because of problems with the recording and audio syncing, most of the recordings were unusable because, although they showed a broad array of work accomplished by the cardiac EP team, they were of poor quality and did not completely follow the arc of a single procedure. After entering doctoral candidacy, I used these early recordings as well as my observations to devise a research question, trying out iterations of the research question and the ensuing analysis at small-scale research conference presentations.

Although I needed an additional data collection trip to address the limitations in these first recordings, there were other reasons for an additional trip. Video research methodology texts are clear that an iterative approach to research data collection and analysis is preferred. Heath, Hindmarsh, and Luff (2010, pp. 32–33) provide a number of reasons for using a multi-visit recording strategy. They argue that, through successive recording trips, the researcher can: (1) develop research participants' trust, (2) experiment with setup of audio and video equipment including the configuration of recording devices, and (3) identify and address data quality issues. Beyond these reasons, Heath, Hindmarsh, and Luff (2010, pp. 32–33)argue that, "most importantly, progressing in an incremental, step-by-step manner suits the qualitative approach that underpins [the] use of video recordings." At issue is the way the researcher progresses through her analysis of video data. Hindmarsh, Heath, and Luff (2010, p. 33) advise that video data collection is suited "to an iterative approach where data is collected in brief phases and then subjected to transcription and systematic review." To their point, during the intervening time between my first trips and the last trip I addressed both practical and analytical issues in my research, an act that enabled me to greatly improve the quality of the final video recordings. The relationship between practical and analytically significant decisions in video-based research is tightly interwoven, as the recording guidelines I detail later will demonstrate.

As summarized in table 1, my visits to the Midwestern and Northeastern hospitals afforded me the opportunity to observe twenty-nine procedures in total over 17 days across four years. On one trip to the Northeastern hospital in fall of 2016, I observed six cardiac EP procedures, five of which I recorded. I was unable to record the sixth procedure because of changes in my flight schedule that precluded setting up and dismantling or recording equipment. Table 2 summarizes the procedures that comprise my dissertation data set. As the table indicates, the procedures varied in type, duration, and staffing. Three different positions are described in the staffing column: attending physician (ATT), cardiac EP nurse (EPN), and cardiology fellow (FEL). To protect the anonymity of the participants on staff at the Northeastern hospital, I provide pseudonyms in place of real names. The duration of the procedures are rounded to whole numbers.

Date	**Hospital**	**Number of days in setting**	**Number of cardiac EP procedures observed**	**Number of cardiac EP procedures recorded**
June 2012	Midwestern	5	10	0
February 2014	Northeastern	4	7	3 (unusable for detailed analysis)
June 2016	Northeastern	4	6	0
October 2016	Northeastern	4	6	5
		17 total days	**29 total procedures observed**	**5 total procedures recorded**

Table 1: List of Research Trips

Recording number	Staffing	Recording Duration
001	ATT = “Stan”, EPN = “Hayes”, FEL = “Amar”	3 hours
002	ATT = “Stan”, EPN = “Hayes”, FEL = “Amar”	2 hours
003	ATT = “Derek”, EPN = “Hayes”, FEL = “Amar”	2 hours
004	ATT = “Derek”, EPN = “Hayes”, FEL = “Amar”	2 hours
005	ATT = “Lou”, EPN = “Hayes”, FEL = “Amar”	1 hour 45 minutes
		10 hours 45 minutes

Table 2: List of Cardiac Procedures Recorded and Procedure Duration

Emphasis on Audio Recording – My previous observations of cardiac EP procedures provided many opportunities to view and dissect the types of access that workers in cardiac EP procedures enjoyed. By the time I engaged in my last data collection trip, I knew that asymmetries in access to tactile phenomena would be represented in my recordings. I anticipated that participants’ orientation to tactile phenomena would emerge through talk, so I recorded mic’d talk from the same channel as the team’s headsets. Recall that headsets are used to make the conversation between the people involved in cardiac EP procedures audible over the sound of machine noise.

Recording Guidelines – In order to maximize the quality and relevance of my video recordings (listed in table 2 above), I developed a set of guidelines before my final data collection trip in the fall of 2016. The guidelines came about through making a series of analytically consequential decisions about how to record cardiac EP procedures. Sidnell et al. (2012, p. 113) describe the consequential impact of data collection when they write, "collecting data during fieldwork is a complex practice involving not only various recording technologies, but also social relations and proto-analytical understandings of the activities to be documented." To this end, some of the decisions I made when conducting my study are common to any microethnographic research project, but others are unique to the study of work in medical workplaces.

The first decision involved what material to record. Cardiac EP procedures can be long (up to three or four hours in duration), so the question arose whether it was best to record the entire surgical procedure or just part of it (Lomax & Casey, 1998). I decided to record the procedures from start to finish so as to not inadvertently break the recordings of a procedure and miss crucial information in the sequential progression of the medical team's goals. Recording each procedure from start to finish allowed me to better interpret the phenomena of interest.

The second analytically consequential decision involved choosing the primary subject of the recordings. Principally at issue was whether to focus the camera on particular participants or follow the action or objects in the procedure. Based on my first data collection trips, I chose to focus my recording on workstations and the participants working at them because my goal was to study the social interactions that enable HTC (C-NC) work, as accomplished by the attending physician and cardiac EP nurse with the aid of the cardiology fellow when that additional team member was present.

The third analytically consequential decision involved whether to position the camera as stationary or moving. During my initial data collection trips, I learned that the safest and least intrusive way to record surgical procedures was to limit camera movement. A stationary camera position was safest because it could be positioned out of the footpaths of the circulating nurses. Furthermore, a stationary camera position would be less intrusive because the catheter and computer imaging workstations were distanced from much of the personally identifiable information about the patient, as Heath, Hindmarsh, and Luff (2010, pp. 46–47, 49–50) advocate.

A fourth analytically consequential decision involved camera positioning (Maynard, 2012, pp. 64–79). Any one choice to frame the recording of social interaction has benefits and detractions. For instance, close-up shots of the work of hands miss the participant's gaze. Although wider shots can increase the view of the interaction as it is situated in the environment, this framing choice brings with it overall lower resolution when needing to zoom-in during post-processing. To that end, I chose a three-camera recording strategy with fixed angles following approaches used by scholars studying workplaces (Heath & Luff, 2000b; Mondada, 2006b; Sakai, Korenaga, Mizukawa, & Igarashi, 2014; Sidnell et al., 2012).

I set up the first camera, with a standard lens, on a mini-tripod on the tabletop of the computer imaging workstation. I positioned it in such a way as to capture both the participant's face and his interaction with the computer keyboard and screen (Hindmarsh et al., 2010, pp. 51–52). I set up the second camera, with a standard lens, on a full-sized tripod. This second camera focused on a three-quarter-angle view of the person working at the catheter workstation. Using a three-quarter view enabled me to see the full posture and movements of the hands and face as well as the participant's orientation to and interaction with the boom. To get this three-quarter view I positioned the camera near the foot of the procedure table. I also set up the third camera, with a standard lens, on a full-sized tripod. I positioned it to frame a large-scale computer monitor that showed a redundant set of medical images displayed at the two workstations. This computer monitor, framed by the third camera, was located in an anteroom that was adjacent to the control room. The recording made by the third camera served as a resource for interpreting verbal references to information displayed on the boom and board that was obscured by the angle of the other two cameras. The orientation of the first and second cameras made it possible to see shifts in gaze and manual operation of the computer work station and the catheter workstation. As a consequence of this recording setup, I was able to identify mutual elaboration (i.e., how the intelligibility of actions with hands and eyes together informed appreciation of each action' smeaning) that each participant's hands and eyes lent to talk.

The fifth and last of the analytically consequential decisions was whether or not to be present while recording. Scholars have argued the benefits of both options. On the one hand, a researcher's presence in the recording environment can stifle or affect the participants (Hindmarsh et al., 2010, pp. 53–54). Consider a situation in which participants in a recording used the presence of the researcher and his camera as an opportunity to "perform" (Broth, Eric, & Mondada, 2014, pp. 185–186; Speer & Hutchby, 2003, p. 333). While these recorded interactions between participant and researcher can also be interesting to analyze, a participant's performance may defeat the purpose of the recording to capture social interaction among participants as they would naturally occur. On the other hand, Lebaron (1998, pp. 8–9)advocates for the choice to record while present during the recording. In his dissertation study of gestural hand forms used in architectural design practice, Lebaron argues for the importance of "experiencing" the interactions first hand. In addition, Heath, Hindmarsh, and Luff (2010, pp. 51–52) suggest that there are practical benefits to recording social interactions while being present because being present allows the researcher to supervise the equipment and ensure that it does not malfunction. In the end, I decided to remain present for the recordings because the threat of participant performance was small since, by the time that I made the last video recordings, I was already a familiar face in the cardiac EP suite.

Ethnographic field-noting – While present during the procedure, I could also employ the ethnographic technique of observation and writing field notes (Hindmarsh et al., 2010, pp. 55–56; Sakai et al., 2014). Early in my research when observing at my supporting site, I found field notes to be essential in deciphering interactions during the analysis of my data. Accordingly, as part of my data collection strategy, I moved back and forth between observing work at the computer imaging workstation in the control room and at the catheter workstation in the procedure room. When in the control room, I sat as close to the computer imaging workstation as was appropriate. When in the procedure room, I stood near the foot of the procedure table next to where I set up the second camera. I took field notes during the procedures to index major events (such as a substitution in who was doing the catheter work) that occurred during the recordings. I asked clarifying questions to the medical team members during procedures when I could and as was needed.

In this section, I detailed the video data collection strategy that I executed and my visits to cardiac EP suites as a particular research setting. I also described how I used the ethnographic techniques of observation and writing field notes. Embodied communication studies of technical work clarify that video research in idiosyncratic or otherwise technical environments is greatly benefited by the use of ethnographic data. To ensure a thoughtful, relevant, and high quality data collection trip I used methodological texts on video research to address analytically consequential decisions involved in video data collection. My next step was to analyze my collected data.

Data Analysis

As an inductive qualitative method, microethnography seeks to describe and explain its focal domain—the structures of social interaction—through a reliance on case-by-case analysis leading to generalizations across cases, but without allowing them to congeal into an aggregate. By moving not only from case to case, but also from moment to moment, microethnography as a practical endeavor “finds the foundations of social organization, culture, and interaction at the microlevel of the moment by moment development of human activities” (Streeck & Mehus, 2005, p. 238). To appreciate the moment by moment dynamics of human activities at a microlevel “humanist researchers study how human realities are produced, activities are conducted, and sense is made, by inspecting video recordings of actual events frame-by-frame” (Erickson, 1982; Streeck & Mehus, 2005, p. 382). Frame-by-frame analysis is an incredibly granular lens by which to appreciate social action. This granularity blurs out the broad contours of workplace politics and professional identities as they are stereotypically understood. Moving frame by frame instead, what is drawn into focus is the “sequential progression of interactional processes within which [human activities] take place” (Streeck & Mehus, 2005, p. 388; c.f., Hindmarsh et al., 2010, pp. 77–82).

Put another way, as a kind of research based in inductive reasoning, microethnographic video research demands that the analyst rely heavily on her recorded data and very little on pre-existing categories used in large-scale social analysis. Microethnographic scholars hold that the ability to enter into the analysis phase of research untainted by dominant categories, such as class and gender, greatly liberates the analyst to look at video of social interactions from a fresh perspective. The logic of this appreciation of social action on a granular timescale is native to the ethnomethodological system of understanding social order as Maynard and Clayman (2008, p. 174) describe:

> Adopting a thoroughly “bottom-up” approach, ethnomethodology seeks to recover social organization as an emergent achievement that results from the concerted efforts of societal members acting within local situations. Central to this achievement are the various methods that members use to produce and recognize courses of social activity and the circumstances in which they are embedded. The mundane intelligibility and accountability of social actions, situations, and structures is understood to be the outcome of these constitutive methods or procedures.

Within the circumstances of social interaction, the members involved, unlike researchers who study them, are accountable and attuned to the unfolding interaction because at each moment they need to form a response appropriate to the context in which they find themselves. Members therefore have a natural and physiologically tuned appreciation of the microdynamics of an unfolding interaction. Researchers must gain such an attitude toward these microdynamics by different means, namely close review of videos of social interactions frame by frame, moment by moment, and case by case to understand the social order within the social worlds they investigate. In order to train their attention to the sequential progression of interaction processes, microethnographers often carry out their analysis by producing conversation analytic transcripts of action.

In this way microethnographic analysis is an inquiry interested in *how* human actions are produced, from which questions of *what* and *why* those specific actions can then be understood. One limitation of microethnographic research is the understanding of these *how*-oriented questions. Another limitation associated with microethnographic video research is that the attendant departure from well-worn categories for social analysis leaves the analyst to generate her analysis from the recordings almost exclusively. Additionally, this form of analysis is limited by its focus on the fine-grained details of social interaction observed on the small scale. These limitations can be overcome if the analysis is well managed to ensure its feasibility and utility.

In what follows I detail the steps that I took to address a *how*-oriented research question through microethnographic analysis of video data collected of cardiac EP procedures, beginning with an operationalization of key phrases in my research question. In the remainder of this section I break down the overall progression of the steps of my analysis and then detail the specific actions I took to complete each step.

Operationalization of Key Phrases from My Research Question

I identified three phrases to operationalize in my research question prior to laying out the practical dilemma of understanding on-topic talk: “tactile phenomena,” “talk-in-interaction,” and “orient to.” Recall that the research question I seek to answer is, “How do workers in HTC (C-NC) *orient to* asymmetries in access to *tactile phenomena* through *talk-in-interaction*?” I chose this question because I knew from observations of twenty-nine cardiac EP procedures that tactile phenomena related to catheter operation was a highly significant, if not the most significant, source of asymmetric access in cardiac EP procedures as a kind of HTC (C-NC) work. The phrase “tactile phenomena” can be understood in this case to designate the productive activities of hands and a person’s manual operation of technologies as these technologies are situated within the built environments designed for HTC (C-NC). In the context of cardiac EP, the manual operation of computing and non-computing technologies indicates several regions of the operating room and several sources of tactile phenomena. These sources of tactile phenomena include: (a) catheter function (b) the catheter operator’s experience using the catheters, and (c) features of the patient’s cardiac anatomy as they are made accessible to the person operating the catheters. In practice, the person using the computer imaging workstation experienced a significant asymmetry in access to tactile phenomena because, unlike the person operating the catheters, he or she could not gain tactile perception of catheter function or the patient's cardiac anatomy.[4]

Next, my research question includes the phrase "talk-in-interaction," which designates the importance of talk and emphasizes the analysis of verbal communication in my study of technology-mediated communication. At the same time, this phrase also encompasses a diversity of interactional material including, but not limited to, the use of gesture, such as tool-tip deictics (pointing), and vocal performance qualities, such as prosody (i.e., the patterns and stresses in the tone of spoken language). Likewise, the phrase "talk-in-interaction" is typical in studies concerned with embodied communication because of its ability to cover any range of communication resources (Broth, 2008; C. Goodwin, 1994; Harrison & Williams, 1994; Heath & Luff, 2000b; Streeck, 2010).

Lastly, my research question includes the use of the phrase "orient to." This phrase designates a broad class of attentional shifts to a phenomena as evidenced in a gesture, utterance, or some other embodied action that references tactile phenomena. This phrase is typical in studies of "talk-in-interaction" as it has been flexibly applied in the literature concerned with embodied communication (C. Goodwin, 2003; Harrison & Williams, 1994; Heath & Luff, 2000a; International Institute for Ethomethodology and Conversation Analysis, 1995; Maynard, 2012).

The phrases "orient to" and "talk-in-interaction" allowed me to encompass the myriad ways that participants react to tactile phenomena during an ongoing interaction. In combination, these phrases enhanced the utility of my analysis in two related ways. First, I was able to build a larger corpus of instances in which participants oriented to one

[4] Admittedly, I could not in advance rule out the relevance of tactile phenomena related to the operation of the computer imaging station. The remarkably unproblematic operation of the computer inputs of keyboard and mouse make this kind of "orienting-to" tactile phenomena of talk less likely and, as a consequence, I found almost no examples in which the participants oriented to their asymmetric access to computer.

another's relative access to tactile phenomena in a diversity of ways with their entire body (e.g., noticing, reporting, exclaiming, puzzling, questioning, and giving a retort). Second, and relatedly, I was able to employ analysis strategies typically reserved for conversation analytic studies of language use. In short, the wording of my research question and my efforts to operationalize the key phrases within that question ultimately left me an opening for other interactional material that enabled me to adjust my analysis to the modalities used by the participants. The analysis strategy of aggregating a collection of examples of certain social actions could only be employed with a sufficiently large corpus of orientations to tactile phenomena. As a consequence of the enhanced utility of my analysis, I enjoyed a better chance to identify patterns within the collections I assembled, which could ultimately contribute to the existing scholarship on communication in circumstances of asymmetries in access to perceptual phenomena. In what follows I provide an overview of the six major steps I took in my data analysis.

Overview of Six Major Analysis Steps

As a practical endeavor I used microethnographic analysis (Erickson, 1982; Harrison & Williams, 1994; Heath & Luff, 2000a; Streeck, 2010; Streeck & Mehus, 2005) in combination with the conversation analytic technique of transcription (Schegloff, 2007). I based my decision to employ conversation analytic transcriptions in combination with microanalysis on a diversity of studies in technologically rich environments (Broth, 2008; Heath & Luff, 2000b; Suchman, 1997) in which participants had significant obligations to manage conversation during intensive visual tasks (C. Goodwin, 1994; Harrison & Williams, 1994). To support these primary approaches I also referred to field notes from earlier data collection trips, performed descriptive coding, and used intermediary transcription to speed up my analysis process.

More precisely, I carried out my analysis by first preparing the raw recordings for initial review. First, I used ELAN, a non-commercial software program produced at the Max Planck Institute for Psycholinguistics (MPI) (MPI for Psycholinguistics, 2016; Wittenburg, Brugman, Russel, Klassmann, & Sloetjes, 2006).[5] This preparation involved making a video analysis file for each of the five procedures in my data set. Second, I reviewed the cardiac EP procedure and, based on that initial pass through data, I developed an initial separation of on- and off-topic talk. Third, I created intermediary transcripts of each procedure, only including the talk and action relevant to addressing my research question. Fourth, I began to identify meaningful conversation structures in the participants' talk in which they "oriented-to" the tactile phenomena, such as sequences and turns at talk. I accordingly created conversation analytic transcripts of specific excerpts from each procedure. I also indexed each "orient-to" excerpt in both the ELAN analysis file and an external spreadsheet. Fifth, I repeatedly reviewed each excerpt in the ELAN analysis file, annotated the conversation analytic transcript of each excerpt, and recorded notes in the external spreadsheet. Sixth, I conducted prosodic analyses of subsets of the "orient-to" excerpts using Praat, another non-commercial software (Boersma, 2002), and developed collections based on the annotations in the ELAN analysis file, the conversation analytic transcripts, and notes recorded in the external spreadsheet. In what follows I outline the actions involved in each of these steps of my analysis. In addition to these six steps, and in the process of completing steps three and four for each of the five procedures, I also presented preliminary transcripts at data

[5] ELAN is a multimedia tool that allows for video playback at different frame rates. The ELAN program enables the analyst to embed her transcription and annotation into a markup language that indexes the timecode in the video. ELAN enables video review and playback as part of the transcription activity. The program also enables the production of still images. Still images and clarifying graphics can be useful at later stages of analysis when accompanied with printed transcriptions.

sessions. Accordingly, I include a short description of the role of presentations to the university's data session group at the close of this chapter.

Step One. Preparing ELAN Analysis Files

The first step in my analysis was to prepare the video and audio recordings for closer review by creating an analysis file for each procedure using the software ELAN. This non-commercial software is designed for multimedia analysis of language use. ELAN is a preferred program for linguists who develop tiered analyses of language structure as the program creates a multi-tiered hierarchy of annotations linked to time codes in video and audio files. Originally devised for linguistic analysis, a "tier" is a highly configurable annotation layer in the ELAN file that allows for time synchronized description of observable conduct and its interpretation. The flexibility of ELAN made it an excellent tool for analyzing the cardiac EP procedures throughout the many stages of my analysis.

Figure 4 (next full page) shows a screenshot from the ELAN language analysis software program. ELAN enables synchronized playback of up to four multi-media recordings using the media controls located below the video playback windows in the upper left quadrant of the image. As shown in the image, up to three video windows can be played at once. Below the media controls, an irregular black band spans the horizontal length of the image. This band is a graphic display of an audio recording sound wave. The audio file along with the three videos is synchronized for playback. On the bottom, towards the far left, the multiple tiers of annotations are set up, including separate tiers for transcribing interaction. The top and bottom tiers listed indicate on-topic "orient-to" talk ("Excerpts") and off topic talk ("Off Topic Talk"). Between these tiers there are tiers for each of the three key team members (the cardiology fellow "FEL," the cardiac EP nurse “EPN,” the attending physician “ATT”) and tiers for supporting roles of circulating nurse(s) “CIR” and anesthesiology team member(s) “ANS.”

I carried out the following steps to prepare my video and audio data for analysis of each procedure using ELAN. First, I imported the video and audio recordings for each procedure. In total that consisted of four files per procedure, one “.mp4” file for each camera recording and one “.wav” file for the audio recording. Second, I synchronized the video and audio files using visual and auditory cues. Third, I set up a tier for the transcription of each participant's talk and action. Tier setup entailed establishing one tier each for the attending physician (ATT), the cardiac EP nurse (EPN), and the cardiology fellow (FEL). I also set up one tier for each auxiliary team roles: the circulating nurse(s) (CIR) and anesthesiologist as well as an anesthesiology technician (ANS). In addition to these participant tiers, I also set up a tier for off topic talk and one tier for the identification of “orient-to” excerpts to be used in the next step of my analysis.

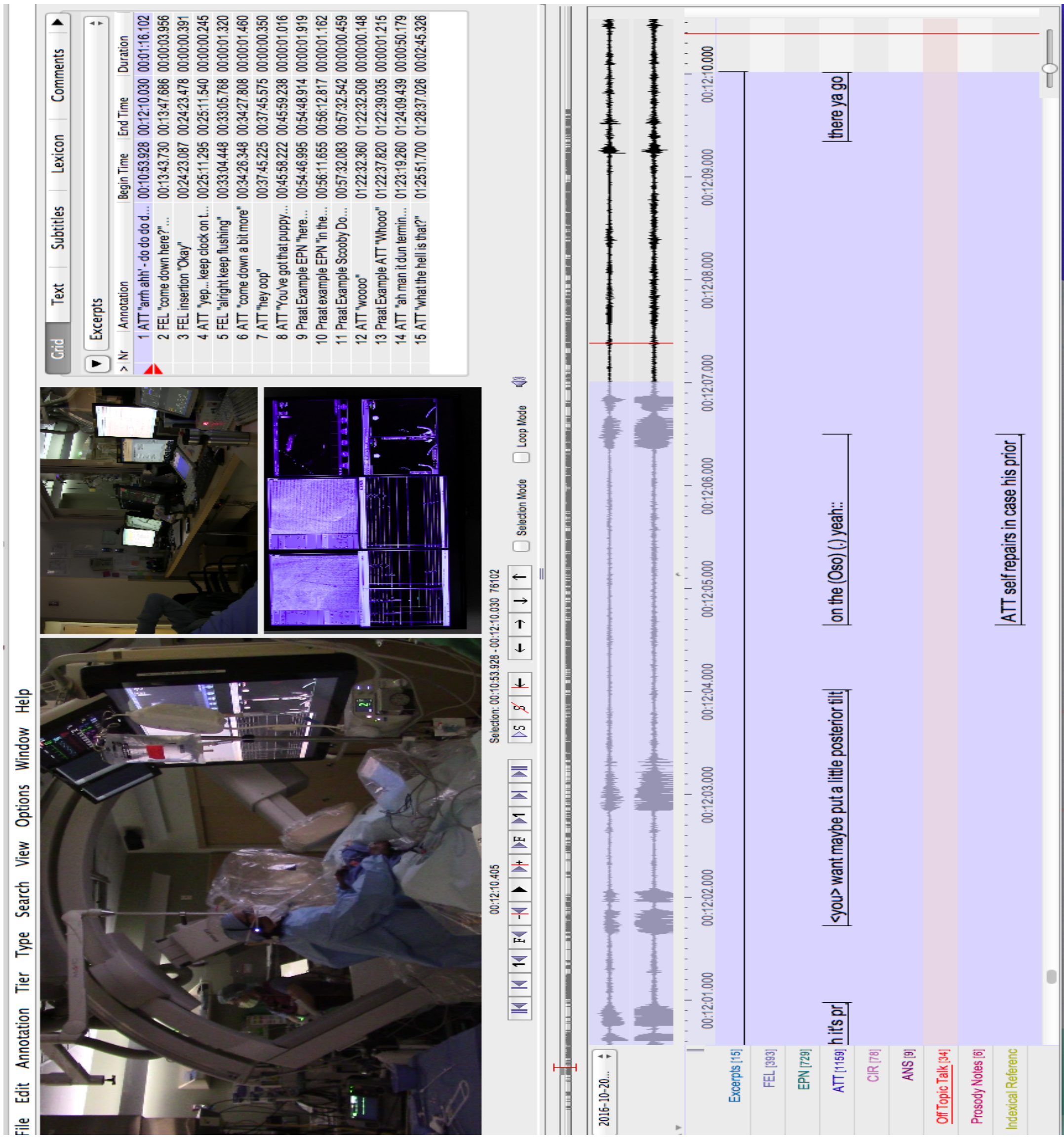

Figure 4: The ELAN Program Interface

Step Two. Identifying Excerpts of Orienting-To

In the second step of my data analysis I identified excerpts of "orienting-to." To begin, I want to reiterate what the phrase "orient-to" describes. In the first place, "orient-to" refers to those excerpts of the recorded interactions in which one or multiple core team members (e.g, the attending physician, cardiac EP nurse, and cardiology fellow) shifted their attention and conversation to the topics of the focal interest for my dissertation, namely tactile phenomena to which these parties had asymmetric access (i.e., on-topic talk). It is also important to appreciate that all other topics outside of those I describe as "orient-to" are deemed off topic and outside of the purview of the subsequent analysis steps listed in the remainder of this chapter. Throughout the rest of this section, I describe how I distinguished on- and off-topic talk.

To identify excerpts of "orienting-to" in my recordings, I watched and listened to the synchronized video and audio files to first identify clearly off-topic talk. In order to make the identification of off-topic talk systematic, I used the operationalization of key phrases of my research question. The identification of off-topic talk was crucial to my analysis as I would later scrutinize the remainder of talk and action represented in the procedure recording for instances of "orienting-to" tactile phenomena. Put differently, working backwards, I identified possible spates of talk that would then be the focus of my remaining analysis. When going through this identification process, I ran into a practical dilemma in distinguishing on-topic from off-topic talk.

The dilemma related to a central issue, namely the identification of the multitude of ways in which the members of the core team (the attending physician, cardiac EP nurse, and cardiology fellow) "oriented-to" their asymmetric access to tactile phenomena in the course of a cardiac EP procedure. This dilemma in identification arose out of the combination of three factors: (1) the intermingled topicality of the team members' interaction, (2) the frequency of long silences and periods of active waiting and observation, and (3) the limited specificity of the team's indexical references.

In regards to the first factor, there are many practicalities in a cardiac EP procedure, beyond the issue of catheter manipulation that the team needs to handle as they arise in the course of the procedure. My review of the cardiac EP procedures showed that visual scrutiny of electrocardiograms was one of the most pressing, common, and unpredictable practical demands on the team's attention and conversation. I considered the demands of scrutinizing electrocardiograms and the conversations they produced to be off-topic talk according to my operationalized research question. My review of the cardiac EP procedures, as well as my previous fieldwork, showed that the activities of visual inspection of electrocardiograms and adjustments to catheter placement were deeply interrelated. As a consequence, team members regularly drifted into and out of off-topic talk in ways that made defining the boundaries of conversations difficult.

In regards to the second factor, as I just described, the team frequently visually scrutinized electrocardiograms for patterns. Consequently, the team spent significant periods of time waiting in silence as they watched for changes in a supposed pattern or waited for a pattern to emerge. The periods of waiting affected the way team members organized their talk. In fact, I rarely found uninterrupted verbal exchanges in my data set. In addition, as opposed to everyday casual conversation in which long periods of silences would be treated by most people as accountable action (and possibly rude), what was common in my review of cardiac EP procedures was that extended talk was rare and extended silences common. The unusual status of silences complicated the identification of boundaries in conversations about on-topic talk.

In regards to the third factor, the work of the team was highly coordinated and their talk was highly indexical. The group appeared to intimately appreciate the context of what was occurring and did not need to explicitly specify what they were referring to when scrutinizing electrocardiograms or describing catheter manipulation. As a consequence of this third factor, there were few explicit verbal cues as to the reference of an utterance. Instead, as the researcher, I relied on contextual cues to decipher indexical references - just like the participants themselves. Relying on contextual cues required me to make some deductive decisions when understanding what the team was talking about and when the topic of their talk had shifted. Once I addressed the practical dilemma of identifying on- and off-topic talk, I directed my analysis to a useful subset of on-topic talk and then moved to the next step of my analysis, which involved creating intermediary transcripts of spates of talk that potentially counted as "orientations-to" tactile phenomena.

Step Three. Intermediary Orthographic Transcription

Based on my first review of the data, I gained an initial (if imperfect) sense of which parts of the recordings deal with off-topic topics. As a next step in my analysis, I adapted analysis techniques from video-based research in the learning sciences (Barron, 2007; Bruner, 2009; Engle, Conant, & Greeno, 2007; Erickson, 1982) to create intermediary transcripts of talk relevant to my research question. Intermediary transcription is a process by which the researcher loosely reports the general topicality of the conversation (Barron, 2007, pp. 174–175) and carries a lighter burden than conversation analytic transcription. The intermediary transcription can function as a starting place for conversation analytic transcription.

When producing intermediary transcripts I used an orthographic style of transcription in which I represented language use in standard spelling and punctuation of a target language (Enfield, 2007). Because I collected all my data in the United States and all the talk was carried out by English speakers, I treated English as my target language. Importantly, orthographic transcription does not include details of speech performance such as peculiar pronunciation, or pauses or delays in speech production. As a general rule, orthographic transcripts do not include glosses of body action because this transcription style is used to analyze talk and not physical actions or gestures.

Preparing these intermediary transcripts gave me the additional opportunity to further clarify which moments in the team's interaction truly pertained to my stated research question. Naturally, many topics and issues arose during cardiac EP procedures. Sometimes during a spate of talk in which the team were primarily orienting to tactile phenomena central to my research interest, they momentarily shifted to an off-topic subject. As a consequence, I needed to be thoughtful when including or excluding a momentary diversion in topic of talk when preparing my orthographic transcripts. When I prepared orthographic transcripts I generally included instances when the attending physician's, cardiac EP nurse's, and cardiology fellow's talk strayed into off-topic issues. To enable closer scrutiny during the next step of analysis, i.e., conversation analytic transcription, I noted any exclusions of off-topic talk in the transcript. Intermediary transcripts serve as anchor points in microethnographic analysis, but they are just an initial step. A successful microethnographic analysis of video data is narrowing, meaning that the analyst moves from the generalities of her data present in intermediary transcripts to appreciating the particulars of social interaction. In what follows, I detail a narrowing scope of analysis and, with it, the production of conversation analytic transcriptions.

Step Four. Conversation Analytic Transcription of Orienting-To

As I have stated, when creating conversation analytic transcripts I found it particularly crucial to correctly identify boundaries of on-topic and off-topic talk as these boundaries could be blurred or rendered unclear through multiple simultaneous activities represented in the recordings of cardiac EP procedures. Once I completed the intermediary transcripts of each procedure, I then reviewed them while rewatching the procedure videos to correctly identify excerpts "orienting-to" catheter work. Because the intermediary transcripts documented the whole procedure from start to finish, I next identified the boundaries of on-topic talk found within them. These excerpts were often less than a minute in duration and never longer than three minutes. I then converted these excerpts into conversation analytic transcripts.

A few major concepts undergirding the conversation analytic perspective on action and the organization of talk-in-interaction warrant mention, including action, sequence, and sequential interaction. "Action" refers to both speech and physical actions carried out with objects and technologies at hand; "sequences" consist of actions that project or implicate a relevant next action or one of a range of actions. Thus, "sequential organization" deals with the concept that participants act (or design their actions) with regard to, and occasioned by, prior actions (Schegloff, 2007). Through close analysis and repeated viewing, the analyst can identify the boundaries of sequences in that these sequences serve as an organizational resource for the participants themselves (Schegloff, 2006). The intelligibility and significance of an action for the participants themselves are at least partly achieved by virtue of the action's position within the developing course of action, in that the sequential character of talk is both context sensitive and context renewing (Atkinson & Heritage, 1984). The "ever forward progression of social interaction," also called enchony, dictates that sequences of action have a meaningful chronological order (Enfield, 2011, p. 59; Schegloff, 2007). The co-participant produces a subsequent action in juxtaposition with a prior action. Put another way, the first action implicates a subsequent action and that subsequent action can be, and is treated as, responsive to the first. What is also important to appreciate is that the actions are relevant for the participants themselves. If there was a trouble spot in their interaction, the participants would attempt to repair it. Sequential organization is the vehicle through which participants produce and make sense of each other's actions and activities. Sequential organization enables the routine and ordinary character of everyday activities and events to be accomplished by participants themselves in concert and in collaboration with one another.

In addition to revealing the structure of everyday talk-in-interaction, I use multiple formatting conventions adopted from conversation analytic transcription. Chief among the formatting conventions is the use of line numbering. Much like an annotated figure or a diagram in an ethnographic report, the line numbers in a conversation analytic transcript enable the researcher to later reference precise moments in an interaction through her prose. The other formatting conventions are employed so the researcher can better represent talk-in-interaction on paper as it actually unfolded on her video. For instance, I adopted formatting conventions to show the organization of a conversation into turns at talk, marking overlapping talk, using non-standard spelling to reproduce peculiar pronunciation, the transcription of laughter and out breaths, the transcription of pointing and other kinds of gestures, and measurement and demarcation of silences and pauses.

Importantly, conversation analytic transcripts used in microethnography also include transcription of body movement and action (Hepburn & Bolden, 2012). While all manner of body movement is potentially relevant to the meaning of an interaction, in my analysis I paid particular attention to hands and eyes as these two sensory organs are crucial for the practical operation of computing and non-computing technologies. Specifically, I noted unusual changes in each participant's use of hands and eyes within the intermediary transcription process, but smaller changes or movements of the hands and eyes (such as gaze shifts) were left to the conversation analytic transcription process and only as needed. For clarity, a change in the use of hands and eyes would constitute either participants looking away from their displays for more than a few minutes, or removing their hands from the proximate area of their controls. Controls in this context refer to either the catheter handles or the computing keyboard and mouse. There were not any specific differences in the ways I transcribed changes in the team members' use of their hands and eyes. With the transcription of both hand and eye movement, I looked for patterns of action and ways that body movements inform talk, precede talk, or supersede on-topic talk.

After completing a conversation analytic transcript of an excerpt of talk, I named or marked the excerpt in three places. First, I named the excerpt containing the conversation analytic transcript using the first (or most memorable) utterance. Examples of excerpt titles included "alright now I'm comin down," "let's scoot back," and "I think it's just whoop." Second, I marked the excerpt in the ELAN analysis file for easy playback. Third, I entered the transcript title, the procedure date and number, and the starting time code into an external spreadsheet. In the next step of my analysis, I used this external spreadsheet as an index of excerpts that facilitated my repeated review and my annotation of excerpts of "orienting-to."

As a whole, transcribing in a conversation analytic mode further refined my familiarity with the particulars of the team's handling of each recorded procedure. In particular, by transcribing in a conversation analytic paradigm I discovered a few ways in which team members "oriented to" germane tactile phenomena such as catheter function and cardiac anatomy. At times a team member who was manually engaged in catheter manipulation would provide a verbal report about his or her tactile perception of the catheter or the patient's cardiac anatomy. At other times a team member who was not operating the catheters would direct the catheter operator's actions, or would request an update on the catheter operator's activities and impressions of this aspect of the procedure. Through conversation analytic transcription I began to suspect that prosody might be one important way that teams oriented to their asymmetric access to tactile phenomena, an idea that gained strength in my repeated review and annotation of excerpts.

Step Five. Repeated Review and Annotation of Excerpts

At this point in a microethnographic analysis the basic mechanics of video analysis activities become simple and perhaps seemingly unsophisticated. Put plainly, high quality microethnographic analysis is achieved through repeated viewing that, over time, helps the analyst make insightful observations about interaction on the small scale (Atkinson & Heritage, 1984, p. 4). Through this repeated viewing, important features of the data stand in greater contrast to an ever more familiar ground (Atkinson & Heritage, 1984, p. 4). Yet, curiously, repeated viewing makes an excerpt familiar, an effect that is essentially and beneficially estranging (Hindmarsh et al., 2010, pp. 62–66). Repeated viewing of a clip enables the analyst to become familiar with many, although not all, of the features in her data. Upon additional review the analyst becomes able to focus on more and more subtle and important features of action and can provide a structured examination of how those features shape the much broader and easy-to-notice contours of an interaction.

Proceeding from one excerpt to the next, the activity of reviewing and re-reviewing the excerpts enabled me to identify a narrowing set of possible themes. With a refined sense of the interaction represented in an excerpt, I then annotated or otherwise refined the existing conversation analytic transcript in a way that better represented the phenomena captured in the recording. With still more review and re-review, my understanding and evaluation of themes within the set became more detailed and critical.

Accordingly, my annotation and pre-writing about these themes became more detailed and critical, which helped me decide what the final step of my analysis would be.

Via the iterative process of reviewing and annotating excerpts, I was further persuaded that prosody was an important feature in the way the members of the core team "oriented-to" tactile phenomena. With this concept in mind, I re-reviewed my excerpts and annotated all conversation analytic transcripts for those prosodic features. Then, to aid with later needs to reference these moments in the excerpts, I also listed the line numbers in my external spreadsheet of all excerpts of "orienting-to" so as to proceed with the last step of my analysis.

Step Six. Prosodic Analysis and Collection Building

In the last step of my analysis I used the external spreadsheets and annotated transcripts to identify fragments of talk in the ELAN analysis files. I started to assemble collections of interesting excerpts very early in my analysis and continued to do so in an incremental fashion throughout the course of it. Ultimately building collections of excerpts, I began to explore the significance of interesting features of prosody in the team's communication when "orienting-to."

Elsewhere I have described prosody as patterns and stresses in the tone of spoken language. This description of prosody is helpful, but lacks some specificity needed to understand how I carried out the prosodic analysis. Gumperz (1982, p. 100) notes that, as a topic of study, prosody includes:

> (a) intonation, i.e., pitch levels on individual syllables and their combination into contours; (b) changes in loudness; (c) stress, a perceptual feature generally comprising variations in pitch, loudness, and duration; (d) other variations in vowel length; (e) including utterance chunking by pausing, accelerations and decelerations within and across utterance chunks; and (f) overall shifts in speech register.

Such prosodic cues hold semantic signaling value that "carry some of the weight of selecting among a variety of possible interpretations by directing the listener among shares of meaning inherent in the semantic range of the words used" (Gumperz, 1982, p. 104). Furthermore, prosodic cues carry semantic signaling values that also "tie[s] these key semantic features together into a theme, and mark out a developing line of argument" (Gumperz, 1982, p. 104). Put simply, the prosodic qualities of talk color the meaning of the lexical content conveyed. Research into prosody in natural conversation indicates that people interpret prosodic cues in real time (Binns, 2007). People have the capacity to interpret meaning at multiple levels at once. As Gumperz (1982, p. 101) writes: "In conversations, we must continually make judgments at simultaneous levels of meaning, through an inferential process which both interprets what has been said and generates expectations about what is to come. The process is always situated or context bound."

With an appreciation of the fundamentals of prosodic cues I located relevant excerpts in ELAN and then exported audio clips to import to Praat for prosodic analysis (Boersma, 2002).[6] I used Praat to do prosodic analysis in a combination of ways, including looking at pitch contours, loudness, and duration of sounds produced in the excerpt. Figure 5 shows a graphic produced with the aid of the Praat software. The figure shows a change in the pitch contours when producing the words in an everyday phrase "go and buy one cheaper but." As shown in the figure, on the top the phrase is shown in chunks with tick marks indicating the end of each word. In the middle is a graphic representation of the pitch contours of each word. At the bottom is a representation of the volume and the timing to produce each word as measured in seconds.

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[6] Praat is a speech analysis software that allows for the analysis, measurement, and creation of graphical representations of prosodic contours. The Praat program enables the analyst to import files from ELAN for analysis. As part of Praat's functionalities the software program allows for audio playback.

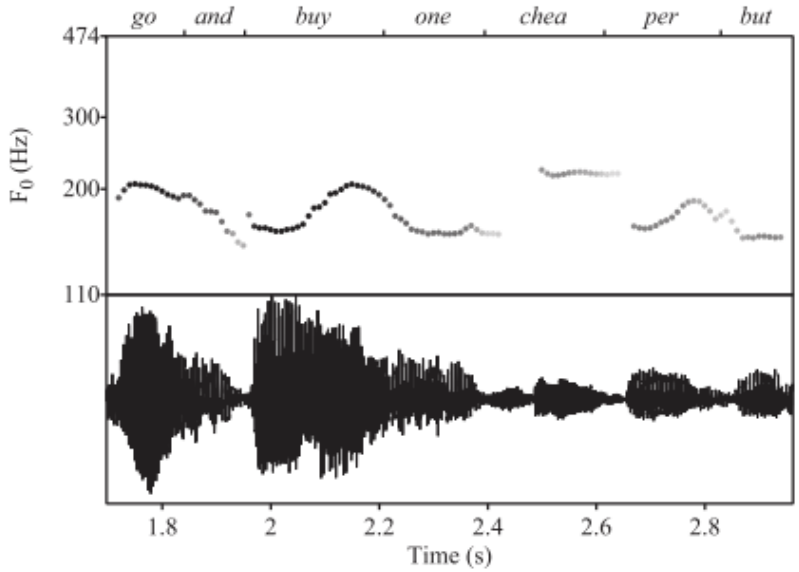

Figure 5: Example of Analysis of a Prosodic Cue

I based the exact prosodic analysis that I performed on each excerpt on unique qualities of the excerpt. Some excerpts offered great examples of vocal stress on words or other utterances. An example of vocal stress occurred when the cardiology fellow was audibly occupied with catheter manipulation while producing a response to the attending physician who was directing the fellow's manipulation. Other excerpts were unique in the ways that the duration of sounds changed with the pronunciation of a word. An example of duration occurred when the cardiac EP nurse specified precisely when to stop a catheter manipulation by saying "keep going, keep going, there." When producing and then repeating the words "keep going" the cardiac EP nurse said these words more slowly, so that when he finally said "there" at the end, his return to a regular speech rate was noticeable, and emphasized to the fellow carrying out this instruction just when to stop. Sometimes excerpts with variations in pitch and duration also included an increase and decrease in the loudness with which some words were produced.

Using the examples from my prosodic analysis I then turned to build collections of the shared prosodic qualities in these sounds used to produce each excerpt. The nature of the sounds used to produce words was helpful in that it elaborated a fuller expression of what the word or phrase meant to the ensuing interaction. Sometimes, the team members produced sounds that were not words at all, but the prosodic qualities of these sounds again lent meaning to the interactions unfolding across these excerpts.

To guide this last stage and last step in my analysis, I adapted techniques from conversation analytic studies for collection building (Sidnell, 2012). Using these adapted techniques I identified a core set of excerpts that provide examples of an interesting feature. I was most interested in the prosodic features in which participants "oriented-to" tactile phenomena. In the next chapter I will identify a variety of ways that participants "oriented-to" tactile phenomena. For now, I will note that the germ of collection building began with the selection of a core set of excerpts to compare with an exploratory analytic purpose (Hindmarsh et al., 2010). Through the analysis of the core set of excerpts and the refinement of conversation analytic transcription of those excerpts, I built out a collection that explored small variations in the examples each excerpt embodied. Ultimately, through this exploration of small variations, I identified social practices carried out using prosody. The process of collection building continued until there were several video collections purpose-built for the exploration of distinct phenomena. With a collection of examples, I began writing my analysis and answering my research question.

Data Session Presentations

The findings I developed through the data analysis steps described above greatly benefitted from subjecting my emerging analysis to the scrutiny of like-minded scholars. Doing so is an accepted and normative practice in microethnography called "data sessions" (Hindmarsh et al., 2010, pp. 156–157; Lebaron, 1998). Data sessions can take two forms, formal and informal, and are differentiated by the finality of the analysis presented. Informal presentations begin with sharing and watching video recordings as a group to then discuss directions for further annotation, transcription, or comparison with other example clips. Formal presentations are much different and tend to be run more as a screening of transcribed and annotated video segments (Lebaron, 1998, p. 11), followed by a prepared talk that outlines the finalized analysis, and an open discussion of comments and criticisms that inform revisions to that analysis. For the purposes of my dissertation data analysis, I presented at three data sessions during Fall 2016 using an informal format at the beginning stages of my analysis.

This chapter presented a description of my research setting, which brought to life the small particulars of cardiac EP procedures as a kind of HTC (C-NC) work. I described the video data collection methods I used to capture the moment-by-moment details of cooperation among key members of the cardiac EP team. I then laid out the microanalytic analysis I carried out with these recordings. In the next chapter I describe the findings from my investigation.

Findings

INTRODUTION

Studies of work and technology have missed opportunities to investigate cooperative work accomplished with a combination of computing and non-computing technologies. Based on my literature review, I posed the research question: how do workers in HTC (C-NC) orient to asymmetries in access to tactile phenomena? I chose to focus on asymmetries in access to tactile phenomena because it is the most significant limitation in HTC (C-NC) work. In the literature review, I demonstrated that asymmetries in access imperil coordination efforts and complicate workers' abilities to coordinate and maintain awareness. Yet, in order to accomplish a shared goal, workers must achieve coordination and maintain awareness. My investigation into the work of cardiac EP suggests that what is true of CSCW in general is especially true of work in HTC (C-NC), precisely because of the significant asymmetries in access that workers under this configuration face.

Through a microethnographic analysis of talk-in-interaction in cardiac EP, I uncovered two practices that the team members used to overcome asymmetric access to tactile phenomena in a manner that allows them to coordinate directed adjustments to catheter position and foster awareness of tactile qualities of catheter manipulation. The first practice served as a mechanism for coordinating the direction of catheter work and other fine-grained manual maneuvers. The second practice aided the team's awareness of catheter work in the context of each procedure as that context dynamically shifted. Both practices demonstrate prosodic features of the team's talk-in-interaction. I begin by presenting each practice in distinct excerpts, which I preface by noting the asymmetries in access that shaped coordination (for the first practice) and awareness (for the second one). Embedded in my discussion of each instance of each work practice I include references to three auxiliary audio files, labelled with a number and letter (e.g., 1-A). These auxiliary audio files contain excerpts of salient uses of prosodic cues. I then discuss how these practices tended to coincide.[7] In the close of the chapter I revisit my research question and discuss how prosody met and neutralized each of the factors that contributed to the team's asymmetric access to catheter behavior.

ASYMMETRIES IN ACCESS THAT SHAPED COORDINATION IN HTC (C-NC)

Cooperative work involving a combination of technologies requires coordination, but in practice asymmetries in access can shape the ways that team members coordinate. I found this to be the case when examining the asymmetries in access present in cardiac EP as team members coordinated the execution of catheter work. When working from the control room, team members could neither touch the patient nor feel the catheter behavior, in part because this non-computing technology was designed for a single operator. They could only see evidence of the patient's condition, cardiac anatomy, and catheter function by using the board. Beyond these cues, the team members who worked in the control room depended on communication with the catheter operator in the procedure room through the use of mic'd headsets. Information about the catheter function and cardiac anatomy as particular classes of tactile phenomena were crucial to the work of the team members in the control room. Thus, the team members in both rooms had to collaborate to offset the asymmetries in order to make any meaningful progress in the procedure. Collaboration was paramount in cardiac EP procedures because the working division of labor in cardiac EP procedures dictated that the direction and execution of catheter manipulations were separate responsibilities, carried out by two

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7 I used transcription conventions to represent the rich subtlety of talk and other conduct. When presenting each excerpt, I include a document of the action represented in a conversation analytic transcription style (Jefferson, 2004). I use standard conventions to mark speakership (i.e., using three letter abbreviations) for each speaker indicated by their role. An appendix outlines the transcription conventions in full.

team members. Often one team member operated the catheters from the procedure room, while directions on catheter manipulation came from one or more team members in the control room.

When providing directions on catheter manipulation or navigation, the team members working from the control room made creative use of their somewhat limited access to the catheter operator. Though they lacked the ability to communicate with the catheter operator face to face, those working in the control room could use a shared set of anatomical references, such as coronary sinus, to direct catheter navigation. In addition, those in the control room also enjoyed the ability to indicate areas in the 3D map of the patient's heart by pointing to, rotating, or zooming the graphic display on the boom and board, accomplishing on the computer screen what the catheter operator could not do physically with the patient, and in this manner augmenting information that was available to everyone.

Beyond the verbal instructions themselves, the way that team members in the control room communicated those verbal instructions enabled the team to achieve coordination via a shared understanding of desired adjustments to catheter position, often expressed as adjustments by degrees. For example, when instructing the movement of a esophageal probe the team member providing the instruction raised the pitch of his voice and elongated the pronunciation of the word "little" highlighting that only a slight adjustment was needed. In what follows, I describe a practice that helped the team members in cardiac EP overcome their asymmetric access to tactile phenomena and coordinate the execution of catheter work.

PRACTICE ONE: PROSODIC CUES CONVEY QUALITIES AND AMOUNTS BY DEGREES

In my analysis I uncovered a practice by which team members (particularly those instructing catheter work from the control room) prompted adjustments to catheter work using prosodic cues. Using this practice enabled the catheter operator to understand other team members' satisfaction or dissatisfaction with catheter position, how close or far the operator was from an adequate position, and how much or how little change was needed among other things. In practice, these prosodic cues served as a mechanism for coordinating the manual tasks, but the cooperation of the catheter operator ultimately achieved the coordination. The catheter operator's actions often served as the primary signal of understanding to the team member providing instruction, and from there an exchange of instructions and signals of understanding could ensue.

During verbal exchanges about catheter work, the team member giving the directions needed to instruct that an action done "just so" because the catheters were very small and each patient's cardiac anatomy was unique. As a consequence, catheter work entailed making specific manipulations within slim margins of error. Team members directing catheter operation needed to request fine-grained adjustments to the catheter position or the techniques used to manipulate the catheter. Specifically, my analysis shows that the prosodic qualities of the instructions regarding catheter work provided fine-grained shades of meaning about the quality or amount of directed action. For instance, a rise in pitch, an increase in pace, or heightened volume added special meaning to an instruction. Words like "little," "more," "higher," "there," and "now" all provided a degree of specificity, but were greatly enhanced when the production of those words or the sounds accompanying those words provided extra information that made the directions more specific and helped the person carrying out these directions execute them precisely.

The ways in which instructions were produced could indicate multiple qualities including the timing, direction, or amount of an instructed instrument manipulation to be produced in response. For instance a raising pitch producing the word “whoop!” was a useful way to indicate a direction for action, which could be mapped to the timing, direction, or degree of catheter movement. In short, the relationship between instructed action and its execution was deeply cooperative. Just as the catheter operator was able to in the same movement advance as well as turn the catheter, the person instructing catheter manipulation could use the sounds produced as a multi-dimensional cue.

The team member providing instructions could observe the catheter operator’s synchronized execution of the given instruction, allowing for constant and real-time adjustment. As soon as the catheter operator executed an adequate action, the team members in the control room could signal him to “stop there!” Because the instructions and the work were both multi-dimensional, the instruction was an input that the worker could map to a spacio-temporal output. For example, when characterizing the thickness of a piece of cardiac anatomy the word “thick” and the percussive production of its first syllable both signify the word’s meaning. The timing of the pronunciation of the word indexed a location of the catheter on the tissue of interest. Together the team could execute a “just so” action. In sum, a rise in pitch or an increase in pace or volume in the instructions given could add more coordinative synchronicity to the collaborative endeavor. In the remainder of this section I present two excerpts that demonstrate with rich detail the use of prosodic cues in coordination to overcome asymmetries in access.

Excerpt “Pretty good right there”

The excerpt titled “Pretty good right there” provides an example of prosodic cues that convey qualities or amounts by degrees. The example included in this excerpt counts as the exception that proves the rule, by which I mean that the team members involved in the exchange took the speaker's prosodic cues to indicate a desired adjustment to catheter position conveyed by degrees, and it was up to the speaker to initiate a self-repair so as to avoid that interpretation of that statement. Conversation analytic methods (Schegloff, 1996) commonly rely on exceptions as tacit demonstration of a social practice's intelligibility. I adopted a similar approach in this chapter to demonstrate the practice for coordination and the practice for awareness.

This excerpt reports an exchange that occurred between the cardiac EP nurse (EPN) "Hayes" working in the control room and the attending physician (ATT) "Stan" who operated the catheters in the procedure room. There were no other substantial contributions by other team members, but at one point a circulating nurse clarified an instruction to administer a dose of medicine.

In line 1 the cardiac EP nurse gave the attending physician a positive assessment of the current catheter position. In stating "pretty good right (.) there" the cardiac EP nurse timed the completion of his assessment. Indicated with a parenthetical mark, the pause in the cardiac EP nurse's expression aligned with a final tweak to the catheter position made by the attending physician. The cardiac EP nurse's production of the term "there" indexically referenced the time and position of the catheter with the attending physician's execution of the catheter's movement. Taking several moments' pause, the attending physician then interjected his own assessment in line 3, mimicking the pause between the production of the assessment words this time with an explicit reference to a region of cardiac anatomy. Then the cardiac EP nurse joined the physician in his new assessment of the adequacy of the catheter position (line 5). From this point the attending physician directed an order to the circulating nurse to start a burn (lines 7 and 8) and the circulating nurse then requested (lines 10 and 12) and received (line 16) missing information needed to carry out the attending physician's order.

Transcript "Pretty good right there"

EPN pretty good right (.) there:
(3.7)
ATT >close enough< (.) anterior do you like,
(1.3)
EPN I think so
(1.1)
ATT uh increase by one hundred
>ah go on here please<
(0.5)
CIR three one five
(0.8)
three one five
(0.9)
EPN ((coughs))
(2.9)
ATT one hundred more
(21.2)
EPN and I THink if you just cl::::::ock [your catheter]
ATT [that's my plan]
EPN about an eighth of an turn that should move it
(0.5)
clock doesn't sound like it should work but I
think £ that's what it does £ =
ATT =yeah I think that's right
(0.6)
I am doing it
(0.7)
now
(1.4)
(up)
(1.9)
EPN uh whatever that's good
(1.2)
ATT ahhh that's counter
EPN .Hhh huh
(1.0)
must be more straight than umm
(0.7)
ATT previously recorded
(0.5)
EPN don't know

42		(0.9)
43		reverse curve
44		(9.4)
45	ATT	°°now how am I going to make this (real/move)°°
46		(11.1)
47		that like came from the appendage? Or_
48		(0.6)
49	EPN	I think you're good
50	ATT	(now its all good)
51		(1.9)
52		all right
53		(0.4)
54		(that shows red)
55		(5.2)
56	EPN	probe might have been too low when you
57		actually put it in::
58		(2.3)
59	EPN	yeah
60		(0.4)
61	ATT	there we go
62		(16.6)
63		°°umph°°
64		(3.7)
65		ahh where is that
66		°°umm°°
67		(0.8)
68	EPN	°°its a little in the vein and a little more
69		posterior°°
70		(2.7)
71	ATT	come off

What followed was a long pause during which the attending physician began to administer a burn to the patient's heart. Although the burn was not again discussed during this excerpt it continued throughout the duration until the attending physician requested it stop (line 71). The cardiac EP nurse broke the pause and interjected a suggestion to "cl:::::::ock" the catheter as a next maneuver after the burn was complete (line 18). The attending physician heard the suggestion and immediately confirmed his intention (line 19). The cardiac EP nursed continued (line 20), without acknowledging the attending physician, to specify only one eighth of a turn of the catheter. The cardiac EP nurse continued, after pausing for a half second, related the potential improbable logic of the maneuver, and laughed as he did so (lines 22 and 23). Latching his response, the attending physician again assented to the suggestion (line 24) in near synchronicity with its execution. To demonstrate the synchronicity the attending physician drew the nurse's attention with the timing of the pause in line 27 before he completed his report (line 28).

Continuing the negotiation of catheter work, the cardiac EP nurse and attending physician fine tuned the position of the catheter (lines 30-36), questioned previous data suggesting one maneuver over another (lines 37-39), and tried another maneuver in light of new information shown in the EKG (lines 43-45). Next the team members questioned (line 47) and then reassured (line 49) one another about the efficacy of the new maneuver. Finally having achieved, identified, and confirmed satisfactory catheter placement (line 52), the attending physician and cardiac EP nurse together addressed new issues that arose indicating problems with the hard won satisfactory placement.

Indications of the problem followed a break in their exchange (line 61) at which point the attending physician's mic'd voicing evinced his corporeal engagement in catheter work (line 63), openly questioned where he had placed the catheter, and showed signs of his active consideration of the question (line 65). The cardiac EP nurse reported where he thought the catheter was and the attending physician without answering ended the burn, marking the close of their orientation to catheter work for the moment (line 71).

The excerpt presents a few instances when a team member successfully conveyed additional information via prosodic cues. In the first instance, as documented in auxiliary audio file 1-A, the cardiac EP nurse's assessment in line 1 offered a prosodic cue through a meaningfully timed pause that conveyed to the attending physician when to stop his adjustment. By identifying a moment through the completion of line 1 the cardiac EP nurse in essence created an opportunity for the attending physician to coordinate his movement of the catheter with the operator's assessment.

In a second instance, as documented in auxiliary audio file 1-B, prosodic cues conveyed unintended specificity to the amount of adjustment requested. In line 18 the cardiac EP nurse elongated and emphasized the word “clock” as a suggestion to the attending physician of how the catheter should be turned in a clockwise fashion. In this instance, the emphasis put on “clock” seemed to be due to the cardiac EP nurse’s difficulty producing the word and just after he produced that word he then refined his suggested directions to clock the catheter at only an eighth of a turn. The emphasis the cardiac EP nurse put on the word “clock” communicated something he did not intend. The refined instruction corrected what prosody had inadvertantdly conveyed.

Excerpt “Hey Phil”

As the previous excerpt described, team members accomplished directed adjustments to catheter positioning using prosodic cues. Team members also used prosodic cues to direct adjustments to other medical equipment beyond the catheters. For instance, the catheter operator was required to “scrub in” in order to maintain a sterile barrier around the surgery site. Once the catheter operator scrubbed in, he relied on other team members in the procedure room to adjust certain equipment outside of the sterile surgery site. In the next excerpt, the catheter operator directed the anesthesiologist to adjust the position of the patient’s esophageal probe.

This excerpt, titled “Hey Phil,” offers an additional example of the way that the prosody of a speaker’s directions served as a coordinating mechanism for a cooperative action. The excerpt details a short exchange between the attending physician (ATT), “Stan,” and an anesthesiologist (ANS) “Phil” as they negotiated an adjustment to the placement of an esophageal probe. Other team members did not appear in this section of the recording; only the attending physician and the anesthesiologist negotiated the probe's revised placement.

In line 1, the attending physician summoned the anesthesiologist by saying "Hey Phil" and received the anesthesiologist's reply in line 2. The attending physician began his request to have the probe moved but broke his utterance before specifying the length and direction to move it. In the time that the attending physician began to voice his request (line 3), the anesthesiologist moved from his workstation located a few feet away from the head of the procedure table and came to stand at the leaded plexiglass barrier at the top of the procedure table. This barrier protected the anesthesiologist's work area from x-ray radiation.

Taking a moment to consider, the attending physician finally completed his request in line 5 by specifying "two inches." Hearing the attending physician's request, the anesthesiologist moved to the side of the procedure table near where the patient's head was positioned so that he could adjust the probe. Gaining the anesthesiologist's response ("sure" in line 7), the attending physician monitored the anesthesiologist's movement of the probe while watching the fluoroscopic image on the board. Watching and waiting, the attending physician broke his silent observance in line 9 by exclaiming "dap!," which signaled to the anesthesiologist to halt any further adjustments to the probe.

Transcript "Hey Phil"

1	ATT	hey [Phil]
2	ANS	yes=
3		=can you pull the probe up about
4		(0.6)
5		two inches
6		(0.4)
7	ANS	(sure)
8		(5.0)

```
 9   ATT     dap!
10           (0.5)
11           a <little bit> more
12           a touch more
13   ANS     ((inaudible))
14           (0.6)
15   ATT     good!
16           (1.5)
17           thank you
```

The attending physician then began a second request that served to refine his prior instruction. In line 11, the attending physician placed special emphasis on his request for “a little bit more.” The attending physician elongated the words “little” and “bit.” He also shifted into a noticeably higher register when voicing the word “little”, and shifted back down to a normal pitch for him when voicing the word “bit.” Keeping his usual pitch but varying his cadence of speech, the attending physician again beckoned “a touch more” in line 12 and the anesthesiologist followed his instruction before the physician was satisfied with the adjustment. To signal his satisfaction with the probe adjustment as a whole, the attending physician said “good!” in line 15 and thanked the anesthesiologist in line 17. The assessment and token of thanks served to complete the project. The anesthesiologist moved back to his workstation just as the attending physician took up a catheter handle to proceed with the operation.

The excerpt “Hey Phil” contains a single instance when a team member successfully conveyed additional specificity to the amount of adjustment requested through prosodic cues. Coupled with the elongated production of “little,” as documented in auxiliary audio file 1-C, the rise in pitch in the attending physician’s voice provided the anesthesiologist with a greater specificity of instruction. The production of the next word “bit” then built upon the production of “little” to convey that the amount of change desired was accomplished through the anesthesiologist’s co-timed movement of the probe. In short, the attending physician and the anesthesiologist achieved coordination in the probe's movement through the co-evolutionary execution of an instruction with that instruction's delivery. The cooperative actions in this excerpt shows that sometimes specific numbers and units of measure are not sufficient for making adjustments to an instrument's position. To achieve a more precise and satisfactory position, the cooperating pair relied on prosodic cues that intuitively mapped the execution of a movement in a steady but slight upward motion. In effect, prosody helped the cooperating pair zero in on the right spot and signal the transition from course to fine grain instrument positioning. The example also conveyed the economizing features of directives that involved meaningful prosody.

In this section I identified a practice of coordinating adjustments to the position and navigation of certain medical instruments. In this case the anesthesiologist had the medical instrument of focal interest as he was holding the esophageal probe. The catheter operator's handling of the catheters was not at issue during this spate of talk. Although the catheter operator could not handle the esophageal probe he was able to view the movement of the probe in the fluoroscopic images displayed on the boom. I highlighted that asymmetries in access to tactile phenomena in turn shaped the ways that members of the team used prosodic cues to guide catheter manipulation. The excerpts in this section showed that prosodic cues could provide extra meaning to verbal instructions with great economy in communication. I highlighted that the multidimensional character of prosody served as a robust palette for mapping instructed manipulations to physical realities of execution.

ASYMMETRIES IN ACCESS THAT SHAPE MAINTENANCE OF AWARENESS

In this section I describe how asymmetries in access to tactile phenomena shaped catheter work in other ways, notably the ways that prosodic cues in reports about catheter manipulation fostered a wider awareness of the context of catheter work among the cardiac EP team. The circumstances by which asymmetries in access shaped awareness of catheter work and other tactile phenomena are important to understand before describing the practices by which team members in cardiac EP overcame these asymmetries.

The catheter as a non-computing technology was designed for use by a single operator. It had an integrated input-output interface so that the operator could rotate, push, pull, twist the catheter in virtually any direction. Importantly the felt experience of supplying input to the catheter, maneuvering it, was integrated with the experience of the technology's output, the resistance on each maneuver. Put simply, the world of touch was privately known. Only the catheter operator was able to functionally maneuver the catheter or feel the resistance from the patient's body. This fact significantly contributed to the team's asymmetric access to catheter behavior.

In prior excerpts, I described how members working from the control room coordinated with the catheter operator. When providing directions on catheter operation, team members working in the control room needed an accurate appreciation of the current context of catheter work. Visual displays of medical images supplied a great deal of information about catheter operation, but not all of it. Some kinds of tactile information about catheter function and cardiac anatomy remained crucially inaccessible through these visual displays. Thus, the team members in the control room required additional information about the catheter operator's situated perceptions of the catheter function and cardiac anatomy to accurately provide directions on how to manipulate catheters and where to navigate them. To foster greater awareness, the catheter operator sometimes provided verbal updates on the team's progress via the mic'd headsets.

The unusual structural organization of talk in cardiac EP procedures not typical of everyday conversation also made collaboration paramount. Traditional talk tends to have clear openings and closings indicated by long pauses. However, if a pause of a second or two occurred in the middle of everyday conversation it would be deemed accountable, or breaking with the norm of the understood social order of the interaction. This interpretation of the pause would hold unless some other explanation was provided or apparent to the people involved (Garfinkel, 1967, p. 1). By contrast, the on-topic talk in cardiac EP that I analyzed was not classically episodic and frequently contained long pauses that did not necessarily signal the end of the interaction. Instead, cardiac EP team members were often occupied during long pauses as they either carried out individual tasks (such as the execution of a tricky catheter maneuver) or waited for some cardiac activity to either occur or stop occurring. For example, scrutinizing electrocardiograms required close observation during which discussion about other aspects of the procedure would be suspended. Interestingly, the cardiac EP team members by and large did not treat long pauses in the middle of an ongoing conversation as accountable.

While understood as unremarkable by the team members, the sheer duration of these long pauses could nevertheless potentially negatively impact the team's cooperative effort because they created opportunities for discoordination. For instance, it was possible for a team member to become involved with other activities, lose focus and disengage, or continue working on something relevant to the procedure of which the other team members were not aware. Thus, once the pause ceased, team members might misunderstand the current context of other team members' actions because they were not aware of the actions preceding them. In essence, the team's awareness of the context of cooperative work could decay over periods of long pauses.

To combat the threat of discoordination, the catheter operator provided feedback about catheter function and cardiac anatomy when difficulties arose; in addition, team members sometimes requested information from the catheter operator. When reporting on catheter work, whether requested or spontaneous, the catheter operator was often simultaneously occupied with some aspect of catheter work such that his body was physically tensed to control catheter movement. The reports on catheter work consequently came laced with prosodic cues that fostered a greater awareness of the body's engagement in catheter work, much more than words alone could convey.

PRACTICE TWO: PROSODIC CUES OF CORPOREAL ENGAGEMENT

Through a microethnographic analysis of cardiac EP procedures I uncovered a practice by which the catheter operator provided updates on his progress through prosodic cues that indicated the state of his body doing work, a corporeal engagement. In practice, the prosodic cues carried information that fostered greater awareness of the catheter work underway for the other team members with the least access to that work. The prosodic qualities discussed here can be attributed to the catheter operator needing to manipulate or maintain control of the catheter while reporting to the team members in the control room about the catheter position or their progress on a maneuver. Talk (such as giving a report) that occurred while the operator was in the midst of a corporeal engagement often naturally resulted in providing additional evidence of his engagement. During these complex sorts of interactions, I observed that catheter operators practically pushed out their words with apparent vocal stress, a by-product of communicating the necessary updates while tensing the body to complete fine-grained maneuvers with an instrument.

In the three excerpts that follow, I present examples of awareness created by prosodic cues of a corporeal engagement. These excerpts explore two ways that team members preceded with their newfound awareness. In some examples, awareness of the catheter operator's corporeal engagement drew members in the control room into a closer collaboration with the catheter operator, offering help, assistance, or greater support. In other examples, awareness of the catheter operator's corporeal engagement granted the operator greater independence and lessened his burden for collaboration. In either circumstance, the team took into account the additional information gained via prosodic cues when assessing the context of the procedure. Evidence of corporeal engagement enabled the cardiac EP team as a whole to tighten or loosen the coupling of their work in ways that made sense for the dynamically shifting context of the procedure. For example, when the team tightened their coupling, the team member directing catheter manipulation in the control room often reconsidered the direction based on the newfound awareness provided by the catheter operator's update and its inherent prosodic cues.

Excerpt "What's our Heprin situation"

The excerpt titled "What's our Heprin situation" involves three team members: the cardiology fellow (FEL) "Amar," the attending physician (ATT) "Bill," and the cardiac EP nurse (EPN) "Hayes." The cardiology fellow worked from the procedure room, while the attending physician and cardiac EP nurse worked from the control room. Primarily in this excerpt the attending physician and the cardiology fellow negotiated catheter work and the cardiac EP nurse overheard their talk as a silent bystander. Late in the excerpt, the cardiac EP nurse responded to prosodic cues made by the cardiology fellow that indicated a corporeal engagement.

At the start of the excerpt (lines 1-20) the attending physician and the cardiology fellow asked and answered questions to clarify information about the administration of an inter-operative dose of anticoagulant medicine (Heprin). During this spate of off-topic talk, the cardiac EP nurse was heard answering a question asked by a circulating nurse prior to the beginning of the excerpt (lines 9 and 12). In the midst of those activities the cardiology fellow reported on the condition of the patient saying “ooh she's movin quite a bit” (line 22) and the attending physician responded with a joke (line 24) appreciated by the fellow (line 25). The cardiology fellow next inquired “is she just tossin” (line 28) to the circulating nurse who then acknowledged the question and went to check on the patient (line 30). While the nurse was doing so, the cardiology fellow reported his assessment of the situation in the procedure room for the other team members in the control room (lines 31-32), and repeated the statement under the impression that his last report was not heard (lines 34-36). The circulating nurse, having checked on the patient, then asked a question of the cardiology fellow that established the most recently ordered medication dosages (lines 38-44), and responded to other off-topic talk from another circulating nurse (line 50).

The cardiology fellow, who had remained with the patient, noticed that the patient moved again, and made an audible reaction (lines 52 and 54), saying “Ooh [...] oh!” The cardiac EP nurse who had been preoccupied with other matters in the preceding discussion of the patient, noticed the fellow’s reaction and sought an explanation. She asked the fellow “what are you OOOing” (line 56) to which the cardiology fellow updated the cardiac EP nurse with the patient’s activity (lines 57).

Transcript “What’s our Heprin Situation”

```
ATT     what's our heprin situation
        (0.3)
```

FEL we haven't heprinized yet
(1.4)
ATT she's on eloquist
EPN she is
FEL correct
(0.8)
EPN one one she’s
(1.6)
ATT so why don't we do another
EPN whole hundred pounds
(0.2)
ATT take (..) ten thousand(.)eh an thousand an
hour I thought it would be low but
(1.3)
FEL can we do ten thousand unit bolas of heprin
and run it at a thousand
(6.5)
ATT yea
(0.3)
FEL ooh she's movin quite a bit
(1.2)
ATT no that gonna be a mapping pain in the ass
FEL <yep>
(7.9)
CIR he did a
FEL is she just tossin
(1.2)
CIR I'll double check
FEL I don't well she was movin her legs
couldn't tell if she was coughing
(1.0)
she was a she was moving her legs and I
couldn't tell if it was just coughing or
movement
(1.3)
CIR youre givin a heprin bolas an-
(1.5)
(do you want to put one thousand)
(4.5)
you know you told him right
FEL yeah yeah
CIR yea
(1.3)
FEL thank you
(2.4)
EPN ((singing))
(6.2)
CIR that's close you got michael and michelle

```
51          (4.5)
52   FEL    ooh
53          (0.3)
54   FEL    oh!
55          (2.7)
56   EPN    what are you OOOing
57   FEL    no she's just kickin her legs up
58          (6.3)
59   EPN    (slip first is higher than the sheaths in)
```

As also documented in auxiliary audio file 2-A, this excerpt demonstrated that prosodic cues “ooh … oh!” given by the catheter operator that seem to indicate a corporeal engagement are treated as such by the team members in the control room. The excerpt shows that the team members understood the practice of reporting on catheter work and that prosodic cues provided during the report indicated a corporeal engagement, unseen but heard. In short, the cardiac EP nurse’s question to the catheter operator that clarified the meaning of the prosodic cue provided evidence of his sensitivity to the asymmetry in his access to tactile phenomena experienced in the procedure room. The nature of the catheter operator’s response showed that he also understood how the prosodic cues he had just provided could be understood as evidence of a corporeal engagement.

Excerpt “Go down to where you think”

The excerpt titled “Go down to where you think” provides a complex demonstration of the ways that prosodic indications of a physical effort can attract and hold a cooperating partner’s attention. In this excerpt the cardiac EP nurse (EPN) “Hayes” and the cardiology fellow (FEL) “Amar” both focused on a difficult catheter maneuver with very little explicit articulation work regarding the coordination of their efforts. The attending physician did not appear in this portion of the recording, but he was nearby and wearing a headset. In this excerpt, the cardiac EP nurse, working from a seated position in the control room, directed the cardiology fellow to maneuver his catheter to a specific area of the patient’s cardiac anatomy called the “cavotricuspid isthmus” (CTI). As a turn-by-turn examination of the excerpt will make clear, after much time and effort the directed catheter navigation proved difficult for the cardiology fellow.

At the start of this excerpt, the cardiac EP nurse directed the fellow to “go down to where you think we would have put the C-T-O [he meant C-T-I] in” in line 1. After a long pause, the cardiology fellow asked a related clarifying question in line 4 and received a quick affirmative response from the cardiac EP nurse in line 6. From there, the fellow’s turn in line 8 makes clear that the cardiac EP nurse has satisfied his interest regarding the patient’s history.

The next actions by the cardiology fellow can be understood as an execution of the cardiac EP nurse’s original direction to move the catheter to the CTI. In line 10 the cardiology fellow said, “try this,” in a very low voice which nevertheless showed signs of vocal stress. In the next lines 11 and 13, the cardiology fellow said nothing, but his breath was audible in the recording and, from the quality of his outbreaths, one can hear that the fellow has tensed up his upper body in an effort to complete the directed catheter manipulation. The cardiac EP nurse’s next turn (line 14) encouraged the fellow’s effort with “come on” and made an assessment of his effort with “eh” (line 15). From here the cardiac EP nurse suggested the possibility that the maneuver was adequate, saying “that’s sorta in isn’t it” in line 17, and then the nurse requested further refinement of the fellow’s silent instrument maneuver in line 22 displayed on the boom and board.

Transcript “Go down to where you think”

1	EPN	go down to where you think we would have put
2		the (.) C-T-O in,
3		(7.1)
4	FEL	do we do- =did we do a C-T-I on her,=
5		((cavotricuspid isthmus abbreviated “CTI”))
6	EPN	=ya
7		(3.4)
8	FEL	alright
9		(2.4)
10	FEL	**try this**
11	FEL	**((breath and body sounds))**
12		(1.6)
13	FEL	**((breath and body sounds))**
14	EPN	come on

15 EPN eh
16 (0.7)
17 EPN (that's sorta in isn't it,)
18 FEL **((strained outbreath))**
19 (5.5)
20 CIR ((talks about bubbles))
21 (1.9)
22 FEL **get down here a little bit**

This excerpt provides a different kind of example for how prosody of a team member's breath can become interactionally significant for a cooperative effort. In this excerpt, and as documented in auxiliary audio file 2-B, the cardiology fellow produced a chain of utterances that enabled a greater awareness of his efforts to carry out the cardiac EP nurse's direction. The cardiology fellow's comment to "try this" in line 10 of this excerpt provided the cardiac EP nurse in the other room extra information about the status of the work. Next, despite the cardiology fellow not saying anything directly, the effort heard in his outbreaths (lines 11 and 13) engendered encouragement in line 14 from the cardiac EP nurse. It is possible that the cardiac EP nurse's awareness of the cardiology fellow's effort in producing the requested navigational moves provoked the cardiac EP nurse's somewhat positive assessment of the fellow's current attempt in line 17, before the cardiac EP nurse ultimately requested a refinement in the catheter position. The prosodic qualities of talk and breathing in this excerpt demonstrate that team members engaged in a cooperative effort are attuned to not only what is said, but also what is not said and how what is not said is communicated.

Excerpt "Tried to look at his left leg lead"

As the previous excerpts show, team members using prosodic cues accomplished directed adjustments to catheter position. Such cues were also employed, however, to direct adjustments to other medical equipment. The excerpt titled "Tried to look at his left leg lead" shows how the cardiac EP nurse and cardiology fellow cooperatively worked to remove noise picked up by one of the electrical leads attached to the catheter inserted into the left leg of the patient while they maintained a sterile barrier around the surgery site.

In this excerpt, the cardiology fellow (FEL) “Amar” was scrubbed in and already carrying out catheter work at the procedure table. The cardiac EP nurse (EPN) “Hayes,” who was not scrubbed in, volunteered his help making needed adjustments to the handle of the esophageal probe, as he knew that the fellow would not be able to make the adjustments himself. Though only the cardiology fellow and cardiac EP nurse are represented in the excerpt transcript, three people appear in the video recording. The attending physician “Stan” overheard the cardiac EP nurse and cardiology fellow’s verbal exchange from a seated position at the imaging workstation in the control room. The following turn-by-turn description of the excerpts provides additional examples of the way that prosodic indications of corporeal engagement fostered awareness of a wider context of action in the procedure.

Transcript “Tried to look at his left leg lead”

1	EPN	tried to look at his left leg lead [Amar]
2	EPN	try and get rid of some of that fuckin noise
3		(2.9)
4	EPN	uhh uhh
5		(2.8)
6	EPN	did that fix it?
7		(0.8)
8	EPN	E-K-G noise
9	FEL	uhhh
10	FEL	it's still kind of noisy
11		(34.0)
12	FEL	there you go I think that helped
13	EPN	(a little) better

At the start of the excerpt, the cardiac EP nurse emerged from the passageway connecting the control and procedure rooms and entered the control room while announcing an intention to adjust an electrical lead attached to a catheter inserted in the left leg of the patient. Still in motion as he completed line 1 “tried to look at his left leg lead [Amar]”, the cardiac EP nurse passed in front of the camera (positioned a few feet from the procedure table) and out of frame. Meanwhile the cardiology fellow lifted his hands from the catheters to stand back from the table and looked in the direction of the passing cardiac EP nurse. In the midst of voicing line 2, “try and get rid of some of that fuckin noise”, the cardiac EP nurse re-entered the frame, and emerged from the far side of the procedure room. The cardiac EP nurse next voiced an effortful sound (line 4), after which the sound of shifting plastic covering controls can be heard as he stooped beneath the plastic draped procedure table to where the catheter’s electrical leads hung down.

After a short pause, while still beneath the procedure table, the cardiac EP nurse asked the cardiology fellow, who was watching the electrocardiograms displayed on the boom, “did that fix it?” (line 6). Before the cardiology fellow could answer, the cardiac EP nurse continued by clarifying his reference to “it” and voiced line 8 “E-K-G noise” to which the cardiology fellow elongated an expression “uhhhh” (line 9). This expression indicated his engagement in making the assessment (line 10) “it’s still kinda noisy.”

Note that by saying “uhhhh” before assessing the EKG, the cardiology fellow did something interactionally meaningful, which enabled the cardiac EP nurse to understand that the cardiology fellow heard the nurse’s question and was trying to answer it. The fellow’s voicing of his epistemic stance was the cardiac EP nurse’s only means of appreciating the context of action because the nurse was still under the procedure table. Furthermore, the cardiac EP nurse needed help making this determination because he could not see the EKGs from under the table and could not adjust the electrical leads based on the EKG readings if he did not remain under the table.

This excerpt provides two instances in which prosodic qualities of a team member’s speech conveyed extra information about the current context of work. The first example is found in line 1 as well as documented in auxiliary audio file 2-C. Along with the lexical meaning of the cardiac EP nurse's words, the prosodic quality of his announcement alerted the cardiology fellow to the nurse's movement towards the catheter workstation. The cardiology fellow then wordlessly turned sideways so that he did not block the procedure table where the electrical leads hung down. The cardiology fellow's action, essentially getting out of the way, provided visible evidence that he was aware of the implications of the cardiac EP nurse's stated intention to adjust the electrical lead. The second example is found in line 9 in which the cardiology fellow's prosodic production "uhhhh" provided the cardiac EP nurse awareness that his question was heard and would be answered. This second examples is also documented in auxiliary audio file 2-D. The nurse consequently remained under the procedure table in case further adjustments to the electrical leads were needed. The extra information that prosodic qualities of talk-in-interaction provided lessened the impact that the team members' asymmetric access to relevant objects that needed to be adjusted using touch.

In both instances, I found the economy of prosodic cues to be striking, especially in the way that the team adapted seamlessly to the accomplishment of catheter work itself. We see few extraneous words or long-winded explanations in these examples. In short, the team exchanged meanings and fostered awareness about the context of the cooperative effort in multiple levels of meaning simultaneously. Without such communicative economy, updates about catheter work (and cognate tactile endeavors) could have required breaks in the practical activities of the work itself. The sound of the catheter operator's effortful body made the team's communication of awareness almost effortless.

Coincident Practices of Awareness and Coordination

Thus far I have presented two practices carried out through prosodic cues in verbal communication. One practice aided in the coordination of instructed catheter manipulation and its execution, and the other practice helped foster awareness about catheter work as a situated activity carried out by a skilled and effortful body. I found multiple independent instances of each practice in my analysis of the team's orientations to catheter work and cardiac anatomy, but it was equally often that a given excerpt in my data set would show both practices at play. I next review an excerpt in which practices of both coordination and awareness are represented in the team's orientations to catheter work and cardiac anatomy. My examination of the coincidence of these practices within a given excerpt maintains the integrity of a microethnographic approach as the significance of verbal exchanges has remained rooted in a meaningful sequential organization. Later in my discussion, I will explore the relationship of the practices using the interactional details of their coincidence.

Excerpt "Arrh ahh' – do do do do do do clock it"

The excerpt titled "Arrh ahh' - do do do do do do clock it" represents the activities of two of the three cardiac EP team members as they oriented to catheter work and cardiac anatomy. In this excerpt, the cardiology fellow (FEL) "Amar" operated the catheters in the procedure room as the attending physician (ATT) "Stan" sat with the cardiac EP nurse (EPN) "Hayes" in the control room. In the course of this excerpt the attending physician directed the cardiology fellow's catheter manipulation, and the fellow in turn reported his experience making these tricky catheter maneuvers.

This excerpt contains more than four instances in which the cardiology fellow provided updates with cues of an ongoing corporeal engagement. The verbal content of each of these updates informed the attending physician of changes to catheter position, while the prosodic context of these updates informed him of the tricky job of handling the catheters, in a sense broadening the team's awareness of the catheter operator's struggle with the maneuvers themselves. Because the maneuvers were so difficult, the turn-by-turn analysis of the excerpt allows us to appreciate how these signs of corporeal engagement affected the work in the control room. With a greater awareness of the catheter operator's difficulties, team members in the control room could better understand how to help the catheter operator in the procedure room. In addition to the numerous examples of corporeal engagement, the excerpt also provides an instance of the practice of conveying nuanced amounts of desired adjustment to catheter position.

In line 1, the attending physician playfully mimicked the music playing in the cardiac EP surgery suite "arrh ahh' - do do do do do do= =clock it=" and finished his utterance with a directive for the cardiology fellow. In response, the fellow remarked on the quality of a recent fluoroscopic image (line 3) therein providing an explanation for his failure to "clock" the catheter before the attending physician's prompting. The cardiology fellow then notified the attending physician that he was carrying out the directed action, saying "hang on =(I'm going to) **clock** =>there we go<" (line 5). The fellow's notification, especially his production of the word "clock," evinced his corporeal engagement in carrying out the directed maneuver. The production of the word "clock" in line 5, coupled with the final phrase completed at a clipped rate, indicated the fellow both completed the maneuver and completed the report of the maneuver in near synchronicity.

Transcript "Arrh ahh' – do do do do do do clock it

ATT arrh ahh' - do do do do do do= =clock it=
=might need to be a little higher up maybe?=
FEL =yeah I think so= =I had a good picture a second
ago
hang on =(I'm going to) **clock** =>there we go<
(22.3) With (11.3)off-topic talk on the lights

FEL	except it just keeps on going in and out (hh)
ATT	somethin's gettin in its **way**
	(4.6)
FEL	I bet if I do this:
	(11.9) With (9.3) off-topic talk about lunch
ATT	oh it's pretty good,
	<you: maybe want to put a little posterior tilt
	on it,
	on the (Oso) (.) yeah::
	there ya go
	(8.9)
FEL	alright I moved that the **wrong** way
	(15.9)
ATT	alright my friend
	(1.8)
	Ommm
	(5.6)
FEL	its comin along
	(0.9)
	just gonna get rid of the **tilt=**
ATT	=yeah that's too much tilt (hh)
	(1.6)
	come off a <**tiny**> bit
	(0.8)
FEL	°°<an:>- loosen it°°
	(10.0)
FEL	its funny it doesn't **tilt the way I want**
	it to
	(2.5)
FEL	there we go
	(5.1)
ATT	umm hmm
	(20.7)
FEL	okay it's R-A-O it's L-A-O

What followed next was a long pause in the on-topic talk between the cardiology fellow and the attending physician in which the cardiology fellow's notification in line 5 appeared to satisfy the attending physician's request as signified by the physician's move into off-topic talk not transcribed here. During this off-topic talk, the attending physician requested a change in the room's lighting from a circulating nurse on duty. After the lights were adjusted, the attending physician provided no further assessment of the catheter position, which further indicated the adequacy of the maneuver.

Breaking the long pause, the cardiology fellow resumed on-topic talk in line 7 indicating his difficulty with maintaining the catheter's position. At a low volume and with vocal stress the fellow said: "except it just keeps on going in and out (hh)." The attending physician immediately responded with an interpretation of the cause of his difficulty with the catheter saying in line 8, "somethin's gettin in its **way**." The attending physician's quick response showed his appreciation of the ongoing and effortful physical engagement he heard in the fellow's announcement.

Next in line 10 the cardiology fellow, building on the physician's interpretation, announced "I bet if I do this:" at the same time that he performed this maneuver. After this announcement there was another pause in on-topic talk during which the attending physician, while gazing at the board, heard and watched the fellow carry out the maneuver and again fell back into off-topic talk with the circulating nurses about lunch scheduling. Then when the attending physician resumed on-topic talk, going on to exchange assessments (line 12), directions (lines 13 and 14), and affirmations (lines 15 and 16) with the cardiology fellow until another moment in which the fellow's difficulty with catheter maneuvers became apparent.

After a pause the fellow reported a new difficulty with catheter manipulations in line 18 when he said: "alright I moved that the **wrong** way." In his report the fellow's pronunciation of the word "wrong" showed his special difficulty with the maneuver at the moment he made his complaint. To this, the attending physician granted the fellow almost 16 seconds of uninterrupted attempts to get a maneuver right before summoning the fellow in line 20. The attending physician waited almost two seconds and re-initiated his prompting of the fellow, then waited another five and one-half seconds until the fellow finally provided a new report. In lines 24 and 26 the fellow reported: "its comin along (0.9) just gonna get rid of the **tilt**=." Again with this report, the fellow evinced his corporeal engagement with the catheter in hand which produced special emphasis on the word "tilt."

In this instance the attending physician immediately affirmed the fellow's refinement and followed with a refinement of his own in lines 27 and 29. The attending physician's own suggested refinement provides another instance of prosodic cues that conveyed special small adjustments to catheter manipulation. When in line 29 the attending physician said, "come off a <tiny> bit" he elongated the word "tiny" further emphasizing the minuteness of the desired adjustment. In line 31 the fellow showed his understanding of the direction by providing the next logical maneuver to the catheter's tension loop, the fellow stated with similar emphasis, "°°<an:>- loosen it°°." With a mutual understanding of the actions needed, the fellow carried out catheter work for nearly 10 seconds before making a final report emphasizing his continued difficulty maintaining an optimal position on the catheter. In lines 33 and 34 he said "it's funny it doesn't tilt the way I want it to" at which point he finally achieved a satisfactory position and provided a positive assessment to close out the excerpt in lines 36 through 39.

This excerpt provides ample examples in which the cardiac EP team oriented to catheter work using practices to better coordinate and maintain awareness despite significant asymmetries in access to tactile phenomena. In my description of the excerpt I highlighted five instances in which the cardiology fellow fostered a broader awareness about his difficulty with catheter work by providing reports that carried signs (and sounds) of his corporeal engagement. For review, these instances occurred in lines 5, 7, 18, 26, and lines 33 to 34. One of these instances elicited an immediate response from members in the control room (line 27), in another instance the response from the control room was slightly delayed (line 39). What is interesting is the complex communicative status of these prosodic cues that at once "gave" as well as "gave off" information about catheter work (Goffman, 1959, pp. 2-9). For example, regarding the first instance in line 5, one might ask what does stress on "clock" do for the interaction? The fellow's production of the word clock gave (or gave off) information about his bodily involvement in carrying out the attending physician's directive. This instance is available for review in auxiliary audio file 3-A. As a sequence, the stressed production of the word "clock" immediately then preceded a change in the catheter position in the Carto™ screen. The stress on the word may have prefigured a chance for the attending physician to observe a coming change to the catheter position as shown on the Carto™ screen.

Similarly, in line 7, the cardiology fellow reported trouble with the catheter. This instances is also available for review in auxiliary audio file 3-B. Referring to the catheter in a non-specific and context-dependent way, the cardiology fellow reported that the catheter was not staying in place and instead was moving "in and out" of the desired location. The way the cardiology fellow reported this trouble was with a vocal stress in his voice that can only be described as produced with the cardiology fellow's body, neck, and vocal folds tensed. The resulting report gave (or gave off) information about the cardiology fellow's physical status and the nature of his corporeal engagement managing the troublesome catheter in that moment.

Line 18 provided a third example of prosody that gives or gives off information about the cardiology fellow's corporeal engagement in catheter work, available for review via auxiliary audio file 3-C. The cardiology fellow's production of the single stressed word "wrong" in line 18 accentuated the difficulty of the manipulation. The attending physician did not directly respond; instead, he provided the cardiology fellow with an almost sixteen-second period of time to get the manipulation right. Possibly, the stress put on the word bought the cardiology fellow time to continue adjusting the catheter. However, there was a limit to the amount of time they could spend because the team needed to limit the patient's exposure to x-ray as well as their own exposure. After the sixteen-second period had elapsed the attending physician summoned the cardiology fellow to move on from his attempts to adjust or re-adjust the catheter.

While in some instances vocal stress appeared to buy the catheter operator time to grapple with the instrument on his own, in other instances the cooperation between the control and procedure rooms tightened with the insertion of a prosodic cue of corporeal engagement. An instance of tightened coupling is found in catheter operator's report (line 26) and the complementary reply that came from the control room (line 27), available for review in auxiliary audio file 3-D.

In short, there were a variety of instances in which the catheter operator fostered a wider awareness of catheter work. In these instances the team members negotiated the resolution of practical problems in catheter work with a greater appreciation for the tactile and physical realities of the way that work was carried out.

But the practice of employing prosodic cues of corporeal engagement was not the only practice represented in this excerpt. Near the end of the fellow and attending physician's exchange, one finds a nuanced example of the practice of coordinating via the use of prosodic cues. In line 29 the attending physician asked the cardiology fellow to “come off” or retract the catheter a small amount by saying “come off a **<tiny>** bit.” In this instance, available for review in auxiliary audio file 3-E, the elongated the word “tiny” to further emphasize the minuteness of the adjustment he desired. In effect, this intonation feature of line 28 was helpful in how it conveyed the finitude of the adjustment he requested. Then in a similar fashion, the cardiology fellow’s response with a complementary adjustment showed his understanding of the direction when he stated “°°<an:>- loosen it°°” placing similar emphasis when he elongated the first word of his reply. Each speaker produced these adjustment words, “tiny” and “an[d]”, using a slower than normal speech rate, yet another prosodic cue.

In practice prosodic cues enabled tactile phenomena privately experienced and individually executed to be publically shared and cooperatively negotiated according to the team’s working division of labor. In what follows I describe the factors contributing to the team’s use of prosody as a means of clarifying how prosody arose in both of the work practices supporting the team’s awareness about and coordination of catheter work.

SUMMARY

To be able to discuss the theoretical significance of these work practices and relate my observations to existing research, we need to understand how prosody arose as a focal feature of communication in cardiac EP. At least three factors contributed to the team members’ asymmetric access to catheter work and emphasized their need to cooperate. These factors included the team’s working division of labor in cardiac EP (separating responsibilities of directing and executing catheter work) and the two-room layout of the surgery suite (separating the computer imaging workstation and the catheter workstation). But the root cause of team members’ asymmetric access was the design of catheters as non-computing technologies for a single operator.

Prosodic cues, as audible phenomena, compensated for all three of these factors. Irrespective of the working division of labor, all the team members enjoyed the ability to make and understand prosodic cues. All team members irrespective of their role in catheter work were able to make meaningful sound.[8] Plus, prosody as an audible phenomenon could pass through both rooms of the cardiac EP surgery suite with the aid of the team's use of mic'd headsets. Last and crucially, the meaningful sounds (e.g., a rising pitch or an elongated syllable) contained in prosodic cues could be translated into a tactile experience and vice versa. Here a metaphor may be helpful: when a conductor uses a baton to direct a player's performance, the movement of the baton suggests particular sonic production. Prosodic cues, as I will elaborate in the next chapter, functioned in much the same way.

However, prosodic cues were not used in isolation. The team also relied on at least two other shared resources. Team members' directions and updates about catheter work depended on visual information displayed on the boom and board. In addition, much of the information displayed on the boom and board would have been unintelligible to a non-expert, but members of the cardiac EP team could draw on a shared set of anatomical references to direct or execute catheter navigation. Yet the high-tech displays and technical knowledge alone were not enough for the workers to overcome their asymmetric access to tactile phenomena. Ultimately, prosody compensated for the multiple factors contributing to asymmetric access to tactile phenomena. It was intriguing that prosody was used as a mechanism to coordinate catheter work as well as foster awareness about it. The significance of the use of prosodic cues in both work practices is a key point of discussion in the next chapter.

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[8] The team's ability was more than an embodied capacity: team members learned to be competent communicators in the circumstances of asymmetric access. However, the acquisition of the team's abilities is not central to my present concern.

In this chapter I documented two practices that enabled the cardiac EP team to overcome asymmetries in access to tactile phenomena to coordinate directed adjustments to catheter position and to foster awareness of tactile qualities of catheter manipulation. The first practice served as a mechanism for coordinating direction of catheter work and other fine-grained manual maneuvers. The second practice aided the team's awareness of catheter work in the context of each procedure as that context dynamically shifted in the aid of decision making. Both practices can be attributed to prosodic features of the team's talk-in-interaction. Leveraging the coincidence of both practices provided an opportunity to examine how the incidence of one practice interactionally informed a subsequent instance of the other practice. In the next chapter I discuss the significance of this coincidence with the aim to establish a broader appreciation of HTC (C-NC) as a cooperative engagement realized through simple forms of aural connection via headsets.

Discussion

INTRODUCTION

My dissertation sought to address the question: how do workers in HTC (C-NC) orient to asymmetries in their access to tactile phenomena? To address this question, I studied the cooperative work practices of a team working in a cardiac EP surgery suite. This chapter discusses the answer to my research question and explores the significance of my findings for studies of work and technology broadly conceived. At certain points I return to data presented in the last chapter so as to situate my discussion in some specific interactional details. To contextualize my discussion of prosodic cues and speak broadly about the significance of this research, I highlight a theoretical perspective on the "living body" (Streeck, 2013) adopted from studies of communication that may be fruitfully applied to the study of work with technologies irrespective of their type or combination. Notwithstanding this point, I argue for the special relevance of this theoretical perspective to studies of HTC (C-NC) based on my data analysis.

To appreciate the subtlety of prosodic cues it is important to begin by acknowledging that team members in cardiac EP treated the dilemma of their unequal access as a mundane feature that they rarely, if ever, directly discussed or lamented. Likewise, the team members also regarded the solution for this dilemma, prosodic cues, as unremarkable. Put another way, the team members in cardiac EP oriented to their access and overcame asymmetries in their access without much acknowledged difficulty. Although the team members treated their use of prosodic cues as perfunctory, the subtleties of these cues are quite remarkable and arguably novel given the existing research on prosody.

Research into prosody has largely been and remains the domain of linguistics. A few scholars have investigated prosodic cues when distributed parties struggle to be heard or to re-negotiate what is heard. Publishing a study of workplace communication for an embodied communication audience, Goodwin (1996) highlighted that workers in airport ground transportation relied on prosodic cues to pick out particular voices over shortwave radio conversation in spite of cross-talk on the open channel. In the same vein, Ward and Tsukahara (2000) drew attention to the use of prosodic cues to signal "back channel communication" wherein conversational partners took some discussion off an open line. Reed and (2011) discussed the use of prosody for coordinating actions across multiple roles. My study is somewhat different from each of these as none of them focus on the capacity of prosody to translate experience in one sense modality (such as touch) to another modality. When referring to "translation capacity" I mean that experience understood in one sense modality (e.g. hearing) could be translated to action in another (e.g. touch or kinesthetic experience). In the discussion that follows I suggest that we potentially gain a new appreciation of one of the mundane activities in HTC (C-NC) work (i.e., coordinating and maintaining awareness about execution of work with a non-computing technology) and the use of prosodic cues as a specific "body technique" (Mauss, 1979, p. 97; 1973) or forms of embodied knowledge useful in resolving asymmetries in access to tactile phenomena.

TRANSLATION CAPACITY OF PROSODIC CUES

My study found that workers in HTC (C-NC) oriented to and even allievated their asymmetries in access to tactile phenomena by relying on prosodic cues. My study was based on analysis of video recordings of cardiac EP procedures in which members of a medical team relied on prosodic qualities of their voices to negotiate the execution of work with a particular type of non-computing technology, catheters. How then did prosodic cues support these work practices? And how are the work practices of coordination and awareness related to prosodic cues? What can be gained from appreciating the use of prosodic cues? Addressing each question in turn, my analysis suggests that prosodic cues served to translate information experienced in one sense modality into another modality. My analysis additionally suggests that the translation capacity of prosodic cues served as a crucial means of coordinating and maintaining awareness about catheter work. My research contributes a perspective on the consequential roles of voices and bodies, appreciable from this analysis of prosodic cues, to the CSCW literature.

In this section I begin by revisiting the work practices of coordination and awareness presented in my findings so as to discuss the general traits of prosodic cues. I then elaborate on the mechanics of translation embedded in the use of prosodic cues related to each work practice. I finally open a discussion regarding the benefits of considering these work practices holistically and provide an exegesis of each work practice within studies of CSCW and embodied communication.

Discussion of Prosody for Coordination

My research into coordination in HTC (C-NC) findings suggests additional insights into coordination that challenge the primacy of visual information and the analysis of artifacts and technologies as conduits of coordination. In this section I illustrate the translation capacity of prosodic cues, a capacity of the voice and hence the body, which supported the coordination of catheter work despite the team's asymmetric access to catheter function. I then turn to a concept developed in linguistic anthropology to better discuss the mechanism involved in translation for coordination.

Translation in Prosodic Cues for Coordination

One can glean some general traits of this work practice from the excerpts describing coordination in the Findings chapter. The excerpts describe that one or more team members in the control room provided instructions to a colleague in the procedure room regarding the "just so" execution of catheter work. These instructions suggested to the catheter operator stationed in the procedure room, how to move the catheter or particular features of the cardiac anatomy proximal to the catheter tip. Those delivering the instructions did so in such a way that particular words were laced with prosodic cues. The instructions regarding the coordination of catheter work principally focused on fine-grain adjustments to catheter position. Accordingly the person providing the instructions about catheter movement needed to convey changes to catheter position by degrees. In addition to the positioning of catheters, team members in the control room sometimes described qualities of cardiac anatomy and physiology. Hearing these prosodic cues, the catheter operator then moved the catheter and appreciated the tactile experience of the cardiac tissue in light of other team member's instructions. Although there is more to say about the use of prosodic cues in relation to other supports (e.g., the information displayed on screen) for coordination, at present I want to focus on the translation of heard cues and felt experiences in the scenario described above.

Sound Symbolic Utterances

Existing sociolinguistic research clarifies the mechanism embedded within these cues and their translation capacity. I make use of the concept of sound symbolic utterances (Nuckolls, 1992, p. 53) to help us better discuss the mechanisms of prosody that convey qualities and amounts by degrees as a means of coordinating catheter work using one's voice. "Sound symbolic utterances" describe the use of imitative "sounds, rhythms, visual patterns, and psychophysical sensations" which can be foregrounded through, among other means, intonational elaboration and syntactic isolation. Nucklos' own investigation into sound symbolic utterances relies on recordings of conversational storytelling in Quechua, a South American Indian tribe with an oral storytelling culture.

Three features of sound symbolic utterances – (1) heightened engagement, (2) spatio-temporal indexicality, and (3) imitation and iconicity – add to an appreciation of the cardiac EP team's coordination of catheter work through prosodic cues. Speaking to the first of these features, according to Nucklos (Nuckolls, 1992, p. 51) sound symbolic utterances have the ability to heighten a listener's engagement through the creation of perceptual images; she writes:

> [The] salient qualities of an action, event or process that thereby invites the listener to project into the experience [...] The projected involvement, in turn, points the listener to deeper kinds of imaginative, intellectual, and emotional engagement with the narrative.

In Nucklos data the storyteller's use of sound symbolic utterances created communicative involvement by simulating aspects of a perceptual experience. Sound symbolic utterances are not merely global modifiers of heightened expressiveness of an overall story. Rather sound symbolic utterances are "communicative of precise and explicit information" (Nuckolls, 1992, p. 53). Rather speaking to the second of these features, Nuckols' examples demonstrate ways in which vocal intonation makes "explicit the salient features of an action's spatio-temporal unfolding." In addition to these first two features of sound symbolic utterances, Nucklos also describes the use of sound symbolism–in terms of voicing imitative sounds and iconic sounds–as a key driver for enhanced engagement.

The specificity of the voice and bodily action described by Nucklos is worth noting for CSCW scholars interested in coordination work practices. Nucklos' data presentation and her description of these features of sound symbolic utterances prompt me to speculate on the role of sound symbolic utterances or similar features in my own data. Entertaining the possibility that sound symbolic utterances might be a good explanation of the translation mechanism embedded in the prosodic cues to coordinate, I offer some brief analysis as a starting point for discussing my data in relation to the CSCW literature on coordination in control rooms.

In the excerpt titled "Hey Phil" the attending physician voiced "dap!"on line 9 at an exact moment after watching and waiting for the anesthesiologist to adjust the esophageal probe. This utterance had an improvisational and quasi-linguistic quality to the way it signaled, "stop" to the anesthesiologist. As the CSCW literature on coordination in control rooms found, the use of cues like these supported coordination *in situ* (Heath, 2000; Heath & Luff, 1992a; Nevile, 2004) and served to shape the anesthesiologist's next action. The use of such cues would be poorly articulated as an explicit codified procedure, but did help with the coordinated conduct of instrument manipulation.

In some instances the prosodic cues in cardiac EP could be said to have fostered enhanced engagement through the imitative and iconic relation between the sound or word produced and what it referred to. For example the cardiac EP nurse's prosodic cues were imitative of the degree of change desired by elongating his voicing of the term "clock it" he emphasized the degree of desired change. In each of these examples of imitative and, or iconic sounds, it is interesting to bear in mind that the cardiac EP nurse and the attending physician each drew from a practical wealth of experience with the catheter as a piece of equipment and the anatomical heart as a piece of tissue. The team members in cardiac EP were well situated to produce imitative or iconic sounds for tactile phenomena that each person knew incredibly well.

With a greater appreciation of the translation capacity of prosodic cues used for coordination, it is worth noting the contrasts in the use of prosody with other supports for coordination present in this work environment. For example, in the excerpt titled "Pretty good right there" the cardiac EP nurse voiced "pretty good right (.) there" in the first line of the transcript, using the timing of pause in his direction as part of the crucial information in the coordination of catheter work. To time his cue the cardiac EP nurse relied on the board to see where the attending physician's instrument was at the relevant moment. The attending physician was also relying on the boom as a secondary support in hearing these cues. In sum, the voice and the use of prosody played the primary role in this example of catheter work coordination and the use of the screens played the supporting role.

The team member in the control room lacked access to tactile phenomena germane to catheter work, but could nevertheless see information about the catheter and cardiac anatomy on the boom and board. The team member operating the catheters the procedure room could not only feel the catheter in the patient's heart, but could also see information about the catheter and cardiac anatomy on the boom. In sum, although the tactile experience of catheter movement was private, the display of catheter movement was public. Thus, the control room team member's prosodic cues were useful in the team's coordination because even though they did not have tactile access to the catheter itself, they were often able to direct their team member who had access to it in a satisfactory manner by relying on visual information as a support.

Discussion of Prosody for Awareness

My literature review noted that CSCW research on awareness in control room settings focused on the analysis of the situated use of technologies and artifacts as primary supports of awareness among workers (Benford, Bowers, Fahlén, & Greenhalgh, 1994; Heath, Svensson, Hindmarsh, Luff, & Vom Lehn, 2002). From this literature I gleaned that artifacts and technologies are useful in the representation and transformation of information for awareness. For instance, take Heath and Luff's (2000b) illustration of how information is cast and recast to create and maintain awareness through the use of a public announcement system in the London Underground. What one finds fewer examples of is the voice and body's role in representing and transforming information to support awareness (Berndtsson & Normark, 1999) as shown in my data.

In much the same way as I approached the discussion of coordination, I will now illustrate the translation capacity of the prosodic cues that supported awareness. I begin by providing a scenario drawn from my analysis, and then turn to a concept developed in psychology, termed sonification, to better explain the mechanism involved in translation for awareness. Ultimately this section of my discussion elucidates the concept of corporeal engagement as a way to describe prosodic cues coincident with the hands-on manipulation of the material world and the felt experience of that work.

Translation in Prosodic Cues for Awareness

A team member in the procedure room updated his colleague in the control room on his progress about catheter work. The words and sounds contained in this verbal update suggested the catheter operator's satisfaction and sometimes dissatisfaction with the placement of the catheter. As before, the words expressed in the update carried lexical content, but the words and other meaningful sounds were laced with prosodic cues. Hearing those cues, the team member in the control room could then appreciate the tactile experience of the cardiac tissue in light of this team member's update. In addition, the team member in the control room could also see information about the catheter and cardiac anatomy on the screen, but this visual display could not convey the tactile experience of catheter movement that was often relevant to the progress of the procedure. Again, although the tactile experience of catheter movement was private, the display of catheter movement was public. Specifically, the team needed to ensure sufficient awareness regarding the status of catheter work as a corporeal engagement. Here the catheter operator had private access to vital qualities of catheter and cardiac phenomena, while the information was at best only partially visible on the screens, and at worst totally absent from visual representations to those in the control room. Although there is more to say about the screen-based visual information and its contextual relevance in the team's interaction, at present I want to focus on the translation of felt cues into a public audible experience in this scenario.

Movement Sonification

Existing psychology research on movement sonification (Effenberg, 1995; Effenberg, Melzer, Weber, & Zinke, 2005) offers a potential clarification of the mechanism embedded within the translation capacity of prosodic cues. According to Kramer et al., (1999), sonification involves the use of non-speech audio to convey information or perceptualize data with the goal of enhancing perception of action . Proponents of movement sonification argue that "auditory movement information can influence aspects of perception and action that seem to be relevant for the interaction of an individual with a partner or with its environment" (Schmidt & Effenberg, n.d., p. 208). Movement sonification is one way to better discuss the mechanisms of prosody that convey a corporeal engagement. The representational ability of the human voice and bodily action invites consideration by CSCW scholars interested in awareness work practices. The features and the examples of movement sonification provided prompt me to speculate on its role in my own data and to entertain the possibility that it may explain the translation mechanism embedded in the use of prosodic cues to facilitate awareness. Now, I turn to discuss three other examples.

In the first example, in the excerpt titled "What's our Heprin situation," the catheter operator reacted audibly to the movement of the patient on the table, voicing successively louder "ooo-ing" sounds. These sounds represented a physical (perhaps even an emotional) reaction to the experience of feeling the patient kick and thrash on the procedure table when her sedation was wearing off. In the second example, in the excerpt titled "Go down to where you think," the catheter operator repeatedly evinces strained out breaths and other bodily sounds. Here there is no lexical content accompanied with prosodic cues of a corporeal engagement. Instead, information about the catheter operator's physical engagement was enough to elicit a response from the team member in charge of the computer imaging work station. Lastly in a third example, in the excerpt titled "Tried to look at his left leg lead," the team member adjusting the electrical wires made sounds that make clear that he was simultaneously engaged in a physical and cognitive activity (both moving and thinking as he moved). This information and the format of the team member's utterance and action mutually informed the other team member standing at the procedure table.

In short, the sounds of an effortful body engaged in practical action lent its own precise and explicit information to the team and fostered their awareness about work-relevant tactile phenomena. In all of these examples, the catheter operator's private tactile experience was represented and transformed into a audible experience that could be shared publicly. In cardiac EP artifacts and technologies were not the conduits for representing and transforming tactile information instead the worker's own voice and body played this role.

With a greater appreciation of prosodic cues' translation capacity in support of awareness, notable contrasts in the use of prosody with other supports for awareness present in the cardiac EP environment. For example, in line 7 of the excerpt titled "Arrh ahh' - do do do do do do clock it", the cardiology fellow as the catheter operator used prosodic cues to make others aware of his difficulty with the catheter placement that was otherwise only partially visible in the medical images displayed on the boom and board. The images showed where the fellow's catheter tip was located and showed that the tip was not moving, but the images did not clarify the catheter operator's difficulty with its operation. The images displayed on the boom and board served as secondary supports to hearing these prosodic cues of a clearly challenging corporeal engagement. Once again, the voice and the use of prosody had the primary role, and the use of the screens had a supporting role.

PROPERTIES OF ANALOG COMMUNICATION

My literature review also highlighted that even with different types of communication asymmetries, participants in a social interaction tend to leverage a communication resource held in common to alleviate their asymmetric access. The findings presented in the last chapter cohere with this trend in the embodied communication literature. My investigation focused on the role that the voice (specifically prosody) served as a shared resource for alleviating the cardiac EP team's asymmetric access to catheter behavior, a specific type of tactile phenomena central to these procedures. I found that workers in HTC (C-NC) overcame asymmetries in access to one rich medium, human touch, using another rich medium, the human voice.

In this section I unpack the cardiac EP's teams use of the voice. I specifically discuss the human voice as an exquisitely adaptive media that defies categorical distinction (Streeck, Goodwin, & Lebaron, 2011, p. 12). It is helpful to consider the voice as an analog media for cooperation, in a sense thinking abstractly about this media, after delving into the detail of prosody that support work practices of coordination and awareness. This portion of my discussion focuses on two qualities or properties of the voice as an analog communication medium: the capacity for speech to be improvisational and to be quasi-linguistic.

The team's use of their voices allowed for improvisation and spontaneity, by which I mean that the team's bodies and voices made "automatic contributions to sense making" (Streeck, 2009, p. 3). In cardiac EP, the key moments of interaction were not pre-planned nor could they be. Instead the use of sounds and language were occasioned in the moment and produced (in a sense) in a spontaneous fashion. I observed that in at least half of the excerpts the timing of the interactions was relevant, and I will detail two. The first line of the excerpt titled "Arrh Ahh do do do do do clock it" is an excellent example of improvisational language use. Beginning in line 1, the attending physician Stan playfully mimicked the music playing in the cardiac EP surgery suite and finished his utterance with a directive for the cardiology fellow to "clock it." The timing of the directive coincided with an opportunity for action. Like the previous excerpt, the team members' talk represented in lines 52-54 of the excerpt titled "What's Our Heprin Situation" operated in much the same fashion. In these lines the cardiology fellow voiced his felt experience of catheter work by repeating the word "ohh" multiple times with tangible emotion.

In each of these examples team members produced utterances seemingly spontaneously as a responsive marker of action, but importantly that did not mean that the timing of the deployment of these utterances was not interactionally relevant. Quite the opposite was true. The timing of some of the utterances depended on the ability to monitor instrument movement in real-time as this information was displayed on the boom and board. The production of the utterances, seemingly out of the blue, were produced while the team involved in catheter work watched the screens together. The utterances served to spatially and temporally mark instrument action for the person handling the instrument, a point I build upon the prior discussion of prosodic cues as supports for coordination of catheter work.

Talk-in-interaction as an analog form of communication also allowed for quasi-linguistic utterances. At times members of the cardiac EP team produced utterances that were not quite recognizable as language but something more improvised while remaining richly communicative. In many of the excerpts the use of language was conventionally linguistic, but there were some instances in which the cardiac EP team departed from language convention in deploying an utterance. The excerpt titled "Hey Phil" provides an example of a quasi-linguistic utterance when the attending physician voiced "dap!"on line 9. This utterance was not only spontaneous but was also a quasi-linguistic aural mark of an adequate instrument adjustment, and a way of saying "stop" using a recognizable sound that nonetheless lacks a specific lexical meaning. A second example is located when the cardiology fellow says "uhhhh" on line 9 of the excerpt titled "Tried to look at the left leg lead." The fellow made a quintessential marker of thinking through audible sound (Mercer, 2000).

Based on these two properties one could characterize the voice as an interstitial media for cooperation. This descriptor emphasizes that cooperation occurred in large part because the voice is highly adaptable as it allows for "in-between states." The two properties of analog communication discussed in this section operated in different ways, and their uses were seemingly effective for different reasons. There is extensive literature that discusses the timing of utterances in talk-in-interaction, and the topic is central in textbooks. Even the timing and occurrence of pauses are closely analyzed. So in some ways the spontaneous production of a directive like “clock it” or feeling sounds like “ooh” are interesting—in my study particularly—because their productions are apropos of phenomena in a work environment with quite limited access, yet their meanings seemed largely understood by the participants involved. The use of quasi-linguistic utterances attracts scholarly attention as well. Research into natural language acquisition discusses quasi-linguistic utterances, nonsense, and other word-like verbal behaviors (Soderstrom, Blossom, Foygel, & Morgan, 2008).

In combination, these semi-spontaneous and quasi-linguistic properties of analog communication are connected to a thicket of issues in the study of embodied communication regarding the so called “interstitial meaning-making practices” as Streeck, Goodwin, and Lebaron (2011, p. 14) describe:

> In much of academic inquiry, the scene within which participants build action together is divided into categorically distinct phenomena [...] however a range of crucial hybrid acts come into existence in the spaces between canonical distinctions. These activities move across boundaries and intertwine diverse materials into enduring structures that reshape not only the physical and semiotic environment, but also the ways in which participants classify for each other what is happening in their interaction.

What I want to say about these properties has less to do with the novelty or exceptionality of these excerpts but rather how they are easy to overlook, tricky to neatly conceptualize, but nevertheless useful in the negotiation of a practical task like catheter work. Indeed, to my knowledge the scholarly community concerned with embodied communication has not systematically studied these two properties of analog communication. Here it is beginning to become clear that my study contributes to this scholarly dialogue in embodied communication. Furthermore it should be noted that the findings of my study agreed with much of what this literature contributed to the earlier review.

FINAL THOUGHTS

My literature review emphasized the importance of work practices for awareness and coordination in cooperative work. My study of HTC (C-NC) reinforces the importance of awareness and coordination, as these work practices were central to the way the cardiac EP team not only overcame their asymmetric access to catheter work, but did so interestingly through the use of prosodic cues. In the prior sections devoted to the discussion of coordination and awareness separately, I showed that prosodic cues allowed for translation from auditory experience to tactile experience as well as the translation of a tactile experience to an auditory one. In other words, the translation capacity of prosodic cues was bi-directional. The translation capacity of prosodic cues speaks to the properties of analog communication as interstitial. Borrowing from Goodwin’s (2000, 2002) writing, I argue that prosody served to connect the team's use of an ecology of sign systems and together contributed to meaning by virtue of the mutual elaboration of sounds, words, and actions.

There are a few final remarks to make at the close of this discussion when trying to appreciate how workers in cardiac EP used prosodic cues to overcome asymmetries in access to tactile information. First, and with the appreciation of the similarities of these work practices, I contribute to the discussion regarding the affinities between coordination and awareness in HTC (C-NC). Although the discipline of CSCW has long addressed awareness and coordination work practices as separate entities, running the risk of slicing up the problems of cooperation, I suggest that it may be helpful to discuss coordination and awareness work practices together rather than separately. Of course these practices can never be entirely separated because they are interactionally intertwined as seen in the coincidence of the work practices in HTC (C-NC).

Second, based on my research in which the voice and body played a central role in supporting coordination and awareness in HTC (C-NC), I open a discussion on the role of the body as an under investigated support for coordination and awareness studies of cooperative work. In both practices, prosody was a primary support for the team's coordination and visual displays were a secondary support. Yet CSCW has run the risk of missing the role of the body by addressing awareness and coordination primarily as these relate to technology design.

Third and similarly, previous CSCW research tended to approach asymmetries as a problem to solve, in a sense seeking to rebalance human ability through design of computing technologies and alleviate asymmetric access in computerized work. CSCW's design-driven approach can lead us to accentuate and nominalize cooperation into distinct work practices in ways that belie the fluidity of cooperation as a situated achievement of skilled bodies. My analysis suggests that the degree of adaptability of the body and voice remain difficult to approximate in systems design. This point harkens back to the lessons of CSCW studies of the slow, partial, and step-wise computerization of office work (Suchman, 1996). I would suggest that the adaptive properties of the human voice presented in this dissertation offer a meaningful contrast with the artifacts and technologies described in CSCW studies, including the designed supports for coordination and awareness. The lesson we glean from this study is that focus on the design of technologies can obscure some of the interesting ways that bodies and voices manage key requirements and overcome the challenges found in cooperative work.

Fourth and lastly, based on my findings I contribute to a broader discussion of theoretical perspectives useful in guiding CSCW's continued investigation of cooperative work. From all that I accomplished and learned through this dissertation, I suggest that the living body is a fruitful theoretical perspective for research related to the investigation of the study of work with technologies irrespective of their type or combination. The "living body" (Streeck, 2013) is a concept I adopt from phenomenology, in particular as it is presented in the literature concerned with empirical investigation into embodied communication.

It seems that one of the reasons that system designers struggle to build systems that could approximate work with non-computing technologies was that they consider the body as merely instrumental, rather than see the full potential of the "living" body. An instrumental view of the body discounts the ways that workers involved in HTC (C-NC) do not just use their voices to coordinate or maintain awareness as they would an instrument but instead coordinate and make others aware as part of their lived experience of cooperation. Perhaps considering the body as living, especially as it relates to the voice, may help system designers to build systems that could better serve as secondary supports to the living body as it is engaged in cooperative work in a heterogeneous technology landscape.

Although innovative and thorough in its own right, the research presented in this dissertation has some limitations that future work might address. Two limitations in particular would be fruitful for future inquiry. The first limitation concerns this work's limited range of study. Examining HTC (C-NC) in different work contexts and to compare cases across those contexts instead of relying on a single case in a single context as I have done here would allow researchers to tease apart the various ways that workers' access shaped the work practices they employed beyond what I have discovered. Numerous contexts are available for such future study. For example, online repositories of aerospace missions offer an enticing and expedient source of new data germane to interests in cooperative work.

The second limitation concerns the cursory treatment of linguistic details described in prosodic cues. I did not explore whether there were categorical boundaries around the use of prosodic cues (like changes in pitch) related exclusively to one practice but not another. Specifically, the prosodic cues that I identified in the practice of coordination highlighted changes in pitch and elongation in word production, whereas the prosodic cues that I identified in the practice of awareness highlighted vocal stress and reduced speaking volume. At this point it would be premature for me to claim such a strong relationship between the uses of these cues. Thus, although I acknowledge some trends in the excerpts identified so far, we cannot assume that prosodic markers such as pitch and vocal stress always neatly fit within one category or another.

Conclusion

Beginning with the construction of polylithic artifacts by aboriginal men who built stone knives with resin handles, workers engaged in hetero-technic cooperative work (HTC) have long leveraged an advantageous combination of different technologies to pursue shared goals. To achieve their goals, workers in HTC need to coordinate and take action with an awareness of the current context of their work. Given the importance of coordination and awareness to the success of a cooperative effort, it should come as little surprise that paleo-anthropologists, among others, considered the HTC acts needed to construct polylithic structures to be a rudiment of human's capacity for spoken language (Greenfield, 1991; Ingold, 1994; Reynolds, 1994; Stout & Chaminade, 2009). From its beginning, HTC promoted two essential human abilities: (1) the ability to do work with the help of others, and (2) the ability to use language to aid in this work (Reynolds, 1994; Tomasello, 2010, p. 339).

Although HTC is rooted in prehistory, this dissertation investigated it from a contemporary vantage. I adopted the name HTC (C-NC) to describe a cooperative work arrangement wherein workers rely on a combination of computing (C) and non-computing (NC) technologies. I demonstrated that examples of HTC (C-NC) work are found in a variety of contexts, including mechanics performing engine repair and repairs to the International Space Station, where workers leverage the unique capabilities of computing and non-computing technologies to accomplish goals that they otherwise could not. The use of multiple and different technologies in combination mitigates the limitations of a single technology type, but also introduce complications into cooperative work. One significant complication is that workers in HTC (C-NC) almost unavoidably contend with asymmetric access to work relevant tactile information. Though the significance of workers' asymmetric access to one another's felt experience of technology use likely varies with each cooperative work arrangement and its objectives, my review of studies of work and technology suggests that such asymmetries are as ubiquitous as they are under-investigated. Understanding how workers contend with these asymmetries stands to draw analytic attention back to the living body, and the felt experience of work.

My review of studies of work and technology suggested that the lack of treatment of HTC (C-NC) was likely an unanticipated by-product of scholars' enthusiasm for the introduction of computers to the workplace and efforts to witness, or hasten the dawning of, a new technological era where work with non-computing technologies would be lost to obsolescence. I argued that in making the shift to study computerized work, scholars of work and technology lost touch with the body and came to neglect the felt experience of work. In order to regain an analytical lens on the role of the body and sensory perception in a cooperative endeavor, I ultimately turned to studies of computer supported cooperative work (CSCW) and embodied communication for their treatment of three topics: (1) coordination, (2) awareness, and (3) asymmetries in access to information.

Based on my literature review, I posed a research question: How do workers in HTC (C-NC) orient to asymmetries in access to tactile phenomena? To address my research question I employed microethnographic data collection and analysis techniques to record and transcribe a set of five minimally invasive cardiac surgeries.

In presentation of my findings I described crucial work practices by which workers in HTC (C-NC) overcame their asymmetric access to tactile phenomena to coordinate and maintain awareness about catheter work. Engaging in the coordination work practice, the team member directing instrument manipulation used prosodic cues that served to convey qualities or amounts of desired instrument manipulation by degrees.

The work practice for awareness supported those overseeing, but not performing, instrument manipulation. Engaging in a work practice to foster awareness of catheter work the team member manipulating the instruments relied on prosodic cues that conveyed evidence of his corporeal engagement. In studying the medical team's cooperative work, I found that team members flexibly adapted to the particular access afforded by their work configuration. The first practice served as a mechanism for coordinating the execution of work with non-computerized technologies through the use of sound symbolic utterances. The second practice fostered a greater awareness of the status of a worker's execution of non-computerized tasks via movement sonification. In both work practices workers in HTC (C-NC) overcame asymmetries in access to one rich medium, human touch, using another rich medium, the human voice.

To explore and extrapolate on these transmodal work practices I discussed the theoretical underpinnings of Streeck's (2013) conceptualization of the "living body" and related my analysis back to the literature of CSCW and embodied communication. Doing so, I was able to reinvigorate understanding of coordination and awareness for a CSCW audience. In my discussion I recapitulated and teased apart arguments against an instrumental view of the body in communication that so easily slips back into studies of cooperative work when scholars allow the worker's body to fade from view.

Appendix A: Institutional Review Board Letter

OFFICE OF RESEARCH SUPPORT

THE UNIVERSITY OF TEXAS AT AUSTIN

P.O. Box 7426, Austin, Texas 78713 · Mail Code A3200
(512) 471-8871 · FAX (512) 471-8873

FWA # 00002030

Date: 11/21/16

PI: Erin C Whitworth

Dept: Information, School of

Title: Communication of Tactile Phenomena in Hetero-Technic Cooperation: Case Study of Minimally Invasive Cardiac Surgery

RE: Non-Human Subjects Research Determination

Dear Erin C Whitworth:

The Office of Research Support (ORS) reviewed the above protocol submission request and determined it did not meet the criteria for human subjects research as defined in the Common Rule (45 CFR 46) or FDA Regulations (21 CFR 56). IRB review and oversight is not required because the activities involve:

- [x] No human interactions
- [ ] Classroom activities used to teach methodology and technique
- [ ] Program evaluation where results are not generalized to other services or programs
- [ ] Secondary use of de-identified data set (no direct or links to identifiers)
- [ ] Obtaining information that is not about living individuals
- [ ] Obtaining information from publicly available sets
- [ ] Biographical research that is not generalizable beyond the individual
- [ ] Archival research using existing literature
- [ ] Other (Explain):

At this time you are free to begin your research as IRB approval is not necessary. You should retain this letter with the respective research documents as evidence that IRB review and oversight is not required.

If you have any questions contact the ORS by phone at (512) 471-8871 or via e-mail at orsc@uts.cc.utexas.edu.

Sincerely,

James Wilson, Ph.D.
Institutional Review Board Chair

Appendix B: Conversation Analytic Transcription Conventions

I created transcripts to lay out talk sequentially, utterance-by-utterance. Transcripts are titled and the lines of the transcript are numbered for easy reference. Speakership is indicated with three letter abbreviations. I mark speakers by roles instead of names. The attending physician is indicated using the abbreviation “ATT,” the cardiac EP nurse is indicated with the abbreviation “EPN,” the cardiology fellow is indicated with “FEL.” When necessary I transcribed the anesthesiology team’s and the circulating nurses’ talk, their turns are marked with “ANS” and “CIR” respectively.

There are several conventions used to indicate the organization of talk. Sometimes talk by the same speaker breaks over multiple lines of the transcript within lines of the transcript. The line breaks are not meaningful to the analysis unless otherwise indicated by other transcription conventions listed below or mentioned in the main text of the Findings chapter. The table below describes the symbols appearing in my transcripts, based on Hepburn and Bolden (2013, pp. 117-125).

Temporal and Sequential Organization	
[ ]	Square brackets indicate a spate of overlapping talk between two or more speakers.
=	Equals signs marks the absence of any discernible silence between two turns or between two parts of a turn. This “latching” convention is applied to talk by a single speaker talking multiple turns or an exchange of turns at talk by two

	or more speakers.
Pauses	
(.)	A period inside parentheses marks indicates a hearable silence, or micropause, within an utterance. Micropauses are two-tenths of a second or less.
(1.2)	Parentheses and numerals are used to mark longer pauses. Pauses are measured in tenths of a second.
Speech Delivery and Intonation	
okay okay	Bolded and underlined talk indicates vocal stress emphasis. Underlining is used to indicate some form of stress or emphasis. The more underlining within a word, the greater the emphasis. Talk appearing in the transcript that is both bolded and underlined indicate strong emphasis. Talk that is just bolded or underlined indicates a lesser degree of emphasis.
°okay°	Degree signs are placed around quiet or soft talk.
OKAY	Capitalized spelling indicates especially loud talk.
oka-	A hyphen marks the sudden cut-off of the sound.
okay::	Colons indicate the prolongation or stretching of the sound just preceding them. The more colons, the longer the sound is stretched.

Speed and Tempo of Speech	
>okay< <okay>	The combination of greater-than and less-than symbols (> <) indicates that a stretch of talk is compressed or rushed.).
Voice Quality	
£	The British pound sign indicate spates of talk produced in a "smiley" voice or with suppressed laughter (Jefferson, 2004).
Turn or Unit Final Intonation: Some lines of the transcript include punctuation, but the use of punctuation marks is not grammatical. Instead punctuation indicates different forms of intonation.	
okay. okay? okay, okay_	A period at the end of a line indicates a falling intonation contour, not necessarily an assertion. A question mark indicates a strongly rising intonation or pitch, but not necessarily an interrogative. A comma indicates slightly rising intonation, not necessarily a clause boundary and not necessarily marking that the speaker is continuing. An underscore indicates the end of a turn delivered at an even level intonation.
Features Accompanying Talk	
.hhh .HHhh	The appearance of a lower or upper case letter h indicates aspiration. The greater number of h's the longer the aspiration. Hearable in-breaths are shown with a period before the h.

Transcriptionist Comments and Uncertain Hearings	
(okay) (okay/oak) ((note))	Text inside a single parentheses marks an uncertain hearing. Alternative hearings are separated by a forward slash inside single parentheses. Text within double parentheses indicates a transcriptionist's note.
off-topic	It has been my practice to document but not transcribe off-topic talk in my analyses.
[Amar]	When a participant's real name is spoken I use their alias in lieu of their real name indicated in square brackets.

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