Micro-Coordination: Looking into the details of face-to-face coordination

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ABSTRACT

Sociality is one of the most fundamental aspects of being human. The key to sociality is coordination, that is, the bringing of people "into a common action, movement or condition" [134]. Coordination is, at base, how social creatures get social things done in the world. Being social creatures, we engage in highly coordinative activities in everyday life—two girls play hopscotch together, a group of musicians play jazz in a jam session and a father teaches a son how to ride a bicycle. Even mundane actions such as greetings, answering a phone call, and asking a question to ask a question by saying "Can I ask you a question?" are complex and intricate. Actors not only need to plan and perform situated actions, but also need to process the responding actions—even unforeseen ones—from the other party in real time and adjust their own subsequent actions. Yet, we expertly coordinate with each other in performing highly intricate coordinative actions.

In this work, I look at how people coordinate joint activities at the moment of interaction and aim to unveil a range of coordinative issues, using "methodologies and approaches that fundamentally question the mainstream frameworks that define what counts as knowledge" (p.2, [80]) in the field of Computer Supported Cooperative Work (CSCW). To investigate computer mediated interactions among co-located people, I examine different interactional choices people make in the course of carrying out their joint activities, and the consequences of their choices.

By investigating co-located groups as they played a collaborative, problem-solving game using distributed technologies in experimental settings, I (1) provide critical case reports which question and challenge non-discussed, often-taken-for-granted assumptions about face-to-face interactions and coordination, and (2) tie the observations to the creation of higher level constructs which, in turn, can affect subsequent design choices.

More specifically, I ran two studies to look at how co-located people coordinate and manage their attention, tasks at hand, and joint activities in an experimental setting. I asked triads to work on a Sudoku puzzle collectively as a team. I varied support for the deictic mechanism in the software as well as form factors of mediating technology.

My research findings show that:

(1) different tools support different deictic behaviors. Explicit support for pointing is desirable to support complex reference tasks, but may not be needed for simpler ones. On the other hand, users without sophisticated explicit support may give up the attempt to engaged in complex reference.

(2) talk is diagnostic of user satisfaction but lack of talk is not diagnostic of dissatisfaction*.* Therefore, designers must be careful in their use of talk as a measurement of collaboration.

(3) the more people talk about complex relationships in the puzzle, the higher their increase in positive emotion. Either engaging with the problem at hand is rewarding or having the ability to engage with the problem effectively enough to speak about it is engaging.

(4) amount of talk is related to form factor. People in both computer conditions talked less about the specifics oF the game board than people in the paper condition, but only people in the laptop condition experienced a significant decrease in positive emotion.

(5) different mediating technologies afford different types of non-response situations. The most common occurrences of non-responses were precipitated by speakers talking to themselves in the computer conditions. Participants did not talk to themselves much in the paper condition.

Differences in technology form factors may influence people's behaviors and emotion differently. These findings represent a portrait of how different technologies provide different *interactional possibilities* for people.

With my quantitative and qualitative analyses I do not make bold and futile claims such as "using a highlighter tool will make users collaborate more efficiently," or "making people talk more will make the group perform better." I, instead, illustrate the interactional choices people made in the presence of given technological conditions and how their choices eventuated in situ.

I then propose *processlessness* as an idea for preparing designs that are open to multiple interactional possibilities, and *nudgers* as an idea for enabling and aiding users to create and design their own situated experiences.

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[1] Any opinions, findings, conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

사랑하는 두딸, 채원이와 채영이 (유진이와 진선이) 그리고 항상 나의 옆을 지켜준 아내에게...

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Preface

> It was a very cold evening in December, 1998. I was sitting on a bench outside of the COEX, a building complex consisting of convention centers, exhibition halls and shopping malls, in Seoul Korea, waiting for my blind date. I looked at my watch. She was already 20 minutes late. Without knowing what she looked like, I became uneasy with the situation as the minutes passed. I looked around and searched for my date, a person that I didn't know, expecting to find her among the passersby. It was right at that moment when I saw a person approaching me, smiling and saying something to me. I was relieved by the fact that I had finally found my date, yet at the same time I also became little nervous about meeting her for the first time. Knowing she had said something, even though I couldn't figure out what she was saying, I stood up and walked toward her. I smiled back and started to greet her by asking if she had hard time finding the place, anticipating friendly greetings. Without even a glance, however, she walked past me as if she was a ghost or I was a ghost. At first I was puzzled and quite embarrassed, but then I soon realized that she was not my date and she was not talking to me at all. She was wearing a bluetooth headset and was merely talking on the phone. I knew what bluetooth headsets were, but had never seen anyone using one before. Even in a metropolitan area in Seoul, not many people had bluetooth headsets back then.

Technology is changing how we interact. In particular, it may be hard to perceive what other people are attending to. Although this precise scenario is not what I study, I start with this example because it is so common in everyday life. Think about it: For this imaginary man, when someone approaches him with a smile on her face and starts to talk to him, the primary, experienced, meaningful explanation is that she is his date. From his perspective, they are in the same social space. He initiates the greeting process of the possibly awkward blind date. Yet, for her, she is talking on the phone with someone else. Even when the man approaches her with a smile and starts to talk to her, she is not actually within the same space as the man. She is physically there, but she is interacting with the other person at the other end of her conversation. These two people are at the same *place*, but they are in different *spaces* [78].

What or whom should we then blame for creating this awkward moment? It is not solely the insensibility of the man who cannot distinguish a person talking to him from a person talking on a phone. The very fact that bluetooth headsets exit, and bluetooth technology enables the woman in the story to speak on the phone while the phone is concealed (probably in her back pocket or in her purse) is a substantial factor.

Digital technologies are everywhere, and impact our day-to-day lives, redefining and restructuring what it means to interact with each other. Winograd and Flores [207] once noted that unlike minor innovations such as automatic transmission which made automobile driving just a little bit easier, innovations in digital technologies are so radical that they instigate a whole new paradigm shift for human interactions. Indeed, advances in technologies over the past few decades have emancipated people from temporal and spacial limitations, enabling people at distance to interact with each other and carry out both synchronous and asynchronous social interactions. In addition, technologies also have impacted how co-located people sharing physical communal space carry out and coordinate their joint activities. For instance, one of the properties of face-to-face interactions was arguably *what you hear is what I hear*. Traditionally, unless a person whispered to a dedicated listener, it was not easy for the speaker to create a secure one-on-one communication channel within a group of co-located people. As we have seen in the story above, however, digital technologies have endowed people with an ability to create individual auditory spaces within the same physical space. Furthermore, technologies are increasingly becoming smaller and smaller everyday. These virtually disappearing digital technologies provide immense interactional possibilities for interactors, yet at the same time, create interactional quandaries. *What you hear is* ***no longer*** *what I hear* for the co-located people in our current society. Moreover, with wearable computing devices such as upcoming Google Glass, we cannot even guarantee that *what you see is what I see* even among the people within the same physical space. It will become enormously difficult to tell if a person is looking at me or looking at the personalized display projected onto his/her glasses. There is also a related problem which will form the topic of my dissertation. This is the problem of triple-space, interaction between co-located people in real time whose screens occupy the same computational space. In what I will call *triple-space* interactions, people can attend (or disattend) in the shared verbal space or in the shared computational space. The question is how much shared cognitive space they share or even seek to share. Although I did not study Google docs, it is the most well-known system that exemplifies my research focus.

Motivated by these rapid advances in digital technologies and the consequential impacts on human interactions, I have investigated computer mediated human coordination among co-located people during the past seven years. This document summarizes my research on human coordination.

Part I: Overview & Theoretical Background

1. Introduction

1.1 Overview

Coordinative social interactions are the primordial means through which interactors carry out joint activities [73]. People engage in coordinative activities in everyday life. Even mundane activities such as greetings, answering a phone call, and asking a question to ask a question by saying “Can I ask you a question?” are complex and intricate. Actors not only need to plan and perform situated actions [182,183], but also need to process the responding actions—even unforeseen ones—from the other party in real time, and adjust their own subsequent actions. Yet, we expertly coordinate with each other in performing highly intricate coordinative actions. More often than not, it is considered as a near-truism that we already know everything about how to collaborate productively [205].

In recent years, however, it has also been argued that the evermore ubiquitous and pervasive small screen technologies have begun to estrange us from certain types of face-to-face social interactions that we used to take for granted. For instance, Branham and Harrison describe an anecdotal account of a couple texting each other, instead of talking, while lying next to each other in the same bed [22] as portrayed in Figure 1.1. How strange is that? Yet, this is a legitimate way people interact with one another in the digitally augmented (or digitally fragmented) space.

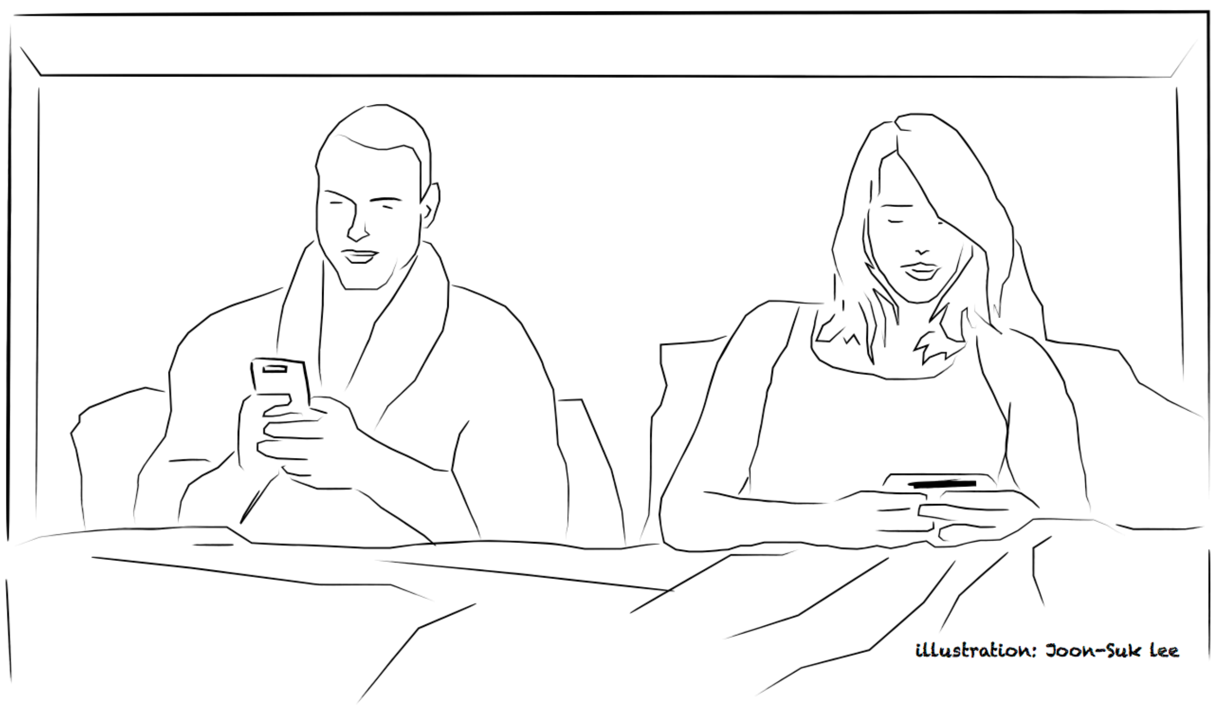

Figure 1.1: A Couple Texting Each Other in the Same Bed

The increasing use of visually segregated small screen technologies such as smartphones, tablets, and laptops among co-located people creates an interactional quandary in which interactors are not only required to allocate and manage their attentions in carrying out both perceptible social interactions within cotemporal/cospacial settings, and concealed digital interactions through transtemporal/transspatial digital media, but are also expected to operate across these two heterogeneous interactional channels, the social and the digital. How do we then manage our everyday activities within and through these complex, dual-layered, disparate, yet concurrently existing interactional channels?

In a way, this is the very question that dictates most of the field of Computer Supported Cooperative Work (CSCW). In my research, I, too, look at how people coordinate joint activities in technology mediated settings. By taking a phemonenologically-situated stance in investigating computer mediated coordinative activities at the moment of interaction, I (1) unveil a range of coordinative issues, using “methodologies and approaches that fundamentally question the mainstream frameworks that define what counts as knowledge” (p.2, [80]) in the field of CSCW, (2) examine different interactional choices people make in the course of carrying out their joint activities, (3) study the consequences of their choices, (4) provide critical case reports which question and challenge non-discussed, often-taken-for-granted assumptions on face-to-face interactions and coordination, and (5) tie the observations to the creation of higher level constructs which, in turn, can affect subsequent design choices.

1.2. Motivation — Why do we need to study *coordination*?

Successful innovations in technologies often impact people's lives quite radically, spawning drastic changes in society and affecting the way people live [207]. In recent decades, the spans in technological turnarounds have become shorter and shorter, and the impacts are getting greater and greater. The innovations in digital computing technologies of the past few decades, in particular, have affected our living patterns profoundly; we live a lot differently from people just decades ago. At the surface level, I point to changes such as the replacement of hand-penned letters to co-workers, friends, and loved ones with digitally constructed emails, SMS and IMs. Shifts between a traditional one-person-one-machine computing paradigm and a new multi-user, connect anywhere, connect anytime computing paradigm are taking place, and once-accustomed coordination activities are redefined and re-captured in a digitally augmented, computer mediated world.

Computationally enhanced and extremely personalized devices such as smartphones and tablets are changing our interactional patterns, opening up new interactional possibilities. On one hand, these technologies made distributed coordinative activities possible among geographically and spatially separated people: we read a friend’s wall-status and respond by posting “Like”s or comments while on a commuter bus, chat on a phone with family members in different time-zones, follow and refollow people we’ve never met, and tweet and retweet 140 characters for unspecified numbers of people to read. All these interactions get exchanged in the digital space. On the other hand, even among co-located people, considerable amounts of interactions loom in digitally augmented space as well. It is not uncommon for co-workers sitting in the same office space to IM. The story about the couple texting each other in the same bed also signifies the impact that digital technologies have on face-to-face interactions.

While we are certainly blessed with rapidly innovating information technology and ever-proliferating pervasive, ubiquitous, ambient computing environments, these technological advances come with important consequences. Great portions of once-visible-to-all day-to-day inter-personal interactions are now becoming increasingly invisible, concealed in the digital space. Digital technologies that open up new interactional possibilities inevitably close others [207].

Kim’s work on a “look” interface studies how sharing visual information on PDAs helps a latecomer or an overhearer to seamlessly catch up with accumulated understandings in group activities [105,106,107]. However, by the same token, the study inadvertently illustrates how the use of digital artifacts hinders peripheral participation and learning for people who do not have access to the shared visual information—that is, information on interactions within the digital space. Indeed, joint activities, collaborative behaviors, coordinations among people, especially those that involve digital artifacts, are less visible to the third person's naked eyes. Kim's work is an illustrative example of how computer mediated interactions consist of dual layered communicative channels (digital and social), and of how certain information can be effectively hidden or lost in these two disparate channels.

The dual communicative channels in technology-mediated interactions (Figure 1.2) signify the essence of the new interactional possibilities (and limitations) that technology is bringing us. The dual space interaction model shows how technology opens up multiple ways to coordinate joint activities for co-located people, but it also hints at how the changes can estrange us from the everyday activities we used to take for granted.

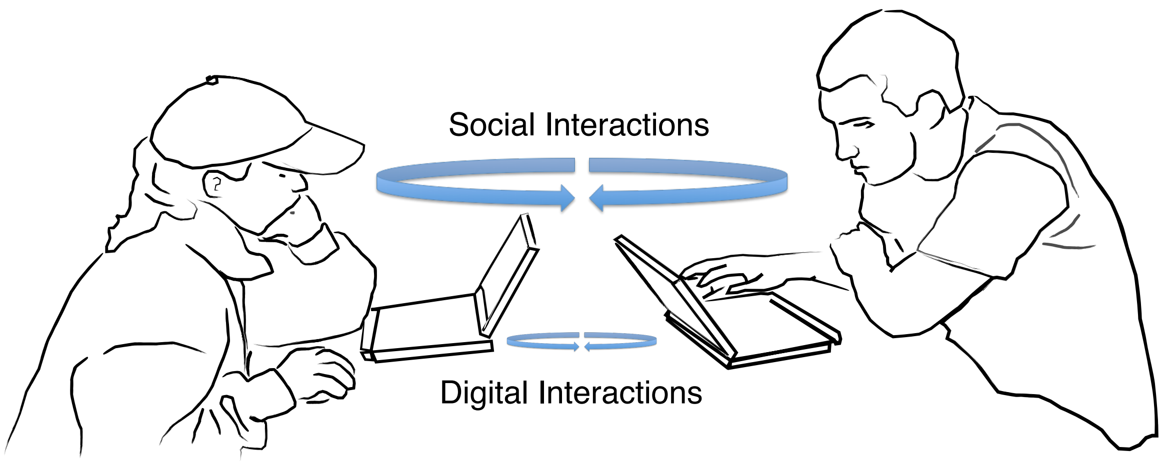

Figure 1.2: Dual Communicative Channels in Technology-Mediated Interactions

These rapid advances in technology create an unprecedented need to further study coordination. From a design point of view, coordination is still under-explored [188]; it is still not clear how to build better collaboration systems and software; it is even unclear what mechanisms underlie computer mediated collaborative activities. However, we engineers and designers who build collaborative systems, tend to take coordination for granted. For instance, some say we all learned all we need to know about coordination and collaboration in Kindergarden [205]. In the creation of collaborative systems, we often add monitors and keyboards and at times we randomly multiply whatever we have by 2 or 3 in the hope that the new system will enable harmonious collaboration. Many employ multiple input devices as an obvious first step in realizing single display groupware [170]. Or we become obsessively concerned with process loss and performance gain, creating systems that turn people into automatons. Much research studies how different interface technologies compare in experimental settings by measuring performance (i.g. [144,149], but less of it investigates how these different technologies are put into use and how different people utilize them differently at different times within different contexts. We still do not fully know how the dual communicative channels affect how we interact with each other in our everyday lives.

1.3. Triple Factor Space Interactions

The belief that people are experts in managing group activities with technology implies that the requirements are simple extrapolations of the already learned techniques. To the contrary, many tasks involve much more than simple extrapolations. For instance, Barron [5] describes how upper elementary school students solving math problems learn to manage a dual factor space: social and cognitive.

In a dual factor space, people need to manage their internal production of 'computational thinking,' and their social skills in managing group processes. Dual space tasks frequently involve asking a group to perform a task often thought of as belonging to the individual. Barron points out that joint problem-solving in dual space requires each participant to make his/her own thinking visible to the group, and to recognize other participant's thinking. She shows that not all groups know how to work together in dual space, and suggests that communication skills should be taught [5].

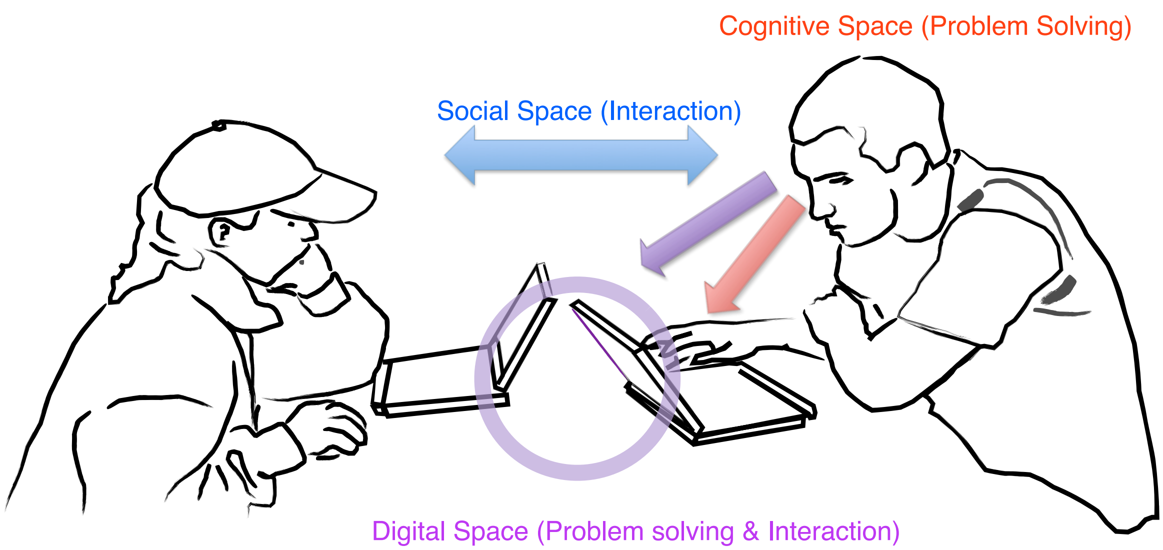

Figure 1.3: Attention and Task Management in Triple Space

In my research, I look at an even more complex yet increasingly pervasive situation: a *triple factor space* (*triple space*) in which people must manage not only the cognitive and social functions described by Barron, but also the challenge of making sense of the changing representations created by the other people on the shared medium.

Increasing use of small screen technologies is creating opportunities to engage in highly coordinative activities for multiple users with multiple screens. ***A situation of seeing the other but not being able to see what captures his/her attention is endemic*** (A situation represented in Figure 1.3). This situation enacts a constellation of three increasingly important properties that often co-exist: (1) participant choice about the definition of "current purposes" inherent in the situation—that is, people may satisfice (in Simon's terms [171]) between goals or sacrifice one (they may not be optimizing); (2) participant choice about mechanisms of engagement with others, that is, people may choose where to direct attention and where not to direct attention; (3) tasks in which the effects of particular actions are not known or not known for a considerable lag. Often coordination research within HCI is concerned with whether one player can see what another player is seeing (as in [187]). The assumption is that seeing the action is sufficient to infer that action's meaning. But in these dual or triple factor spaces, there are two points of failure: the players may not perceive changes in state, or they may not understand the meaning of changes in state.

In my research, I first investigate *triple space* interactions by creating situations that amplify certain interactional difficulties, and observing how people make their interactional choices *in situ*. As biologists dye cells under a microscope to make it easy to see certain properties of cellular activities, I create seamful situations that highlight behavioral challenges analogous to those that must be solved in our everyday lives, because of the presence of computing technologies.

By investigating co-located groups as they played a collaborative, problem-solving game using distributed technologies in experimental settings, and generating *design narratives* [87], I aim to bridge the gap between empirical studies and the design.

1.4. Micro-Coordination Research

In investigating triple space interactions, I study *micro-coordination* among co-located people playing puzzle games collectively on technology mediums[2]. Micro-coordination is "the tight coupling of behaviors to possibility in the moment." Studying micro-coordination means looking at detailed, fine-grained interactions in situ. Micro-coordination is like situated action [182,183] in that it focuses on the problem of how people decide who goes next in interaction, when, and what influences the course of the unfolding of behavior, but the notion of situated action comes from a school of thought that does not believe in looking at people's internal states or even their self reports. Situated action also does not directly inform designs. We—researchers who practice the micro-coordination way of looking at social phenomena—strive to connect what we see with what we build.

1.5. Empirical Study and Design

There still exists an on-going debate over whether or not, to what extent, and how methods for qualitative inquiry such as ethnography or ethnomethodology should be employed in HCI and CS (e.g., [1,45,46,56,83,139,161]). As noted in [1,45], some consider ethnography as a tool to extract requirement specifications from the scene. Anderson [1] points out that such a misconception has its root in confusing the "genres of reportage" of ethnography. He goes on, clarifying that ethnography is a literacy practice, but not a form of data collection and that ethnography is eventualized in a form of analytic reportage far more complex than an impressionistic one. By this he means that ethnography offers not just impressionistic descriptions of the world as it is, but it delivers analytic accounts of relevant issues that an ethnographer sees. The work of an ethnographer is not only to record and produce his/her interpretation of the world, but also to act as an "enlightened eye" for those who do not share the same experiences, delivering and informing what s/he saw to a broader audience [60].

Anderson also remarks on the contribution of ethnography to design as providing "an opportunity to open up the overall problem-solution frame of reference in the context of some proposed solutions to specific identified problems" (p.170, [1]) and "enable(ing) designers to question the taken for granted assumptions embedded in the conventional problem-solution design framework" (p.170, [1]). His view is in fact consistent with Dourish's view of the role of ethnography as providing models for understanding social settings and helping frame research strategy within the setting [56]. Simply put, ethnography enables

[2] I choose to use *mediums* over *media* in order to preserve the nuance of "mediating acts," and to differentiate the meaning from news media.

system designers to see the world through the lenses it provides. The purpose of ethnography is not to conduct “sanity checks” on design, nor is it to produce design specification [45]. There is more to the work of the ethnographer than delivering implications for system designers [56]. The point of ethnography is “to explore the sociality of novel design spaces opened up through the deployment of radical technology configurations in real world situations of use” (p.71, [45]).

On the other hand, it is a general consensus that qualitative research could inform design. Ethnography is both a means to put systems under scrutiny in a post-hoc manner to seek reasons for system failures and a valid and valuable resource for informing system designs [91]. Indeed, in past years, many prominent researchers have shown how studies based on the interpretivist paradigm such as ethnography can benefit positivist works such as system design. For example, [125] and [92] delivered implications for designing alternatives to the flight strip based on their ethnographic work at air traffic control centers. Heath and Luff [81] conducted an empirical investigation observing people at a line control room on the London Underground and came up with design implications for systems to support collaborative work in Line Control Rooms. Mackay [126] came up with implications for designing new email systems based on a series of interviews with office workers. The designs informed by these research works are tightly coupled with their qualitative studies. What these studies bring us is not “widely applicable panaceas, but some practical solutions to practical problems that can arise in a specific interdisciplinary collaboration between systems design and sociologically inspired ethnographic studies” (p.124, [91]).

In addition, even though the utilitarian approach to using ethnography as a mere data gathering tool is criticized for its appropriating the term ‘ethnography’ for something it is not [1], designers still find usefulness in so called ‘rapid ethnography,’ ‘quick-and-dirty ethnography,’ ‘scenic tour,’ or ‘fieldwork.’ Anderson himself also acknowledges that fieldwork has its own values—he states “designers might well work closely with users, engage in fieldwork... without ever engaging in the analytic ethnography” (p.155, [1]). No matter how diluted the ethnographic method one employs in research, it is undeniable that designers can get inspirations from the work and still find it useful. Indeed, designers get inspiration from “postmodernism, feminism, Marxism, Ann Landers, People magazine, the popularity of professional wrestling, (and) the New York Times best-seller list” (p.36, [161]).

Either as in the form of direct design implications or by virtue of a general understanding of people—which can later inspire designs—the accumulated knowledge produced by conducting qualitative research forms the basis for making abstractions and generalizations in the design process. Designers develop these generated abstractions and materialize them into digital artifacts which, in turn, get deployed into people’s everyday lives, instigating changes from within. The changes then necessitate new situational studies in order to build an understanding of the newly reformed nature of people’s lives. This is a dialectic relationship in which studies in qualitative research and studies in design research affect each other and trigger reformation on both sides iteratively. This view also affirms Crabtree and Rodden’s relational model between ethnography and design ”where technology becomes a vehicle for social research, the results of which in turn propel design” (p.71, [45]). This relationship is illustrated in Figure 1.4.

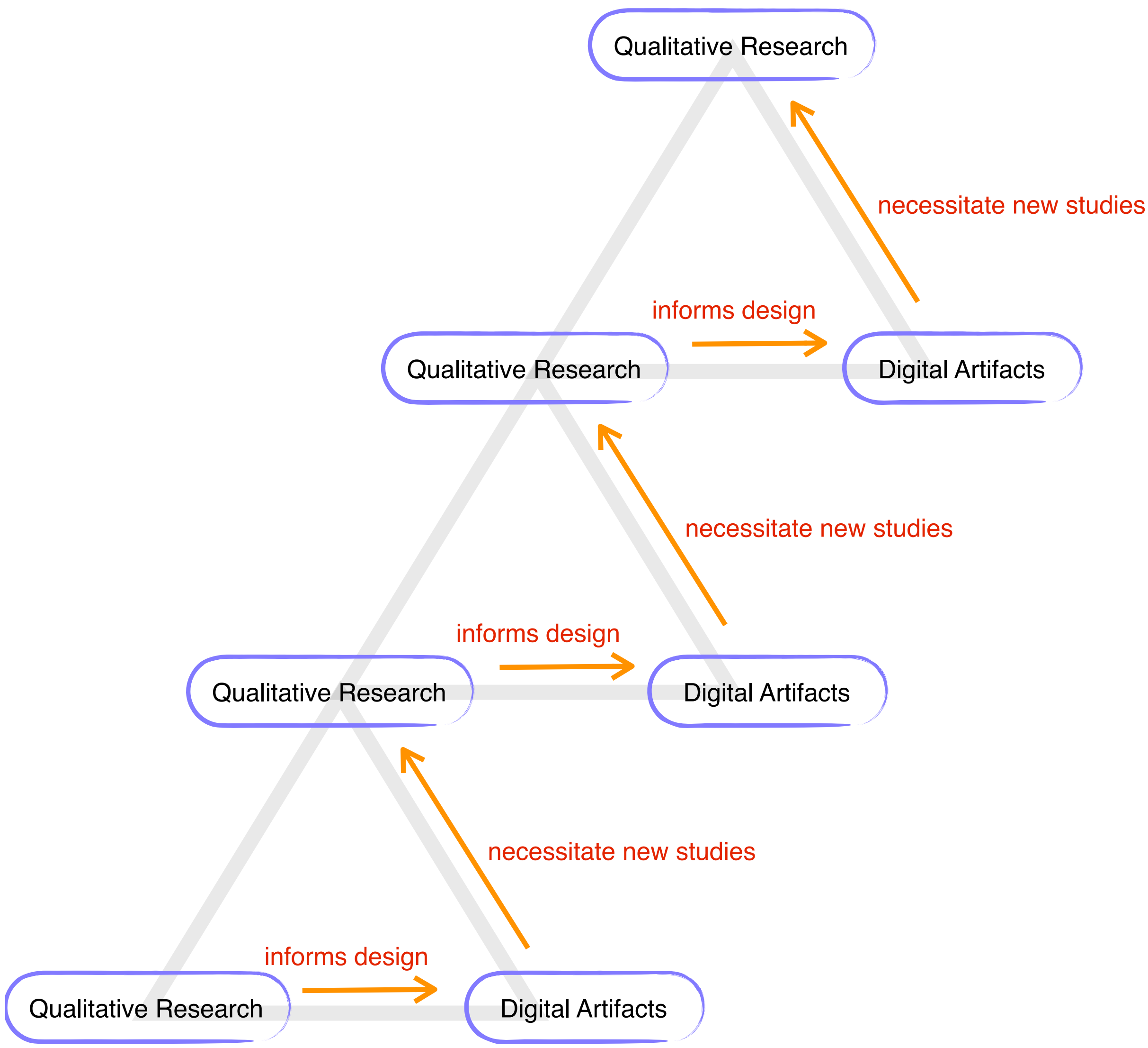

Figure 1.4: Relationship between Qualitative Research and Design

1.6. Contributions

My research also fits into this model of qualitative and design research work. The main focus of this research work is to explore different coordinative issues among co-located people collectively working on a joint activity in *triple space.* By providing detailed situated descriptions of different coordinative issues, and delivering *design narratives* that can inform and support future collaborative systems, this research aims to make a twofold contribution to the field of coordination study: first as a work of qualitative researcher in a digital era and second as a work of system design.

A computer scientist as a social science researcher in a digital era:

Researchers from other disciplines increasingly utilize computer systems while conducting research. As technology permeates our lives, social scientists equipped with computational powers march into digital space and expand their disciplinary boundaries. The works in digital anthropology [158] and virtual ethnography [86] show how social scientists are making their way into the digital realm and into HCI, while the majority of the HCI community is still debating over the extent to which we should embrace social science techniques within our field (e.g., [46,56,139]. While a debate over whether the field of computer science is becoming a subordinate tool whose job is to provide mechanisms for other research disciplines is mostly polemic and only shows futile hegemonic struggles in a multidisciplinary field, I contend that there is a need to extend the boundaries of computer science to include the work of social science for practical reasons.

As mentioned earlier, the advances in digital technologies are hindering ethnographers from seeing an important portion of moment-to-moment interactions. An ethnographer is by definition a third party observer whose eye is always interpretive [1]. The bare eye of an ethnographer is not adequately equipped to see interactions beyond what happens in the social space. In order to fully grasp the nature of interactions within the dual space (Figure 1.1), we need a new breed of ethnographers who have a third eye that can probe into the digital space. By a third eye, I refer to the ability to craft, deploy and manage various investigatory tools into the digital space. As the work of untrained ethnographers tends to overlook critical points in conducting research [63], the work of unequipped ethnographers won't even be able to see anything happening in the digital space.

For instance, when one conducts inductive research, one's ability to create technological investigatory tools on demand becomes crucial. Inductive research does not start with a clearly set hypothesis, nor does it have prior deterministic plans on what to look for. Researchers build concepts and theories as they gather and analyze the data. Oftentimes researchers even learn the types of data they will need to gather as they proceed with the investigation. Moreover when the task is to look at the situated interactions within the digital realm, not only are the interactions invisible, but the almost innumerable diversity in the communication protocols, network infrastructures and types of communicational software make the use of pre-built qualitative data gathering technologies impractical. As no plan can accommodate the richness of situated action, no off-the-shelf technologies will be adequate to capture the very diverse forms of digital information. In the course of laying out my research work in *micro-coordination*, I indirectly show how critical it is to have the skill set of a computer scientist for conducting qualitative research in a digitally augmented world.

In this sense, my contribution as a technologically informed social sicentist investigating face-to-face coordination is to build better understandings of how people jointly conduct group activities. The contribution output of my research are the qualitative descriptions of the cases that inform or reveal critical incidences of human behavior. Moreover I argue that my qualitative research as standing alone should be rightfully viewed as the work of a computer scientist, or that of a new type of hybrid scientist—a computer/social scientist.

A computer scientist as a system designer:

Even though my qualitative research work constitutes a stand-alone contribution to computer science, I also wish to show how the qualitative work can inform a design.

The design I draw from the qualitative research is not specific to the systems, occasions and people I look at for my qualitative research. That is, even though I look at groups of students playing puzzle games collectively on computers, my system design is not confined to another "improved" version of multi-player puzzle games. By providing two important alternatives to existing design thinking, my work provides insights and inspirations for future collaborative system design.

1.7. Methodologies

My approach to understanding technology-mediated coordination among co-located people is a mixed-methods approach in that I use not only a quantitative research framework, but also a qualitative one. Yet it differs from most other mixed-methods approaches. In a typical mixed-methods inquiry, "one method tends to be supplementary to the dominant mode of gathering data" (p.14, [69]); I use quantitative findings to lay the groundwork for delivering qualitative discussions, and at the same time use qualitative discussions to construct contextual understandings of quantitative findings. In addition, in using multiple frameworks, I intend not to make one frame central and all others supplementary. Instead I apply multiple analytical frameworks to investigate a socio-technical phenomenon, and proffer conceptual spaces to help articulate the meanings of the different research frames in relation to one another [52]. While I use a rather distinctive set of mixed-methods in my research, I believe that the study of micro-coordination necessitates this unique approach.

At the core, my research is rooted in the interpretivist paradigm as most qualitative research is. In investigating how people conduct joint activities at the micro level, I chose "micro-ethnography" as a primary investigatory method. Emerging from educational studies that looked at classrooms to investigate people's 'microbehaviors' in the 1960s and 1970s, microethnographic research has been associated with the use of multimedia technology such as video and audio recordings [61,194]. In conducting *micro-coordination* research, I use video and audio recordings to monitor the interactions within the social space and use computer generated log files and a server-side activity-monitoring tool to capture the interactions within the digital space. My research is also inductive research, as I do not start with any particular hypothesis, nor do I have a predetermined set of issues and behaviors that I plan to explore. Instead I seek to build situated understandings of a particular set of people in a particular situation.

In this regard, my research shares some commonalties with an ethnographic work. Yet, I create controlled experiments to look at interactions among triads playing Sudoku together. While experimental research often assumes a positivist stance, and empirical research such as ethnography is considered "naturalistic" and is usually carried out in a real world setting, my study takes place in a controlled setting, yet exhibits an ethnographic standpoint.

More specifically I view my work as an "instrumental case study". In my work, I focus not on creating a theory or drawing a generalization over people's coordinative nature, but wish to develop cases that can "provide insight into an issue or to redraw a generalization" (p.22, [69]). I believe that an instrumental case study is not less important than using qualitative findings to construct a generalization. I present my work "to illustrate an idea, … to show the limits of generalizations, to explore uncharted issues by starting with a limited case, and to pose provocative questions" (p.167, [156]). Table 1.1 summarizes the unique set of methodological properties of my research.

	methodologies
Research Setting	Experimental
Investigatory Method	Micro-ethnography
Data Analysis Method	Grounded Theory
Data Analysis Method	Statistical Test
Data Analysis Method	Conversational Analysis (Ethnomethodology)
Generated Output	Instrumental Case Study

Table 1.1: Research Methodologies

2. *Triple Space* as a Framespace

As mentioned in the previous chapter, *triple space* signifies increasingly pervading interactional situations (and difficulties) caused by prevalent use of small screen technologies in current society. People in *triple space* are expected to perform highly cognitive tasks, engage in social interactions, and manage the challenge of making sense of the changing representations created by the other people on the shared medium. This situation is analogous to sitting with a friend and working on Google Docs to write a paper together, or to working on a programming assignment with a classmate at a coffee shop. *Triple space* tasks often involve co-located people performing a task often thought of as belonging to the individual in technology mediated settings.

In exploring *triple space* interactions, I choose Team Sudoku as an investigatory platform. That is, in my research, I study situations in which three co-located people play Sudoku collaboratively using distributed technologies in experimental settings. Figure 2.1 exemplifies such a situation.

Figure 2.1: Three people playing Sudoku collaboratively using three laptops

In this chapter, I propose *TripleSpaceFS*[3] as a framespace [52] for investigating how people coordinate and manage their attention, tasks at hand, and joint activities in *triple space*. Dickey-Kurdziolek et al. note that framespaces provide systematic ways to apply multiple analytical frameworks to investigate a socio-technical phenomenon, and proffer conceptual spaces to help articulate the meanings of the different research frames in relation to one another [52]. In my research, I, too, use *TripleSpaceFS* as (1) an

[3] I use the term "*triple space*" to describe the interactional situation in which co-located people carry out joint-activities using digital technologies, and the term "*TripleSpaceFS"* to denote a conceptual framework (framespace) for discussing *triple space* interactions.

investigatory framespace to examine triple space interactions from experimental, ethnographic, and ethnomethodological perspectives, and aim to articulate the meanings of triple space interactions from within these three frames. In addition, however, I also use *TripleSpaceFS* as (2) a conceptual framework for conducting a systematic survey on previous research related to various properties of triple space interactions, and as (3) a design space to help develop future technological interventions.

2.1. *TripleSpaceFS*: Three Entities and Four Loci of Interactions

Any inquiry into triple space—whether one takes an experimental, ethnographic, or ethnomethodological stance—needs to start by locating and exploring three constituents of the interaction: *individuals*, *technologies* and *groups*. These three constituting entities interact with one another, affecting the group processes as well as the interactors' individual experiences within the group settings (after all, triple space is all about the *individuals* using *technologies* while carrying out joint activities as a *group*). These three entities are not unique to triple space. In fact, many existing models and theories of human computer interaction, computer mediated communication (and interaction), human coordination, group work and management science research deal with one or more of these entities (if not all).

TripleSpaceFS is, however, unique in that it identifies the three entities (*individuals*, *technologies* and *groups)* in its three conceptual frames (experimental, ethnographic, and ethnomethodological), and uses them to locate four key points of interaction. These four points of interaction are illustrated in Figure 2.2. The first two points of interaction are between a person and a technology. These bi-directional interactions are frequently studied in cognitive/experimental psychology, cognitive science/neuroscience, and HCI. The third point of interaction circumscribes the intercommunications among the distributed technologies. Such interactions are mostly studied in computer science. The last point of interaction is between and among the individuals, and encompasses a wide variety of social interactions. These social interactions are typically studied by social scientists and CSCW researchers.

Interactions in these four loci by-and-large represent different kinds of coordinative mechanisms and processes embedded within triple space (i.e., points 1 and 2 indicate not only man-machine coordination, but also how people manage and coordinate their attentions and the tasks at hand; point 3 marks computer networks (computer coordination), and point 4 shows human coordination.)

Without making an attempt to provide a full historical account of coordination research, in subsequent sections, I survey various disciplines and different kinds of research works that have explored different interactional issues present in four interaction loci. The purpose of the survey is to outline related research, and show the different philosophical and theoretical stances taken by each in investigating the different kinds of interactions in triple space. By doing so, I aim to show how my research fits within the broad and diverse research fields concerning triple space.

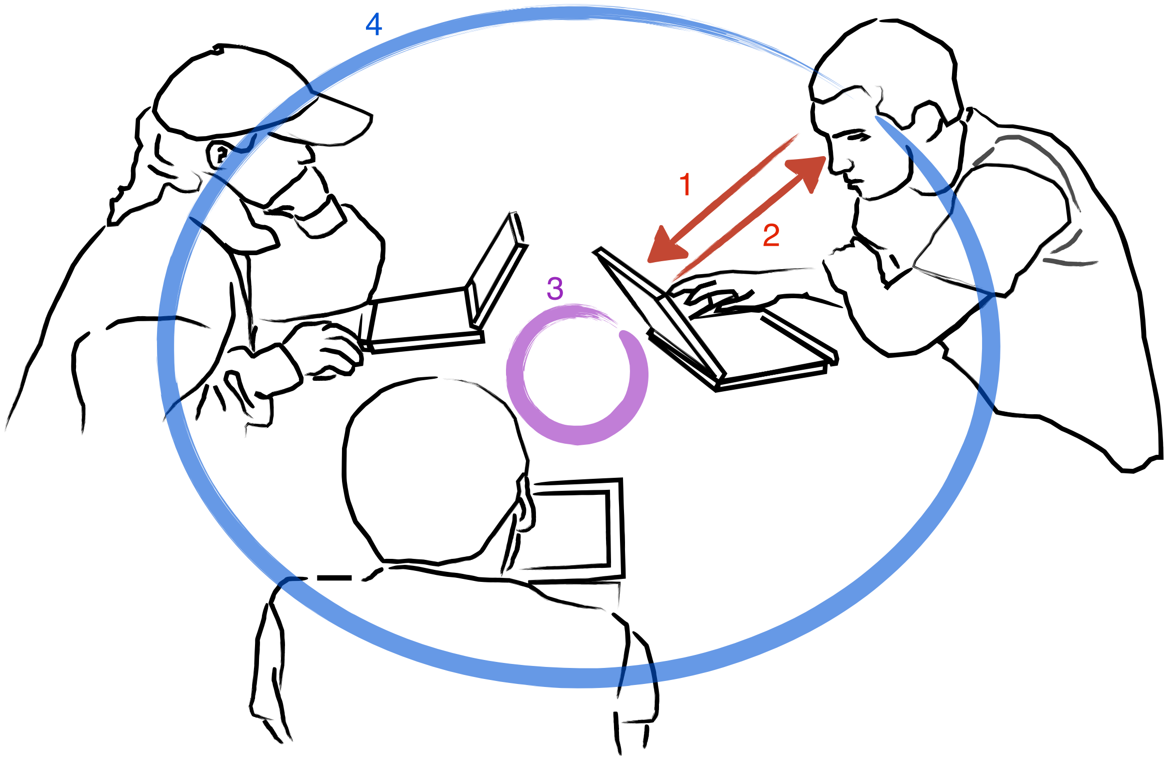

Figure 2.2: Four Interaction Loci in Triple Space

2.2. *TripleSpaceFS*: Related Work

2.2.1. Theory of Attention

In triple space, people must manage to attend to multiple factors; they need to focus on a given task, engage in social interactions with other people, and monitor changes made by others on the shared medium. The link from a person to a computer (denoted 1) in Figure 2.2 typifies an issue of how people manage and coordinate their attention and the tasks at hand in such a setting.

Generally speaking, attention is the ability to maintain a focus on activities, tasks, ideas, stimuli, and behaviors while ignoring distractions. The ability to attend is believed to be limited—there are limitations in the number of things that you can attend to concurrently, and selective—you can choose to attend to a particular stimulus among multiple stimuli. We all know what attention is (or we just believe that we do). In fact, William James, a 19th century psychologist famously stated that "everyone knows what attention is" (from James, W., 1890 [96] in [150], P.1). Many casually equate the term, *attention* with perception, consciousness, awareness, and mental effort/concentration.

In cognitive and experimental psychology, however, *attention* is considered as a very slippery concept [150,181]. Although *attention* is one of the most studied topics in psychology, many psychologists today admit that not all psychologists agree on what attention is [150]. Styles points out that *attention* is not a single concept, but denotes a variety of psychological phenomena [181].

Multiple competing theories on attention exist. For instance, Broadbent's filter theory (also known as early selection model) argues that stimuli are filtered and processed one at a time during the early stage of the attention process, and the selection process determines which one of the stimuli is to be attended [27].

On the contrary, late selection theory posits that the selection mechanism occurs after all stimuli are analyzed [49]. Sometimes *attention* is implicated with conscious focalization (e.g., voluntary attention, top-down attention), in other times it is said to be involuntary and preconscious (e.g., involuntary attention, bottom-up attention) [71,181]. It has been also proposed that the mind has two distinct processing units, one dealing with conscious attention and the other handling preconscious (or unconscious) attention [54].

Link 1 in Figure 2.2 represents previous and current research in cognitive psychology, experimental psychology, and cognitive neuroscience that investigates how human brains function in managing and coordinating attention. These studies typically view the human mind as an information processor, take a positivist stance, and operate within an experimental frame.

2.2.2. Awareness / Notification

Whereas cognitive psychologists and cognitive neuroscientists study the functional structure of the brain associated with human attention, various researchers in HCI and computer science typically strive to support and account for the limited, selective human attention in system design. In HCI, *attention* is often tied with the terms, *awareness*, *situational-awareness* and/or *notification.* For some researchers, dealing with attentional problems in system design means developing and embedding some sorts of mathematical abstractions or computational models of awareness into the systems. For others, solving attentional problems in system design means providing improved situational-awareness (awareness) with some kinds of implemented notification mechanisms. These researchers explore the link from a computer to a person (denoted 2 in Figure 2.2.) and more or less try to computationally implement human attention into system design.

For instance, Rodden [157] builds on a spatial model of interaction developed by Benford and Fahlen [10], and provides a mathematical model of awareness. Metaxas and Markopoulos [135] extend on Benford et al. [11] and Rodden [157], providing yet another mathematical model. By mathematically analyzing and calculating contrast, saliency and information density in video recordings, Liu et al. [118] attempt to preemptively measure viewers' visual attention. While these attempts are novel and important, these approaches are by nature very reductionistic, and any attempt to model the entirety of human attention is destined to meet with at best partial success if not total failure. Remember that *attention* is not a single concept, but denotes a variety of psychological phenomena [181], and that many prominent researchers are still very actively trying to study the functional structure of the brain associated with this diverse set of human attention: "nobody knows what attention is" (p.1, [181]). So to say that attention models attempt to capture what they do not fully know is not an exaggeration; we do not yet fully know how human attention works.

Yet we have to also acknowledge that such computational models have practical values. For example, based on the theory of selective attention [71], some researchers try to implement computational awareness models into robots in order to efficiently accelerate visual data processing by filtering and analyzing the most relevant portions of visual data [66]. In other cases, computational awareness models are used to enable robots to algorithmically infer and maintain state information of the target human's attention [89], or even to manipulate the target human's attention [20]. In addition, computational models are used for calculating human pose, gaze and facial expression in order to make a robot select a person as an addressee, creating the illusion that the robot is consciously managing its attentional focus [117]. Scaneval tracks and computes users' eye-gaze information to provide real-time attention assessment of the user [198].

Again, a problem with these kinds of studies is that what they are modeling is not human attention, but their own operationalized versions of it. For instance, many models equate gaze focalization with attention (e.g., [117,198]); however, it is a well known fact that "opening the eyes and looking" does not mean "seeing" [124]. Inattentional blindness, perceptual blindness, and sighted blindness are the terms for explaining how people can fail to notice an event or stimulus within their field of vision [123,124]. Inattentional blindness is probably best demonstrated by the invisible gorilla experiment [33,172].

In other cases, *awareness* simply means providing necessary information to the users. For instance, BusMobile provides information about bus schedules to promote user awareness of buses' arrival times, while Daylight Display provides information about the intensity of sunlight to help users become more aware of the approximate time of day [147]. These kinds of systems are typically categorized as notification systems. Strictly speaking, notification systems do not manage human attention, but just information delivery and display processes.

Awareness and notification research in HCI and computer science frequently takes a positivist stance, employs reductionistic and practical approaches, and operates within an experimental frame.

2.2.3. Digital Interactions

In Computer Science, "coordination" has come to mean mainly the coordination of information systems and their components. Machine coordination is treated as only the design and enactment of protocols: queuing, locking, layered networking, and so forth. The circle around three computers (denoted 3) in Figure 2.2 represents machine-coordination.

2.2.4. Joint Attention / Group Work / Human Coordination

The circle around three people (denoted 4) in Figure 2.2 represents the broad research domain of human coordination. Such research usually concerns how individuals operate within groups, how group processes are affected by various factors, how individuals jointly manage their attention while carrying out joint activities, and how individuals experience the group process.

Varying research groups and scholars from diverse disciplines have investigated such kinds of human coordination from multiple perspectives (e.g., experimental, ethnographic, ethnomethodological). In the sections that follow, I survey related research works that examine human coordination.

2.3. Joint Attention

For years, many psychologists have asked, "how do people regulate the attention of self and others in order to jointly process information?" That is, in layman's terms, to ask "how do people do things together?" *Joint Attention* is "an expression of the exquisitely honed human capacity to coordinate attention with a social partner, which is fundamental to our aptitude for learning, language, and sophisticated social competencies throughout life" (p.269, [141]). The first thing people learn to do as social creatures is to manage joint attention. Infants learn to follow their mothers' gaze even before they learn to speak [162]. Both experimental and clinical psychologists study joint attention and how it reflects human learning and development (e.g., [137,140,142]). They typically aim to scrutinize the functional structure of the brain associated with joint attention.

2.4. Group Work

Much research has studied how different factors affect group performance. Social psychologists studied how individuals affect group process and outcome. Behavioral phenomena liable to individuals such as social loafing [101], social traps [153] and process loss [180] have been identified as degraders of group performances. Personality characteristics such as dominance, anxiety, affiliation, and leadership are known to affect group interactions both negatively and positively [173,174].

The relationship between group process and task type has also been extensively studied [154,169]. For instance, groups become more active when discussing open-ended problems than those that have only one correct answer [50]. Hackman reports that differences in task type (production, discussion, and problem solving) account for up to 50% of the variance in group outcomes [76]. Carter et al. [31] report a similar correlation between task types (reasoning, mechanical assembly, or discussion task) and group interaction. McGrath's classifies group tasks into eight task types and four underlying performance functions on a two-dimensional circumplex schema [130]. In addition to individual traits of agents and task type, group size [65] and the composition [115] are known determinants of group processes and outcomes. Verbal equity is known to affect how groups perform [19].

Many of these research works are typically grounded in the positivist paradigm, and employ experimental methods and methodologies.

2.5. Coordination Research

In psycholinguistics, upon noticing the limitations of studying human cognition and the psychological process underlying language use based solely on *monologues*, researchers long ago started to look at language use in *dialogues* between pairs in experimental settings. Language use is indeed one of the most primitive yet essentially primary forms of joint action [35]. By conducting micro-analysis at the interactional level on dialogues between pairs of participants in controlled experimental settings, researchers investigated different aspects of language use and, hence, the coordination between the pair. For instance, Brennan and Clark [26] show that people establish a conceptual pact, an ad hoc agreement about how they and their addressees are to conceptualize the referent object, and report characteristics of conceptual pacts. Branigan et al.. [23] show the effects of priming during language production in dialogue. Schegloff points out that certain utterances such as "Can I ask you a question?" function not as simple questions but as preliminaries to further talk [163]. In these and like studies, researchers typically analyze conversations on sentential, clausal, phrasal, and lexical levels.

Some researchers study discourse processes in non-experimental settings as well and look at not only verbal conversations but also other non-verbal cues such as gaze shifts [104] and hand/body gestures [131,132,179], while others look beyond dyads and investigate conversations among multiple parties. Clark and Carlson, for example, examine conversations involving more than two people and explore how utterances are intended to be understood by addressees as well as side-participants [37]. Sacks, Schegloff and Jafferson examine how people take turns and report that turn-taking is interactionally managed and administered by interlocutors [160]. MH Goodwin, a linguistic anthropologist, observes children playing playground games such as hopscotch and jump rope in order to understand fine-grained coordination. She explains how children negotiate, interpret, create and recreate their social order from moment to moment interactions by focusing on disputes within play [74] and reports that characteristics of girls' argumentative speech is quite different from the stereotypical speech characteristic of black female, and more generally from that of female [75].

These research works are usually ethnographic and ethnomethodological. Most of these research works conduct microscopic analysis on conversation and coordination among two or more people and generate quite interesting and important findings. Yet, such research is typically considered the work of social science. Moreover, within social science, there have not been enough studies that investigate computer-mediated coordination, or within HCI, little research exists that examines such fine-grained analysis in studying computer-mediated coordination.

2.6. Coordination Research in HCI

From an organizational behavior perspective, there has been considerable exploration of the idea that "macro-level characteristics of an organizational design affect group structural properties which in turn directly impact performance" (from Pearce & David, 1983, in [90], p. 363). For example, Hossain et al. [90] point out the important role of people with "high social network centrality" in achieving coordinated outcomes in an organization. Valverde and Sole [193] point out that the underlying goals of the community and the underlying hierarchical organization play a key role in shaping organizational dynamics. Hinds and McGrath [85] focus on the ways that structure differentially affects local and geographically distributed teams. Bridging organizational and HCI perspectives, Malone and Crowston describe an area of inquiry they call coordination theory, which defines coordination as "managing dependencies between activities" [127]. A number of other thinkers in HCI and information studies concerned with influencing workplace process and distance communication [21,58,62,99,207] adopt the same approach to the underlying nature of coordination and the set of concerns raised by it. More recently, Herbsleb and his colleagues [32,84] build on coordination theory to support software engineering and awareness tools. From a systems/game theory point of view, there is a quite elaborated literature on the provability of the relationship between decentralization, communication, and control [43,190].

Efficiency and dependencies are important components of coordination, but I argue that they do not provide sufficient groundwork to support design in the general case. Even such widely cited papers as Clark and Brennan's "Grounding in Communication" describe properties and conditions of systems rather than the meaning of interactions [36]. A technology can help a person deal with children or old people or customers in a very efficient manner, but leave them feeling angry, alienated, lonely and so forth. A coordinated performance such as a symphony can be made more efficient by speeding up the playback, but loose its experiential point. A traffic light system can be optimized for flow in one direction, but a person who only travels in the other direction on that street can experience the system as unpleasant and unfair. Yet, our theories of coordination do not really address these factors.

A more encompassing approach is found in some of the oldest and most influential work at the juxtaposition of the social sciences and human-computer interaction. First, analogously to Heidegger's distinction between "ready-to-hand" and "present-at-hand" [82], the relationship between collaboration and coordination may be conceptualized as the relationship between the official program, that is, the one that people in retrospect give as account of "what they were doing" and the unofficial programs, the usually deprecated aspects of managing the interaction that include management of mutual attention, regard and effort. That is, the problem to be solved by interactants could be to a greater or lesser extent the "ready-to-hand" problem of how to engage in an activity well, or the "present-at-hand" problem of how to get through the next few minutes.

This analogy is a psychological one in that it emphasizes what an interactant is thinking about (or capable of thinking about) in the moment. Drawing on anthropology, sociology, linguistics and such more particular approaches as kinesics, ethology, and ethnomethodology, which do not necessarily assume particular cognitive states or structures, Suchman [182,183] draws unflinching attention to those aspects of human coordination that are well described as situated actions. Situated action explanations focus on what we call *micro-coordination*: the tight coupling of behavior to possibility in the moment.

2.7. Measuring Collaboration and Coordination

There are many ways to measure success in CSCW. With its focus on process—it is, after all, called, "computer-supported *collaborative* work"—it is not surprising that efficiency and optimization are often front-and-center. However, let us consider a sub-area where there are other measures. *Collaborative learning*, a widespread educational innovation [204] wherein groups and pairs of students work together to achieve a common academic goal, has been reported to improve not only students' learning [129,133] but also critical thinking processes [70]. Collaborative learning often revolves around a situation created by technology. Yet, although the notion of collaborative learning originates from the works of Vygotsky [195], who advocated the social aspects of developmental learning processes and saw the 'zone of proximal development' as an important site in learning, and of Piaget [152], who viewed inter-subject processes as playing a critical role in cognitive development, the pedagogical advantages in collaborative learning are often demonstrated through studies that employ easily quantifiable metrics such as test scores, class pass/fail ratios, and students' self-reported measures of fun, enjoyment and contentment [i.e., [129,133]]. These metrics often illuminate only rudimentary one-dimensional perspectives on success or failure.

While useful in determining broad-brush policy, these studies can, even in their own terms, lead to over-general conclusions and a failure to expose important variation. An increase in average test score can result from a substantial increase in test scores among the top 30% of the class while the rest of the class decreases performance. The same average gain could come from an overall and yet slight increase in test scores from the majority of the students. Large disparities in group performance may be observed between groups assigned to perform the same tasks that hold no distinguishably different traits [4].

2.8. Micro-coordination Research and TripleSpaceFS

In this chapter, I have surveyed how various research in diverse disciplines studies *coordination*. These different research works typically operate with clearly set goals within a fixed theoretical frame. In addition, when investigations involve multiple frames, as in mixed-methods research, they often "(1) premiate one frame over another and/or (2) provide supplementary dollops of material rather than integrated results" ([47] cited in [52], p.279).

For instance, as I have shown in this chapter, in investigating how people coordinate tasks, attention and joint activities, some researchers try to model the functional structure of the brain associated with attention, while some others try to provide detailed descriptions of how people work together in a specific setting. Some scrutinize how people take turns in conversation in minute details while others build robots alleged to have abilities to manipulate attention. These different studies build important ground work for human coordination. Yet, they often overlook other kinds of research.

Moreover, even though the findings reported from social psychology, organizational literature, small-group research, and group process research are many, we still do not decisively know what determines diversity in group processes and how group process affects outcomes. For instance, many identified factors—individuals, task type and process, and group size—mutually interact with one another, creating innumerable possibilities that could affect group processes. Finding a correlation between a fixed set of factors and group outcomes becomes impractical [53].

Important details such as non-verbal communication, turn-taking, affective tone, and shifts in attention [4] may seem irrelevant to the questions of interest (e.g. "which technology should I use?", "How shall I design?") but, because they focus on the meaning that the individuals and groups are creating in the moment of use—factors that arguably change in the presence of technology—they may ultimately lead to deeply founded design strategies and highly perspicuous constructs.

Hence, there have been an increasing number of empirical studies that focus less on the superficial attributes of the group processes, and that concentrate more fully on the processes and interactions [53]. I build my work along the lines of these studies and investigate coordination in an experimental but in situ context.

In addition, in investigating human coordination, I use *TripleSpaceFS* to build an holistic understanding of *triple space* interactions. I investigate coordination using multiple analytical frameworks, and argue that detailed analysis of the unfolding process is important. My research views *coordination* from experimental, ethnographic and ethnomethodological perspectives. Instead of tying and limiting my inquiry to measuring efficiency and productivity, I ask what kinds of interactional choices people make in triple space, and what the consequences of their choices are. Furthermore, I use *TripleSpaceFS* to systematically search for design opportunities in triple space, develop design ideas for building future collaborative systems, and reflect the designs in respect to *TripleSpaceFS*.

Part II: Micro-Coordination Study: Looking into the details of face-to-face coordination

3. Two Studies

Part II of this document (Chapters 3-7) reports on two *micro-coordination* studies (Study 1 and Study 2) that I have conducted as a part of my dissertation work. In these two studies, in order to examine the properties of coordinated actions involving co-located people using visually segregated technologies, I asked triads to play Team Sudoku—a multi-user, parallel-distributed form of the Sudoku game. This chapter (Chapter 3) describes the two studies in detail. Findings from Study 1 and Study 2 are reported respectively in Chapters 4-5 and Chapters 6-7.

Figure 3.1: Set-up for three Team Sudoku Players

3.1. Research History - Team Sudoku

This section describes two pilot studies that became the basis of my dissertation research. These two pilot studies (one-day pilot and Study 0) preceded the two *micro-coordination* studies (Study 1 and Study 2). By presenting these two pilot studies, this section intends to show the history of Teach Sudoku research, how the research focus has been shifted and expanded over the years, and how different methods have been incorporated so as to support the changes in the research focus.

3.1.1. One-Day Pilot Study

A great deal of research has explored how to support deictic reference in computer-mediated conversation, leading to what appears to be a general consensus among system builders in favor of a multi-mouse approach. While the multi-mouse provides an application-independent, context-free deictic reference solution, not only is it typically more costly to build, but also the usability of the tool regressively deteriorates as the number of users gets larger. Alternatives to the multi-mouse are application-specific, context-laden pointing mechanisms. Different research showed that the context-specific pointing conveys more information than a mere arrow. Yet, the context-free, multi-mouse pointing mechanism is generally taken as the panacean deixis solution in groupware. Moreover, there have not been enough studies investigating tailorability or appropriatability of those different approaches. Upon noticing that the needs for theories about when people profit from different kinds of support for pointing are current and large, we started the Team Sudoku project as a small pilot study to examine the possibility that different pointing mechanisms might affect users' coordination behaviors differently.

The pilot study compared an application-specific, context-laden pointing mechanism, a highlighter, and an application-independent, context-free deictic reference solution, a multi-pointer, in order to investigate whether one type of pointing mechanism would work better than the other in collaborative systems. The study was designed as a between-subject study. A multi-player Sudoku software was developed as a platform for the investigation. Figure 3.2 shows the software used in the study. The software development, the study design and the data analysis were done solely by a former POET lab researcher, Priyadharsini Duraisamy. I took part in administrating the experiment.

Procedures

Participants were recruited from the Psychology Participant pool, N>1200, at our university, and received extra credit for participation. The study was conducted with eight triads on 12/7/2007 in a small room with participants seated in close proximity to one another (Figure. 3.1).

Participants were introduced to one another when they came into the room. After the informed consent process, participants were asked to fill out pre-game questionnaires (Appendix A-1) about demographics, prior experiences with Sudoku and with the teammates (if any). Participants engaged in a system walk-through and an easy warm-up game to learn how the Team Sudoku system worked. After the warm-up session, the groups were asked to work together on two Sudoku puzzles significantly more complex than the warm-up puzzle, in an order counter-balanced across groups. The groups were given 15 minutes to work on each game. After each game, post-game questionnaires (Appendix A-2) asked players about their experiences with the game and with the other players.

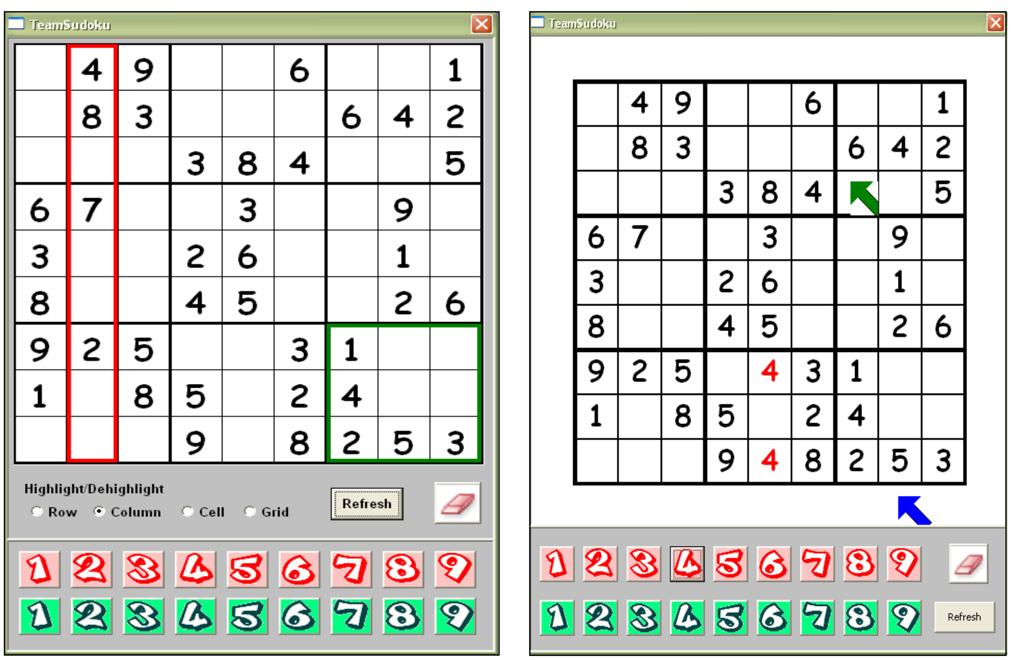

Figure 3.2: Team Sudoku Software – Version 0

Data Collection & Analysis

In this pilot study, three types of data were collected (Table 3.1). A video camera was used to capture the session activities. The camera recorded the sessions from an angle that could capture all the players in a single frame. Software generated logs recorded timestamped incidences of the reference tool use. Questionnaires (Appendix A-1 and Appendix A-2) collected user responses on their experiences of Team Sudoku by asking questions on the extent to which they used the reference tool during the game sessions, the extent to which they felt the need for the tool, and the extent to which the tool helped them to convey their ideas.

However, only the questionnaire data were then analyzed to generate quantitative understandings of the game sessions and to compare the extent to which each tool helped the users. Based on the questionnaire data analysis, Duraisamy concluded in her final report that the context-specific pointing mechanism worked better than the context-free one. However, the results were inconclusive since there was not enough data collected from which to draw statistically meaningful comparisons between the two conditions.

Out of the eight triads, only four groups were analyzed. In her final report, Duraisamy listed three reasons for not analyzing the other four groups.

- One group was only able to play the first 15-minute game due to time constraints.
- One group solved the first game using a context-specific pointing tool and the second one using a context-free pointing tool.
- Two groups took a different approach in solving the puzzle and never spoke or used the pointing feature.

data type	collected	analyzed
video recordings	yes	no
game logs	yes	yes
questionnaire data	yes	yes

Table 3.1: Data Collected - One Day Pilot

3.1.2. Study 0

After Duraisamy left the project, I continued conducting the Team Sudoku study in the spring of 2008. Since the one-day pilot study had too few sessions to yield any statistically meaningful results, I decided to follow up on the project and conduct the study in a more rigorous manner. We, as a research team, were still interested in seeing how the choices in deictic tools would affect participants' coordination patterns and how the different choices might manifest differences in users' performance or usage measures. However, our general interests in seeing *micro-coordination* and exploring diverse coordinative issues grew in this phase.

Procedures

Players were again recruited from the Psychology Participant pool. The participant computer system advertisement had two components: that the study was about a collaborative game, and that participants needed to have played Sudoku before. Players played in groups of two or three.

The study protocol remained mostly the same. After a walk-through and an easy warm-up game, groups were given two Sudoku puzzles to work on collectively in a counter-balanced order across groups. The groups were given 15 minutes for each game. The two Sudoku puzzles both had an equal number of filled and empty cells. These two puzzles (Figure 3.3) were selected to maintain a relatively compatible difficulty level between two games.

Puzzle A

	9	1				6		
5				7	1			
	7		9	3				
	5							2
		8	7	9	6	5		
7							1	
				8	5		2	
			2	6				1
		6				4	5	

Puzzle B

	8	6						3
4				8			7	
7				3	9		6	
	5					1		
			7	6	3			
		3					2	
	6		9	1				7
	9			5				2
1						6	4	

Figure 3.3: Two Sudoku Puzzles

Data Collection

The data collection process was slightly modified from that of the one-day pilot. In Study 0, four types of data were collected (Table 3.2).

A new set of questionnaires, pre-game (Appendix A-3) and post-game (Appendix A-4) with an extended number of questions were devised to gather users' self-reported responses on their experiences playing Team Sudoku. An additional video camera was added as a fail-safe. Two cameras captured the game playing activities. Screen movies of the game board were recorded on a monitoring computer to capture the activity on the game board. Software generated logs recorded timestamped incidences of the reference tool use. The study lasted for a semester and hosted 60 groups of triads and dyads.

data type	collected	analyzed
video recordings	yes	no
screen shot movies	yes	no
game logs	yes	no
questionnaire data	yes	no

Table 3.2: Data Collected - Study 0

Problem Identified

While analyzing the data from this study, we found critical usability issues in the Sudoku software, including usability inequalities among different tool conditions. The highlighter condition required users to perform one more mouse-click to activate the feature than the multi-pointer condition. Users in the multi-pointer condition could activate the reference tool with left-mouse button clicks, while the highlighter condition required users to select pointing options first to indicate whether they were going to select a cell, a column, a row or a 3 by 3 box, then use the left-mouse button to activate the tool. This inequality required me to modify the activation mechanism so that both tools would have exactly the same number of mouse clicks or keystrokes to invoke the feature.

Other usability issues included ambiguities in the choice of entry tools. The software had two sets of number stamps which only differed in color for entry on the game board. Users could use either one or both of these tools to enter numbers onto the game board. Even though researchers stated that the reds were intended to mark temporary entries whereas the greens were meant for the entires that were going to be permanent at the beginning of each session, players could still use these numbers interchangeably. There weren't any mechanical differences between these two tools besides the arbitrary meanings that researchers imposed on them. While this did not cause any problems in the game play nor did it render the software less usable, the ambiguities created unnecessary confusion for the users.

In addition, the multi-pointer functionality was not fully supported in the initial version of Team Sudoku. Instead of supporting multiple mouse pointers on the screen, the software only allowed each user to leave individually identifiable marks on the screen when a mouse button was clicked. This reference tool worked more like a mouse pointer stamp than a true multi-pointer.

The log files did not capture any user actions other than reference tool use. Information on the users' entrance and deletion of a number was not captured in the log files. The software also lacked managerial facilities such as puzzle loading and puzzle authoring features. Researchers had to manually recreate the puzzle within the game space every time a new session was run. These problems led to the reinvention of the Sudoku software as well as a puzzle authoring tool.

Reinventing Team Sudoku

A new version of Team Sudoku (version 1.0) was built during the summer and fall semesters of 2008. The version 1.0 supported 4 different pointing mechanisms: a *multi-pointer*, a *shared-pointer*, a *highlighter*, and a no-pointer (*no-help*). Figure 3.4 shows the new Team Sudoku software.

Supports for the temporary entries were implemented in version 1.0 in the form of note-entries. Note-entries provided users a way to tentatively mark possibilities by putting at most 9 different note-entries in each cell as if they were using pencils to mark temporary possibilities. Version 1.0 of Team Sudoku was used in both *micro-coordination* studies (Study 1 and Study 2).

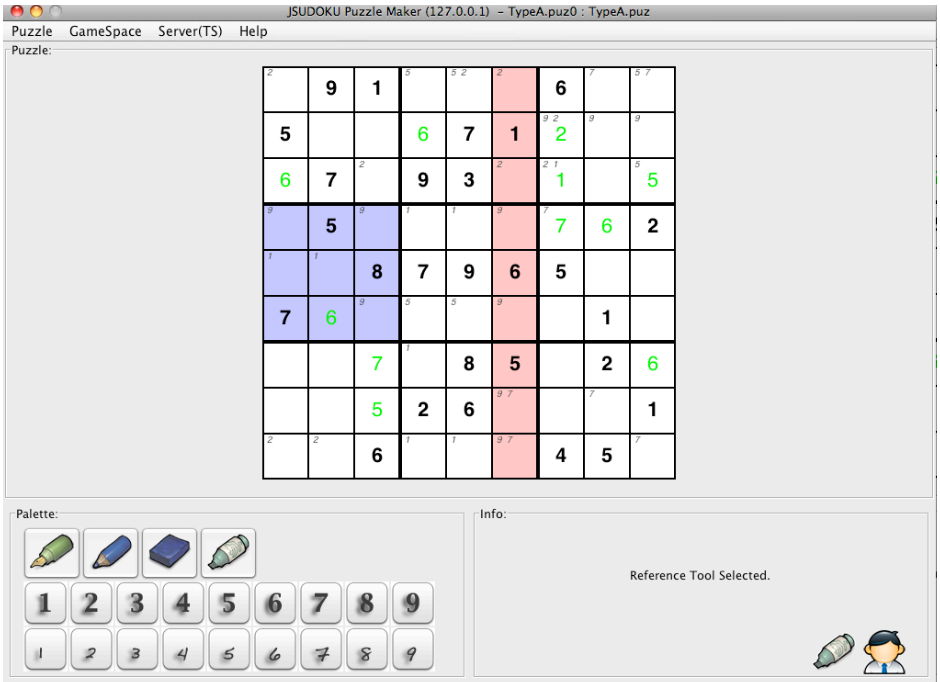

Figure 3.4: Team Sudoku Software – Version 1.0

3.2. Team Sudoku: Software

Team Sudoku is a multi-user, parallel-distributed form of the Sudoku game. Sudoku presents the player with a 9x9 board with digits between 1 and 9 in some cells. The goal of Sudoku is to fill the board so that each of the nine columns, nine rows and nine distinct 3x3 blocks contain exactly one instance of each digit from 1 to 9. Games are differentiated from one another by the number and location of starting digits. In the computerized form, each distinct game initially contains digits that cannot be written over or changed except by starting a new game, and that are a different color (black) from those that are in play (green). Team Sudoku provides users three distinct features for manipulating the board. A pen tool enables users to insert entries on the board, and a pencil tool allows users to tentatively mark possibilities (note-entries). Users can delete any entries on the game board with an eraser tool. Team Sudoku is a multi-user collaborative variation of Sudoku in which players have their own computers with their own copies of the shared game board. When one player fills in a number, erases a number, or uses an indicating tool, the results are promptly shared on all players' screens.

Four different versions of Team Sudoku used in the first iteration of the *micro-coordination* study (Study 1) vary in the support they provide for indicating. The four versions are a *multi-pointer*, a *shared-pointer*, a *highlighter*, and a no-pointer (*no-help*). In all cases, individual players use their private mouse indicators privately on their own screens. In the *no-help* condition, there is no explicit help for shared reference. In the *multi-pointer* condition, each person has a pointer that becomes visible to all the others in real time when the multi-pointer is selected and the mouse button is depressed. This is a slight variation to the commonly implemented multi-pointer solutions. Unlike most other multi-pointer solutions that provide pointers always visible to the others, the multi-pointer used in Team Sudoku is only made visible by the activation mechanism. The design rationale for this variation is to make the activation mechanisms in all conditions compatible to each other. In the *shared-pointer* condition, each player has control of the single communal pointer when he/she has selected the shared-pointer and depresses the mouse button. In the *highlighter* condition, players select the kind of object they wish to designate (cell, row, column, block) by clicking and dragging the mouse over the object to show the other players what they mean.

Each player is assigned a color at system start up. When a player activates referential pointers or highlighters, his/her color appears on all the screens (e.g., if a player's assigned color is red, his/her multi-pointer/shared-pointer appears red on everyone's screen, or when s/he highlights a row, that row appears outlined in red on all screens).

The multi-pointer and shared-pointer conditions are *context-free*, that is, they involve a general sort of pointing. The highlighter condition is *board-specific*, that is, it is tailored to the particular items that the players are most likely to want to indicate. The no-help condition uses the verbal referential skills that we know from ordinary life and that are available in all other conditions.

The second iteration of the *micro-coordination* study (Study 2) only used the highlighter version of the software.

3.3. Study 1

After Study 0, I redesigned the study protocol and conducted micro-coordination study 1 during the spring and summer semesters of 2009.

The changes made for Study 1 include the following:

- Monitoring Software now displayed different colors for each player entry. This helped researchers to identify which player made which changes on the board when watching the screen shot movies. Players' software remained the same.
- Logging features were modified to record not only the highlighting tool features, but all the moves users made on the board—inserting a number, deleting a number, inserting a note, deleting a note.
- In order to better capture the participants' behaviors during the game sessions, 3 cameras were used in the study. Each camera recorded the sessions from the angle that could best capture participants' facial expressions and hand/body gestures.

Procedure

Players were recruited using the SONA computer system from the Psychology Participant pool at our university, and received extra credit for participation. The advertisement said that the study was about a collaborative game and asked for people who had played Sudoku before. Players played in groups of two or three. Each group was randomly assigned to a variant of the game.

The study was conducted in a small room with participants seated in close proximity to one another (Figure 3.1). After the informed consent process, participants were asked to fill out pre-game questionnaires (Appendix A-3) about prior experiences with Sudoku and with the teammates (if any). We also gathered demographic information. Participants were introduced to the Team Sudoku system through a short walk-through session using an easy warm-up game. After the warm-up session, the groups were asked to work together on two Sudoku puzzles significantly more complex than the warm-up puzzle. The groups were given 15 minutes to work on each game. The games were presented in counter-balanced order. After each game, post-game questionnaires (Appendix A-4) asked players about their experiences with the game and with the other players. There was also a short discussion. Video recordings of all the game sessions were collected as well as screen shot movies of the games and computer logs.

Participants

A total of 168 (89 female, 79 male) college students enrolled in the study, forming 24 groups of two and 40 groups of three. Participants ranged in age from 18 to 23 (M = 19 SD = 1.13). 17 of 168 reported that their first language was not English, but none appeared to have difficulty because of this. Almost all the participants had prior experience with Sudoku. Four reported that they did not know the Sudoku rules. When asked how often they played Sudoku on a scale of 1 (rarely) to 7 (several times a day), a majority responded that they did not play Sudoku often (M = 2.51, SD = 1.42). But when asked how much they liked playing Sudoku on a scale of 1 (not at all) to 7 (very much), a majority responded that they liked playing Sudoku (M = 4.74, SD = 1.51). Most participants responded that they had played Sudoku on paper while only a small portion of them had played Sudoku on the computer. Only 6 of 168 reported that they had played a computer version of Sudoku with other people prior to the study.

We allocated three open slots per each sign-up session in order to form three-person groups. When only two participants appeared at the agreed time, we ran the game with them, resulting in 24 groups of two.

Data Collection & Data Analysis

Five types of data were collected (Table 3.3). To investigate different patterns of interactions among players and to understand how different groups managed group coordination, three video cameras recorded each session. With each camera facing one of them, we were able to ensure that each player's facial expressions as well as bodily gestures were captured in video recordings.

The 37 15-minute video recordings of the first Sudoku game for triads were fully transcribed using a slightly modified version of Chafe's prosodic transcription system [34], which focuses on information flow (Appendix D). A total of six researchers worked on transcribing the sessions in three different iterations. Full transcription of verbal utterances was created in the initial iteration. Descriptions of non-verbal gestures as well as critical changes on the Sudoku board were added in the second phase. Transcripts were then arranged into intonation and conversational turn units. The final transcripts were then reviewed several times together with the log files and screen-captured videos.

Final transcripts were then coded with multiple coding schemes in multiple iterations. Open and axial coding [44] was conducted on the segmented conversational turn units, resulting in multi-layered hierarchical coding schemes.

Log files as well as screen capture movies and session videos were viewed multiple times and the first incidences in which players made mistakes on the game board were traced, and detailed notes were taken (Appendix B).

Python scripts (Appendix C-1) were then developed to extract various statistics from the coded transcripts. Statistics on coding categories as well as the number of conversational turns and the number of intonation units that individuals and groups took per session were extracted from the coded transcripts.

Python based log file analyzers (Appendix C-2) were used to track the number of entries and note-entries made by each individual, the number of deletions performed by individuals, and the number of correct and incorrect entries in the final state of the game.

Statistical data from both transcripts and log files were then processed with the questionnaire data to form quantitative understandings of the participants and the sessions. Video recordings of the session and screen capture movies were used to build up qualitative understandings.

data type	collected	analyzed
video recordings	yes	yes
screen shot movies	yes	yes
game logs	yes	yes
questionnaire data	yes	yes
interview data	yes	no

Table 3.3: Data Collected - Study 1

3.4. Study 2

Following Study 1, I designed another iteration of the micro-coordination study. Study 2 was also designed as a between-subject study to examine how the form factors of technologies affect user behaviors. In Study 2, I compared three different technology conditions, a tablet condition, a laptop condition and a paper and pencil condition. The study protocol was modified again to better assist the data analysis.

The changes include the following:

- Each game session lasted for 20 min.
- Pre-study online questionnaires were added. Prior to coming to the study, participants were required to fill out an online questionnaire designed to prescreen people who did not know Sudoku rules. When participants who signed up for the study reported that they did not know how to play Sudoku, they were directed to a web site that had both descriptions of the Sudoku rules and sample games for participants to play.
- Participants no longer played a sample game. Instead, I extended the walk-through session to allow participants to have enough time to use and practice different features of the software. Reasons for taking out the sample game in the study process were (1) to capture the possible processes of setting up and negotiating game playing strategies that might happen during the sample game, (2) to eliminate the possibility that the interactions within the sample game would influence what might happen during the first game, and (3) to expedite the study process.
- Five personality self-report inventories were added in the pre-study questionnaire. The five inventories were Big Five [98], Circumplex Scales of Interpersonal Values [119], Circumplex Scales of Interpersonal Efficacy [120], Beck Anxiety Inventory [8] and Beck Depression Inventory [9].
- The 20-item Positive and Negative Affect Schedule (PANAS) [197] was added to pre-game (Appendix A-5), post-game1 (Appendix A-6) and post-game2 (Appendix A-7) questionnaires to measure participants' mood changes over the period of the session.
- Monitoring software was modified to display players' individual colors for the notes they made on the game board.

Procedures

Study 2 was designed as a two-phased, between-subject experiment. In Study 1, even though the participant recruiting advertisement explicitly asked for people who had prior Sudoku experiences, I still had participants come to the study without knowing how to play the game. So I made Study 2 two phased in order to discourage participants from coming to the study without knowing the rules.

In phase 1, participants were asked to fill out online questionnaires about demographics, prior experiences with Sudoku, and five personality self-report inventories (Big Five [98], Circumplex Scales of Interpersonal Values [119], Circumplex Scales of Interpersonal Efficacy [120], Beck Anxiety Inventory [8] and Beck Depression Inventory [9]). When participants reported that they did not have prior Sudoku experience, they were directed to a web site that had both descriptions of the Sudoku rules and sample Sudoku games.

In phase 2, participants were again brought into a small room and seated in close proximity to one another (Figure. 3.1.). They were introduced to one another when they came into the room. After the informed consent process, participants were asked to fill out a pre-game questionnaire (Appendix A-5) including questions about their experiences with the game and with the other players, and also the 20-item Positive and Negative Affect Schedule (PANAS) [197] that measures how people are feeling in the moment. The groups were asked to work together on two Sudoku puzzles, in an order counter-balanced across groups. The groups were given 20 minutes this time to work on each game. I added 5 more minutes to each game, hoping to see more interaction and more talking. After each game, participants filled out post-game questionnaires (Appendix A-6 and Appendix A-7), including retaking the PANAS. In the post-game2 questionnaires (Appendix A-5), I also asked them to rate how much they were satisfied with the group and the way it worked together on a scale of 1 (not at all) to 7 (very much).

In each game, participants were asked to play Sudoku puzzles either on a 25 x 30.5 inch sheet (base-line, Paper Condition) or on one of two different form-configurations (Tablet Condition and Laptop Condition) of tablet PCs. In paper condition, researchers prepared the Sudoku game board manually prior to the study and asked participants to solve the puzzles on that. In both computer conditions, groups were asked to collaboratively solve puzzles with Team Sudoku.

We made an explicit decision to use a type of computer that has a twist-and-swivel display so that we could configure the same computer both as a laptop and as a tablet. For laptop condition, mice were connected to the systems as the primary input devices, while for tablet condition, stylus pens were provided as the primary input devices. Keyboard input mechanisms were disabled in the systems to maintain compatibility between the laptop condition and the tablet condition in which keyboards are hidden under the laid-down screens, inaccessible to the users.

Participants

Players were again recruited from the Psychology Participant pool at our university, and received extra credit for participation. A total of 138 (75 female, 63 male) college students enrolled in the study, in 24 groups of two and 30 groups of three. Participants' age ranged from 18 to 41 (M = 19 SD = 2.28). Almost all the participants had prior experience with Sudoku. 15 reported initially that they did not know the Sudoku rules, but researchers confirmed that these 15 people were at least fully familiar with the Sudoku rules when they came in for the on-site experiment. Overall, participants reported playing Sudoku quite often (M = 5.35, SD = 1.51) on a scale of 1 (rarely) to 7 (several times a day). If only two participants appeared at the agreed time, the game was run with them, resulting in 24 groups of two.

Data Collection & Data Analysis

Five types of data were collected (Table 3.4). Four video cameras recorded each gaming session. With three cameras facing each participant and one capturing the entire group, we were able to ensure that each player's facial expressions as well as bodily gestures were captured in video recordings.

Five researchers worked on transcribing the sessions, in three different iterations using a slightly modified version of Chafe's prosodic transcription system [34]. Transcripts from audio were created in the initial iteration. Descriptions of non-verbal gestures as well as critical changes on the Sudoku board were added in the second phase. Transcripts were then arranged into intonation and conversational turn units. The final transcripts were reviewed for accuracy several times with the log files and screen-captured videos.

Log files as well as screen capture movies and session videos were viewed multiple times and the first incidences in which players made mistakes on the game board were traced, and detailed notes were taken (Appendix B).

Python scripts (Appendix C-1) were then developed to extract various statistics from the coded transcripts. Statistics on coding categories as well as the number of conversational turns and the number of intonation units that individuals and groups took per session were extracted from the coded transcripts.

Python based log file analyzers (Appendix C-2) were used to track the number of entries and note-entries made by each individual, the number of deletions performed by individuals, and the number of correct and incorrect entries in the final state of the game.

Statistical data from both transcripts and log files were then processed with the questionnaire data to form quantitative understandings of the participants and the sessions. Video recordings of the session and screen capture movies were used to build up qualitative understandings.

data type	plan to collect	analyzed
video recordings	yes	yes
screen shot movies	yes	yes
game logs	yes	yes
questionnaire data	yes	yes
interview data	yes	no

Table 3.4: Data Collected - Study 2

Figure 3.5 summarizes how two *micro-coordination* studies (Study 1 and Study 2) gathered and processed a variety of raw data to establish both qualitative and quantitative understandings.

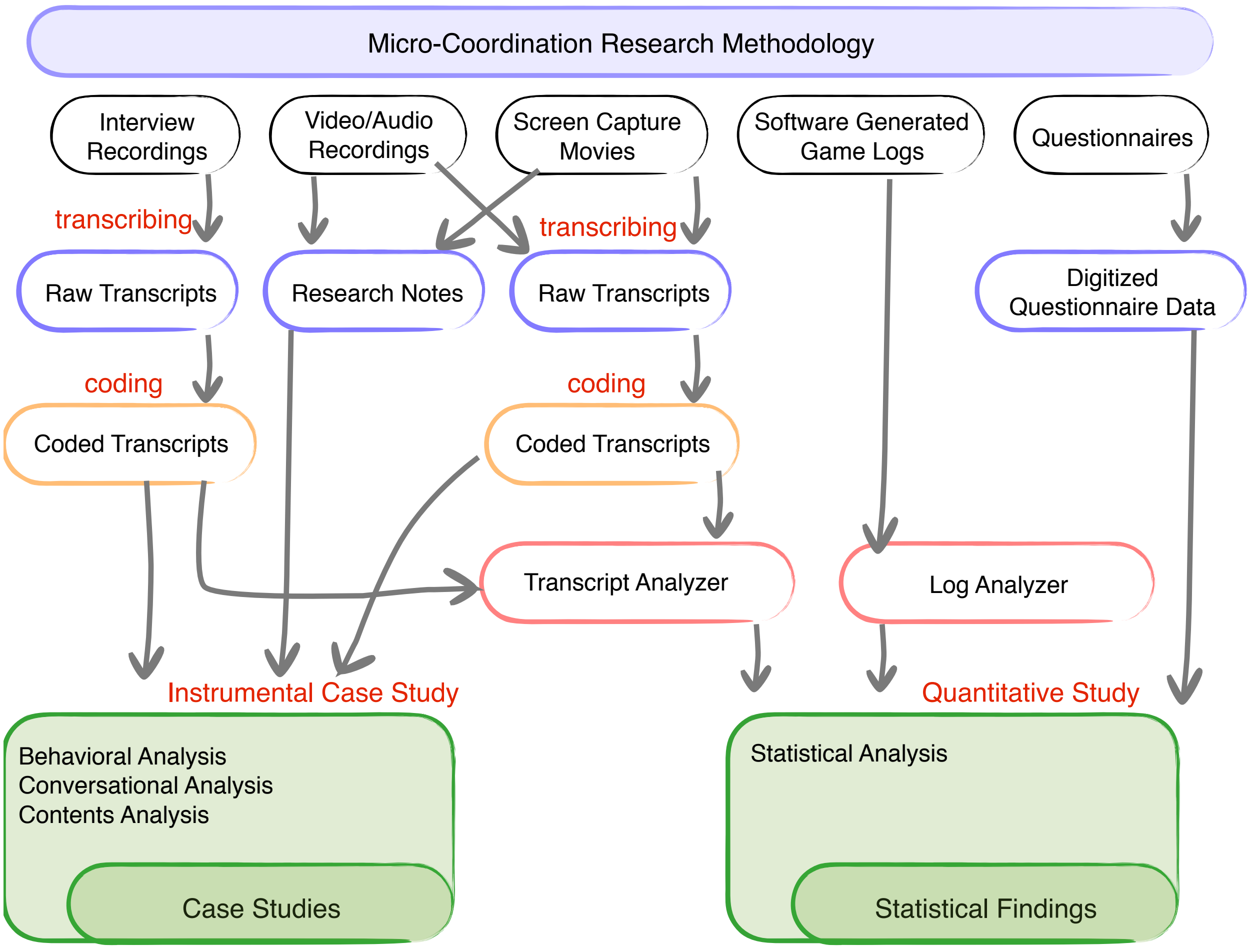

Figure 3.5: Micro-Coordination Research Methodology

Table 3.5 summarizes the number of sessions each Sudoku study ran and the number of sessions analyzed[4]. None of the data from Study 0 was formally analyzed. Data from the pilot study was analyzed by Priyadharsini Duraisamy. 24 dyads from Study 1 were analyzed by another researcher, Nouf Alaloula.

One-Day Pilot Study	Number of Session	Number of Session Analyzed
Triads	**8**	**(4+)**
Dyads	**0**	**0**
Total	**8**	**(4+)**

Study 0	Number of Session	Number of Session Analyzed
Triads	**30**	**0**
Dyads	**30**	**0**
Total	**60**	**0**

Study 1	Number of Session	Number of Session Analyzed
Triads	**40**	**40**
Dyads	**24**	**(24*)**
Total	**64**	**40 (64*)**

Study 2	Number of Session	Number of Session to be Analyzed
Triads	**30**	**30**
Dyads	**24**	**0**
Total	**54**	**30**

Table 3.5: Number of Sessions per Study

[4] + indicates sessions analyzed by Priyadharsini Duraisamy; * indicates sessions analyzed by Nouf Alaloula.

4. “Good Enough” Pointing in Pervasive Computing[5]

Abstract

Opportunities are growing to engage in highly coordinated activities for multiple users with multiple screens. A great deal of research has explored how to support deictic reference in computer-mediated conversation, leading to what appears to be a general consensus among system builders in favor of a multi-mouse approach. While the multi-mouse provides an application-independent, context-free deictic reference solution, not only is it typically more costly to build, but also the usability of the tool regressively deteriorates as the number of users gets larger. Alternatives to the multi-mouse are application-specific, context-laden pointing mechanisms. Different research shows that the context-specific pointing conveys more information than a mere arrow. Yet, the context-free, multi-mouse pointing mechanism is generally taken as the panacean deixis solution in the groupware. Moreover, there have not been enough studies investigating tailorability or appropriatability of those different approaches. The needs for theories about when people profit from different kinds of support for pointing are current and large. In Study 1, I studied groups of three and used systems in which deictic reference could be achieved by a number of mechanisms. The analysis showed that people chose pointing techniques that minimized the effort of communication; however, as the reference task became more complex, they employed more complex tools. Explicit support for pointing is desirable to support complex reference tasks, but not all pointing mechanisms match all cases. Different tools entail different deictic behaviors.

4.1. Introduction

Deixis, which includes verbal and non-verbal designations of references, constitutes the foundational building blocks of human coordination and communication [109]. Joint visual attention is integral to how people establish and maintain the mutual belief that they share the same understanding [35,36,38]. A great deal of research with multidisciplinary perspectives has explored how to support deixis and therefore conversation and communication in carrying out computer-mediated joint activities.

Some research has explored pointing in face-to-face situations, trying to understand the mechanisms of human coordination and the process of grounding. Some of it has explored pointing with different devices in the presence of others. Yet other research has implemented systems, often as models for generalized groupware solutions. Often these systems take the application independent multi-mouse as a primary and essential tool for encouraging multi-user collaboration without providing any design rationale [15]. However, in considering design choices, recent work, such as PointRight [97], expresses dissatisfaction with technological limitations on the number of pointers that can be displayed at the same time on the same screen.

In theory, the multi-mouse approach permits many different kinds of interaction. However, in doing so, it also sidelines thought about the usability cost of having or not having particular solutions. As we rely on semi-distributed systems of communication more and more, that is, systems that are used by people who are co-located and also communicating verbally, we need to understand the boundaries of successful reference and its relationship to the task at hand.

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[5] A condensed version of the findings reported in this chapter has been published as a full paper at CTS (C.HCI&ID) 2012.

Clark long ago noted that observation of fine-grain coordination is indispensable in studying how people establish and maintain common ground [38]. Many of his experiments contrive tasks in which deictic acts are tightly coupled to primary task goals [36,38]. Such research emphasizes the consequences of the referential acts to provide vividly polarizing results, comparing the absence and presence of explicit supports for indicating. Yet in most everyday collaborative activities, pointing is often secondary to achievement of the goal of the task, the degree to which the task must be complete and accurate varies, and, furthermore, many varieties of pointing mechanisms are available.

I expand upon the work of Clark and Krych. Like them, I create a synthetic task. However, I investigate different shades of coordination and deictic gestures by detaching the act of pointing from the immediate goal of the task. In my research, each of the four computer systems that I examine provides a different kind of explicit support for pointing, but each also contains many resources that can be brought to bear on accomplishing the task of indicating. By allowing not one but several different choices of pointing mechanisms, I compare the similarities and differences in the affordances of the different deictic tools against a background more similar to that in the everyday world than in most prior research.

I examine the properties of coordinated action involving co-located people using visually segregated technologies, in this case, laptops. The coordination I examine is that of co-participation in solving a multi-player Sudoku puzzle, using technologies that provide different kinds of supports for pointing actions.

I compare multi-pointers to two additional deictic reference tools and to a no-reference-tool (no-help) condition in this collaborative puzzle-solving context. Clark and Brennan [36] claimed that people use the least-collaborative effort to achieve common ground. In this situation, I find that across a range of tools and micro-situations, people appear to use the least effortful mechanism to convey deictic information. Their choice of tools (fingers, voice, reference tools, other indicators) appears to depend on the complexity of what they are trying to convey. They appear to move to more complex tools only to make more complex references. I provide evidence about how different tools produce different behaviors and also how differences in task difficulty are accommodated by different choices of deictic and indicating techniques.

4.2. Background

4.2.1. Shared Visual Display

Shared physical environment and shared visual space is one of the key constituents for building a shared cognitive environment (Sperber and Wilson as cited in [25], P.95). When the workspace is mutually visible to all participants, people use not only verbal communications but also gestures and other actions to build shared knowledge bases for coordinative activities [38]. While picking up the subtle auditory and visual cues in co-located face-to-face settings and orchestrating fine-grained coordination with others are skills everyone learns to master in everyday life, building systems to support the same level of coordination among geographically distributed work groups has always been a challenging task.

Building on the importance of shared visual environments, research on co-located groups has often emphasized large displays, either as supports for small screen sharing, as in Colab [64,176,177,187] or as the primary focus of design [95,103,151]. SmartBoards are a popular product that emerged from that line of research. Interactive, multi-player games on devices such as the Wii and xBox 360 can be seen as the game correlate of this kind of strategy.

Much research on smaller screens has focused on developing techniques to create virtual shared spaces that preserve the essence of physically shared ones, especially through using video connectivity [16,17,57,185]. Indeed, Kirk and Fraser claim that the onus of designing groupware to support remote collaboration is to bring about solutions that can minimize the discrepancy between co-located work settings and spatially dispersed ones [108].

Other research has contested the need to simulate physical connectivity. Instead, it focuses on abstracting the connections between people at a distance through attempted simulation [145]. Indeed, the claim implicit in "Second Life's" name is that people can conduct life on line [210].

Some early and on-going research also focused on supporting virtual shared space on individual computers in face-to-face collaboration. Perhaps the most important example, Colab [176], supported people working on separate computers together in the same room. The issue of when participants could see one another's contributions proved crucial to how it worked [187]. One lesson of this was that the shared physical environment and shared virtual space sought in distance communication research could also be lacking in co-located, technologically-supported work.

However, the relationship between co-located people sharing physical communal space has changed drastically over past decades. Small screen technology is permeating our daily lives and restructuring interaction. Given the ubiquity of cell phones, portable gaming devices, MP3 players, and so forth, *the situation of seeing the other person but not seeing what captures his or her attention is endemic.* Even table-top displays, which are shared, and allow co-located people to collaborate at the same time on one surface, usually involve a separate rather than a unified perspective on the material on the table [138,166]. Some users see content upside down. In the context of highly structured games, current products, such as Nintendo-DS, may be connected to form a shared space with different views held by each participant.

4.2.2. Indicating in Technologically-Mediated Interaction

Closely related to the problem of shared visual space is the problem of indicating in technologically-mediated communication. Many techniques have been explored. The Colab project struggled with the extent to which *telepointers* would be distracting as compared to informative [176]. MediaSpace captured hands over workspaces [17] and the DrawStream Station used shadows of hands not only to point, but also to convey richer gestural information [79]. Similarly, Ishii's Clearboard project used projected shadows [93]. Spotlight uses virtual lightings (Searchlight and Spotlight) to direct attention on large-screen displays [103].

The affordances of these various techniques have been studied both from pragmatic points of view, in inquiries about their adequacy and from cognitive points of view, as investigation of how people indicate [113,114,203].

By-and-large, these studies reveal how people coordinate and what helps them when acting remotely or when they are focusing on the same screen. There is also considerable work that examines how people coordinate around artifacts that only one has complete access to [38,41,165]. However, there is very little work that examines how people coordinate around artifacts that themselves provide channels of communication while in the presence of one another. (Radar screens could be considered channels that provide shared information in the context of air-traffic control, since all air traffic controllers see the same information, but that sharing did not turn out to be a primary issue in Mackay's study [125].)

Two kinds of general computational models support the possible arrangements of visual sharing and indicating: Single Display Groupware (SDG) or Multi-Display Environments (MDE).

In SDG, multiple physically co-located users interact with a single computer and a single shared display simultaneously [178]. Many systems that support multiple input devices have been developed in alignment with this model [15,143,170,178]. In particular, many employ multiple input devices as an obvious first step in realizing single display groupware [170]. But, since no legacy operating system natively support multiple mice, SDG systems and solutions vary in the multiple input mechanisms they employ. While some of the early systems support SDG at the application level, several solutions implementing SDG at the middleware level provide application-independent SDG solutions. Either way, there is considerable variance in the behavior at the user level.

The MDE focuses on supporting groups of co-located users interacting with a mixture of personal and shared large devices [14]. MDE provides an encompassing environment for both individual and group work. To support opportunistic collaboration between participants, and to create naturalistic mode shifts between individual and collaborative work, different technologies and techniques have been incorporated into MDE applications. The most common approaches to MDE are contents replication [13,136,184] and input redirection [6,12,97].

Although SDG and MDE models are intended to be general frameworks, it turns out that many of them are implemented with one particular understanding of support for deixis: multi-pointers [15,143,170,178,196,202]. Multi-pointers provide separate shared pointers for each user. When these multi-pointers are used on one large screen, they also serve as the individual mouse pointers for each participant. When, however, the participants have separate screens, participants usually have a private mouse pointer that is only shown on their own screen and a multi-pointer that serves the explicit purpose of sharing.

4.3. Kinds of Pointers that Support Co-located Coordinated Work

One of the main interests I have in investigating coordination in a setting in which each individual has his/her own display is to see how people use deictic gestures and deictic reference tools. In addition to a *no-help* approach to shared referencing across the multiple displays and to a *multi-pointer* approach, I present two additional approaches.

The first is a *board-specific* approach: *highlighter*. This condition exemplifies a context-specific approach. This approach supports the idea that the *context-specific* indicator can usefully show more precise information about the referent than a *context-free* arrow pointer can. In the case of shared Sudoku, the objects of interest are those on the board. Indeed, when working individually on a screen, applications create context-sensitive pointers, such as the cursor mark in Microsoft Word. This idea has been explored in collaborative applications in the large; one of the reasons that the Media Space and DrawStream Station projects used video connectivity was because the researchers had noticed that hands convey more information than a mere arrow [17,79]. They were working in settings, architecture and product design, that involve creating and sharing drawings and that entail both iconic and deictic gestures [131]. In my case, supporting collaborative Sudoku puzzles, deictic references seem more important than iconic. Furthermore, the application users have a small number of obvious, specific pointing needs (e.g. cells, rows, columns and blocks).

The second is a *shared-pointer* approach, which differs from multi-pointers because it provides multiple users with just one generic communal pointer, jointly visible to all participants, but controlled by one at a time. Anyone can grab the shared pointer at any time, but they may be taking it away from someone else. Early work on group processes often featured "batons" that could be passed, but these usually signified control of the floor, rather than serving as specific in- the-moment aides to conversation.

4.4. Variation in Software

4.4.1. Variations of the Reference Tools

For this study, I use four versions of Team Sudoku that vary in the support they provide for indicating. In all cases, individual players use their mouse indicator privately on their own screens. In the no-help condition, there is no explicit help for shared reference. In the multi-pointer condition, each person has a pointer that becomes visible to all the others in real time when the tool is selected and the mouse button is depressed. This is a slight variation to the commonly implemented multi-pointer solutions. Unlike most other multi- pointer solutions that provide pointers always visible to the others, the multi-pointer used in Team Sudoku is only made visible by the activation mechanism. The design rationale for this variation is to make the activation mechanisms in all conditions compatible with each other. In the shared-pointer condition, each player has control of the single communal pointer when he/she has selected the shared-pointer and depresses the mouse button. In the highlighter condition, players select the kind of object they wish to designate (cell, row, column, block) by clicking and dragging the mouse over the object to show the other players what they mean.

Each player is assigned a color at system start up. When a person activates a referential pointer or a highlighter, his/her color appears on all the screens (e.g. if a person's color is green, his/her multi-pointer is green on every one's screen, or when the person points with the shared pointer, it appears green, or when s/he specifies a row, that row appears outlined in green on all screens).

The multi-pointer and shared-pointer conditions are context-free, that is, they involve a general sort of pointing. The highlighter condition is board-specific, that is, it is (in theory) tailored to the particular items that the players are likely to want to indicate. The no-help condition uses the verbal referential skills that we know from ordinary life and that are available in all other conditions.

4.4.2. Methods of Referencing

In addition to these explicit supports for indicating, there are a number of different ways to point. Participants in all conditions can (a) use purely verbal communication and (b) appropriate other system features to indicate. The Sudoku software has two different input systems; one for number entries and the other for notes. Notes appear as very small, grey italicized numbers in boxes. Multiple notes can appear in the same box. In the study, participants used these notes as entries, but they also appropriated them as referencing or pointing devices.

Similar improvisational use of digital artifacts and functionalities can also be found in other digital applications. For example, in some massively multiplayer online role-playing games (MMORPG) where players do not have any pointing or referencing tools built in, people repeat a process of grabbing an object and releasing it immediately to make the object flip constantly, making the object salient to others.

4.5. The Study

4.5.1. Procedure

The study was conducted in a small room with participants seated in close proximity to one another (Figure 1). After the informed consent process, participants were asked to fill out pre-questionnaires about prior experiences with Sudoku and with the teammates (if any). We also gathered demographic information. Participants were introduced to the Team Sudoku system through a short walk-through session using an easy warm-up game. After the warm-up session, the groups were asked to work together on two Sudoku puzzles significantly more complex than the warm-up puzzle. The groups were given 15 minutes to work on each game. The games were presented in counter-balanced order. After each game, questionnaires asked players about their experiences with the game and with the other players. There was also a short discussion. Video recordings of all the game sessions were collected as well as screen shot movies of the games and computer logs.

4.5.2. Participants

Players were recruited using the SONA computer system from the Psychology Participant pool, N>1200, at our university, and received extra credit for participation. The advertisement said that the study was about a collaborative game and asked for people who had played Sudoku before. Players played in groups of two or three. Each group was randomly assigned to a variant of the game.

A total of 168 (89 female, 79 male) college students enrolled in the study, forming 24 groups of two and 40 groups of three. Participants ranged in age from 18 to 23 (M = 19 SD = 1.13). 17 of 168 reported that their first language was not English but none appeared to have difficulty because of this. Almost all the participants had prior experience with Sudoku. Four reported that they did not know the Sudoku rules. When asked how often they play Sudoku on a scale of 1 (rarely) to 7 (several times a day), a majority responded that they do not play Sudoku often (M = 2.51, SD = 1.42). But when asked how much they liked playing Sudoku on a scale of 1 (not at all) to 7 (very much), a majority responded that they like playing Sudoku (M = 4.74, SD = 1.51). Most participants responded that they had played Sudoku on paper while only small a portion of them had played Sudoku on the computer. Only 6 of 168 reported that they had played a computer version of Sudoku with other people prior to the study.

The three-person sessions were assigned randomly to different Team Sudoku conditions: 10 groups played with the highlighter, 10 with shared-pointers, 10 with multi-pointers, and 10 with no-help for pointing. When only two participants appeared at the agreed time, we ran the game with them, resulting in 24 groups of two, divided across the four conditions. In this paper, we address only the 40 3-person groups. We base our qualitative discussion on the examination of the 10 groups from each condition.

4.6. Statistical Findings

To see how well participants liked the collaborative, computer-based version of Sudoku, pre and post questionnaires asked whether participants preferred playing Sudoku on paper or on computers. 97 initially expressed a preference for paper and pencil and 21 for the computer. After playing Team Sudoku, 76 maintained their preference for paper and pencil, but 42 preferred the computer. 5 changed from a preference for the computer to a preference for paper and pencil. This is statistically significant, $X^2(2, 116) = 12.52$, $p < .05$. Since many of the players had never played Sudoku on a computer before, and very few had played a collaborative computerized version, it is possible that some of this shift was due to these factors. However, in fact, change of stance towards playing on the computer varied by condition. People who played the highlighter version were more likely to change from a preference for paper to a preference for the computer compared to people in either the multi-pointer condition, $X^2(1, 59) = 5.12$, $p < .05$, or the shared-pointer condition, $X^2(1, 58) = 4.79$, $p < .05$. No one changed preference away from the computer in either the shared-pointer condition or the highlighter condition. 2/5 of those who turned away from the computer were in the basic condition, but 3/5 were in the multi-pointer, again suggesting a lack of preference for the multi-pointer compared to other coordinative schemes.

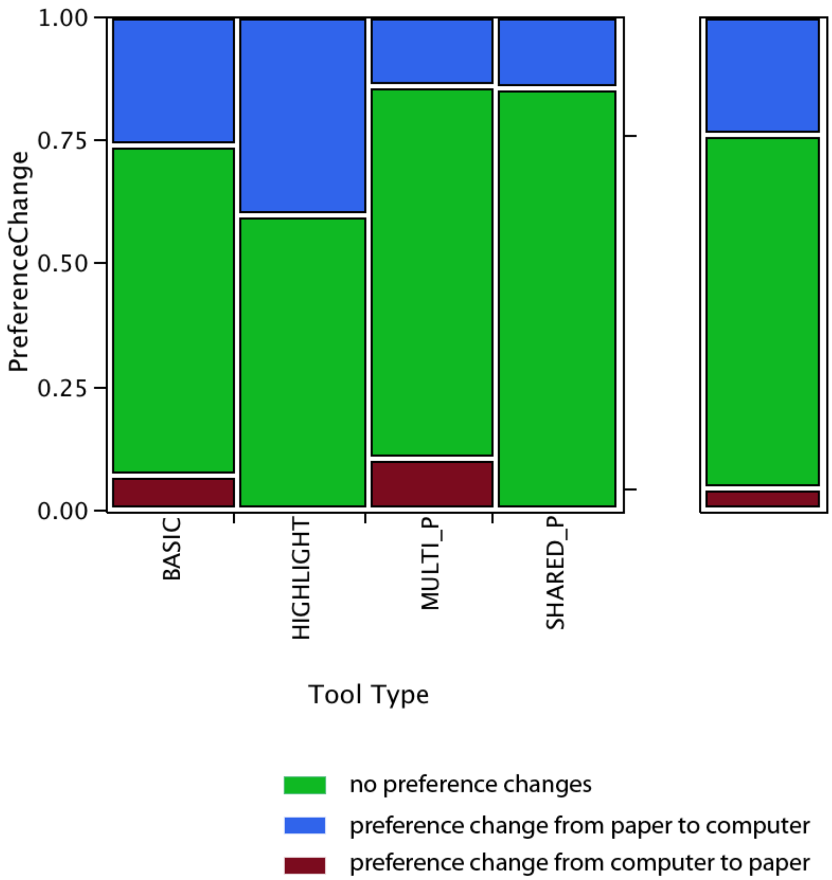

Figure 4.1: Preference Changes Between Pencil and Paper and Computer Forms of the Game after playing Team Sudoku

When asked “how obvious was it what other people were doing during the game sessions?” people who used highlighters were more likely to understand what others were doing than people who had multi-pointers, $t(115) = -2.04$, $p < .05$. No other comparisons showed significant differences. Again, this shows a preference for the highlighter condition.

Condition	Mean	Std Dev
Basic	4.73	1.33
Highlighter	5.18	1.30
Multi-pointer	4.63	1.56
Shared-pointer	4.99	1.52

Table 4.1: Mean participant rating of ease of understanding what others were doing during game, on a scale of 1 (not at all obvious) to 7 (completely obvious)

At the same time, preliminary results do not suggest that design of the deictic support tool makes much difference in the efficiency of the referring process. I randomly selected 6 sessions in each condition and transcribed the first incident in which the tool was used or, in the basic case, the first verbal incident that referred to a specific place, number or action. Not surprisingly, our data show statistically significant advantages for the explicit referencing tools over the basic condition, in part, perhaps, because the first incident of a reference in the explicit referencing tools was on the average not the first attempt at shared reference in the session. The basic condition required 4.67 utterances on the average, which differed statistically significantly for all the other conditions: basic vs. shared-pointer, $F(1, 12) = 9.42$, $p < .05$, basic vs. highlighter, $F(1, 12) = 7.27$, $p < .05$, and basic vs. multi-pointer, $F(1, 12) = 7.80$, $p < .05$.

Condition	Mean	Std Dev
Basic	4.67	2.34
Highlighter	2	0.63
Multi-pointer	2	0
Shared-pointer	1.67	0.52

Table 4.2: Mean number of communicative turns taken before reaching referential consensus on the first occasion

4.7. How Participants Coordinated

To see the differences among conditions and examine how the differences manifest themselves in the context of Sudoku playing, the 40 15-minute long video recordings of the first Sudoku game for triads were fully transcribed and reviewed several times together with the log files and screen-captured videos. Due to the glitches in the recording devices, video recordings for three game sessions were severely damaged and therefore excluded from the analysis.

The data reported in this section show some similarities across tools and some dissimilarities in how people accomplish referring behaviors. This section starts by identifying a number of behaviors seen in all conditions. It then contrasts certain behaviors in the highlighter condition with those in the multi and shared pointer conditions and talks about behaviors seen only in the highlighter or multi-pointer condition. In the discussion, I address the issue of variation in the local task of participants.

4.7.1. Behavioral patterns appearing in all conditions

Jimmy: in the top right box, we need an 8 and a 4.

Sue: hm hm.

Excerpt 4.1: Verbally Indicating a Section on the Grid

Sam: so 7 in the top right box can only be

... *((puts small 7 on cell 1,8 and 1,9))* there and there.

David: right.

Matt: right.

Excerpt 4.2: Notes as Indicators

Pointing Techniques

Whether or not participants had reference tools and regardless of the types of reference tool they were given, all participants sometimes used unadorned verbal communications to spatially describe and reference specific parts of the grid. Excerpt 4.1 shows a case in which Jimmy, without using gestures or the highlighting tool, verbally indicates the top right hand corner region of the puzzle. The screen captured puzzle-grid video of the session and the log files tell that there were the only two empty cells in the box to which Jimmy was referring. So we could tell that Jimmy was implicitly referring to the two empty cells in that region without explicitly saying “we need an 8 or a 4 in those two empty cells.”

In addition, just as people may indicate with feet, gaze, elbows in normal communication, participants appropriated different Team Sudoku tool features to make indexical references during the game sessions. For instance, Sam (Excerpt 4.2) puts small notes (7s) in cell 1,8 and cell 1,9 right before he says “there and there.” Sam both indicates the cells and marks the possibilities. However, in similar situations, many people did not use notes, and others who did use notes, also used collaborative reference tools.

Internal versus External Purposes of Pointing

Bavelas and her colleagues [7] show that wincing when someone is about to be hurt is accomplished with both internal and external purposes. Overwhelmingly, people wince when they see someone about to be hurt, as an apparently spontaneous expression of empathy. The direction of the wince when the person in imminent danger cannot see the wincer is random. But the direction of the wince when the wincer knows that the person in danger can see him/her is communicative. The wincer will mirror the direction that the person in danger has to move to avoid the harm. Likewise, Iverson and Goldin-Meadow [94] report that blind people gesture when talking to listeners known to be blind. Also we frequently and spontaneously gesture when we are talking to others on the phone even though others cannot see the gestures [28]. Most often, deictic gestures, those that indicate, are interpreted as being for purely communicative purposes. However, in the current case, I see multiple occasions across conditions in which people point with their fingers or their individual mouse pointer in situations in which they know that the others cannot see their target.

Soyer: `are you sure about number one.. in that middle square at the top`

((pointing with finger to his screen at the middle square))

Susan: hmm- *((pointing with finger to her screen))*

Excerpt 4.3: Pointing with Fingers to the Screen

For example, Excerpt 4.3 shows a case in which a male participant points to a middle 3 by 3 square box in the puzzle grid while he is talking to other participants. Subsequently, a female participant starts pointing at her screen and waves her finger in a circular motion while looking at one of the other people in her group.

One interpretation of this behavior is that those kinds of deictic gestures are less targeted to others than to the person doing the pointing. By putting a finger on a row or a column, participants in all conditions used self-oriented gestures to trace out portions of the puzzle and to delineate sections of interest. They appeared to be focusing their attention on a particular part of the Sudoku grid. Additionally, participants in all conditions appeared to use their individual mouse pointers for the same purpose.

Communicative Patterns in Deictic References

Four common communicative patterns emerge as employing deictic references across conditions: delineating place for attention, delineating dimensionality of a problem, arguing with specifics, and justifying action.

Cora: what could be wrong?

... here *((highlights a column))*

.. the 8 and the 3 could be wrong

Excerpt 4.4: Delineating Place for Attention

DELINEATING PLACE: People frequently suggest focus on particular parts of the grid as candidates for the attention of others (and themselves). In Excerpt 4.4, Cora is scanning the possibilities by pointing out that either the 8 or the 3 could be wrong. In this case, there is a known problem, but this kind of conversation also occurs when action such as adding a number is contemplated.

Annie: something is wrong here *((highlights a row))* and here *((highlights a cell))*

... because if we stick

.. eh= you

.. we would assume that a 3 would go here

((puts a 3 in the still highlighted cell))

Bob: well we don't know if these numbers are right so we can't see.

Annie: but there has to be a three somewhere.

Bob: yeah

Excerpt 4.5: Delineating the Dimensionality of a Situation

DELINEATING DIMENSIONALITY: In Excerpt 4.5, Annie appears to be at once encountering the dimensions of the problem and explaining it. Bob answers, showing that he has not completely understood the significance of her references as support for her thinking, and she elaborates her logic. Although Annie's pointing directs Bob's attention to certain places, the purpose is to frame the dimensionality of the problem. He could comply with her, for example, by bringing up another part of the board altogether that impacts the problem she has pointed out.

Carrie: we messed up here *((highlights a cell))*

Becca: no way !noo

Carrie: cause the 6 has to go somewhere here *((highlights a second cell))*

and here *((highlights a third cell))*

Becca: but there is a 6 right there *((highlights a fourth cell))*

Carrie: !OH oh my gosh it is.. look at !that

Excerpt 4.6: Arguing with Specifics

ARGUING WITH SPECIFICS: In Excerpt 4.6, Carrie proposes that they have made a mistake. Becca resists this idea. Carrie elaborates on her perception. However, in this case, Becca responds with a counter proposal, drawing attention to a previously unmarked portion of the board. As with delineating the dimensionality of the situation, she draws attention to a number of places that need to be examined in order to understand the problem, but, as in the example of delineating place, drawing attention to a number of places requires confirmation that the situation she has delineated, the confluence of places, has been understood. Furthermore, Carrie, until dissuaded, is talking about a proposed future activity: fixing the problem.

Bill: I'm just gonna let you know what I'm doing cause I don't know like if they're reversed

Cindy: right

Bill: cause like there's the 1 here *((highlights a cell))* and the 2 here *((highlights a 2nd cell))*

Cindy: so these can't be a 1 *((highlights a 3rd cell))* or a 2 *((highlights a 4th cell))*

Excerpt 4.7: Justifying Actions

JUSTIFYING ACTIONS: Unlike the other patterns, this happens when someone has already taken an action and is soliciting agreement (see Excerpt 4.7).

All four of these patterns involve tight referential coordination, that is, they require focused attention on precisely what is being referred to in the moment.

Wilma: five does not have to go there

Carol: which one?

Wilma: hmm- this one *((highlights a cell 2,7))*

Excerpt 4.8: Specifying a Reference More Particularly

Varying Degrees of Referential Elaboration

Another pattern seen across all conditions is variation in the degree of specificity in referential behavior. In the context of this game, many indexical referencing acts need to be quite fully elaborated for others to understand them. As usual in deictic reference, sometimes the initial references are not adequate. In Excerpt 4.8, Wilma first tries to indicate a cell in a grid by saying "five does not have to go there." However, since the word 'there' in this context was not specific enough to tell what part on the entire grid to which Wilma wanted to refer, Carol replied "which one?" Wilma then used both language "this one" and a highlighter to further specify her meaning.

The failure to fully specify is an example of a behavior that Brennan considers in her claim that people minimize the joint effort in making adequate specifications [24]. However, this exists in some tension with the preference for self-repair in language use, in which people tend to anticipate what needs to be said in order to be understood [164].

Tom: *((puts 2 on a cell 9,5))* **[Time - 00:02:30]**

Lee: how did you get that two there? **[Time - 00:02:53]**

Tom: the two

Lee: yeah

Tom: hmm- because we still need 5 2 and 8 ...

Excerpt 4.9: Submerging a Deictic Reference in Another Conversational Move

Interestingly, many successful indexical referencing acts are remarkably unelaborated. In Excerpt 4.9, Tom puts a 2 in a cell (9,5) at 00:02:30. Twenty three seconds later, Lee asks a question, “how did you get that two there?” In this phrase, there exist three words whose meanings are ambiguous and unclear. From an external perspective, it is not clear: (a) to whom Lee is posing the question by saying ‘you’ since there are two other participants, (b) which 2 on the board Lee is asking about by saying ‘that 2’, and (c) what cell in the grid is specified by Lee’s ‘there’. Lee himself may not know who put that particular 2 on the board. Apparently, despite the 20 second gap between the placement of that 2 and Lees query, he assumed that the placement was a memorable event to someone in the group and therefore part of the local common ground. In posing a question without further specifying who “you” is, which 2 is “that 2” and where is “there,” Lee asked others to help resolve the ambiguity drawing on the group’s shared knowledge of “public events so far” [35] and the current state of the artifact. A falling stress at the end of Tom’s reply “the two” suggests that he immediately understands the question and is thinking about how to reply.

In many cases, participants successfully refer to grid elements without any specification comprehensible to an overhearer. I speculate, and hope to explore, that these references were successful because, when people were intensely engaged in the specifics of the problem, they shared tacit cognitive approaches and perceptual sensitivities to the board that helped them anticipate issues such as what another person would turn attention to next.

4.7.2. Behaviors that Differed by Shared Reference Tool

Not surprisingly, given the difficulty of the task, people drew upon many resources to specify their references, and this created many similarities across tools. However, even in this initial investigation, I do find some indications of differential use of tools, especially between the highlighting condition and the shared-pointer and multi-pointer conditions.

Cammy: wait !that can’t be 3 because-

((uses a pointer to point a note 3 on a cell 7,3 and waives the pointer under the number. Notes 2,3,8 are on the cell))

Amy: yeah- yeah-

Excerpt 4.10: Indicating to Specifics (Shared-Pointer)

Adam: the 9 can't fit in there now *((highlights a cell(6,8) — —small numbers (notes) 2,7,9 are on the cell))*

Cindy: a- right

Excerpt 4.11: Indicating to Specifics (Highlighter)

Comparing Highlighters and Shared-Pointers

Both Excerpt 4.10 and Excerpt 4.11 show occasions in which one participant finds an error in the notes on a cell and tries to communicate the finding to the partners. On multiple occasions, people used shared-pointers to disambiguate and emphasize specific problems. In Excerpt 4.10, by saying "that" and starting to wave the pointer right under the problematic 3, Cammy is referencing the problem itself. However, in the highlighter condition, rather than pointing out the specific problem, participants indicate an area where the problem resides. In Excerpt 4.11, upon highlighting a cell with notes indicating that 2, 7 and 9 are candidate solutions, Adam says, "9 can't fit in there". By saying "there", Adam is indicating an area in which he finds a problem, in this case, the cell (6,8). He does not say, for example, "that can't be 9" while highlighting the cell. In the ten highlighting sessions I observed, I did not find a single occasion in which people used a highlighter while verbally indicating a number in the notes. This suggests that the degree of affordance for the kind of reference differs between these two tools.

Park: wait which one?

John: in- this row *((use a pointer to point a cell 9,4))*

and that row and- *((use a pointer to point a cell 8,4))*

Excerpt 4.12: Indicating a Region (Multi-Pointer)

James: I think there's some 8s missing in=

... this

... hold on *((highlights a box))*

Excerpt 4.13: Indicating a Region (Highlighter)

Comparing Highlighters and Multi-Pointers

Both Excerpts 4.12 and 4.13 describe situations where participants indicate not a cell but a region on the board. James, in Excerpt 4.12, upon highlighting a box, says "this" to indicate a box. Whereas the word, "this" does not typically include any game specific notion, it denotes the box James is referencing when accompanied by the highlighting action. When a region in the puzzle is highlighted, the highlighter, a content-specific referencing tool designed to indicate important referential objects in Sudoku, imposes game specific interpretation to the reference. It also maintains the meaning in the visual trace of the tool mark. However, the context-free tools, multi-pointers and shared-pointers, only acquire such game specific meaning through joint activity in the moment. Even though users move shared pointers back and forth along a row or a column to indicate a region, they appear almost always to specify "this row" or "that column”. For example, in Excerpt 4.12, using a multi-pointer, John says “this row” when he points to a cell on the board. He verbally elaborates the action of pointing to a cell, expanding the focal point of the indication from the cell to the row. This example again suggests that the highlighter and the shared pointer afford quite specific differences in emphasis.

4.7.3. Behavioral patterns appearing only in the Highlighter condition

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Dora: *((highlights a cell))*

Bill: *((puts a 3 in the highlighted cell, then glances at Dora and smiles))*

hahah sorry

Excerpt 4.14: Putting an entry into Another’s Highlighted Spot

Demarcation of Territorial Boundaries

Possibly because the highlighter condition is the only one with referential stability (that is, an area is highlighted until the highlighter is removed), one behavior appears only in the highlighting condition: users appeared to occasionally use highlighters to demarcate an area as “theirs.” In Excerpt 4.14, I see evidence that Bill is trespassing on Dora’s space by putting an entry into her highlighted spot.

Aaron: something wrong down here *((moves a pointer along the last row))*

Carl: what do you see?

Excerpt 4.15: Referential Installment (Shared-Pointer)

Adam: ah- in that row *((highlights 7th column))*

Bill: yeah

Adam: here all you have left, here I will take the other ones there

.. put in there..*((deletes 4 in a cell 1,7))* put that one *((deletes 5 in a cell 2,7))*

um- all you have left was 4 5 8 and 9 in the row

.. and then this box right here

... yeah

... in this box right here

.. *((highlights a cell 2,7))* um-

Excerpt 4.16: Referential Installment (Highlighter)

Referential Installments

Subtle differences in how participants drew partners' attention were also noticeable among different conditions. Throughout all conditions people employed what Clark and Brennan called "referential installments" [36] to ground references incrementally. However, in the shared-pointer and multi-pointer conditions, participants produce utterances not only to draw attention to the confined area of the puzzle but at the same time to add contextual meaning to the referents. In highlighter condition, in contrast, participants sometimes tried to draw attention to a specific area first without adding contextual information. For instance, in Excerpt 4.15, Aaron uses the shared pointer to indicate the last row of the puzzle while at the same time telling his partner that the row has a problem. On the other hand, in Excerpt 4.16, Adam first draws Bill's attention to the 7th column by highlighting the area. He then waits for Bill's reply. Only when Bill provides positive evidence that he is attending to the demarcated area of the puzzle by saying "yeah" does Adam begin to describe the problem.

Since I am basing my analysis on a relatively small number of game sessions, it is premature to claim that purely incremental references are unique to the highlighter condition.

However, there was none in the 20 video sessions of content-free pointers that I examined.

4.8. Not All Tools Support The Same Affordances

The examples already given suggest that the explicit pointing tools differ in their affordances. To investigate this further, I randomly selected 6 sessions from each condition and examined the first incident in which the tool was used or, in the no-help case, the first verbal incident that referred to a specific place, number or action.

The utterances in the incident were categorized and coded according to the two different coding schemes, devised to portray the complexities of the problem in the puzzle that the people were handling and the different tools and techniques used in referencing. First, each referential utterance was coded in regard to the difficulty of the referring acts: Single Element labels the easiest task, indicating a single element in the puzzle (e.g. entries, cells, rows, columns and blocks); Direct labels the intermediate task, depicting direct relation between two elements in the puzzle; Indirect labels the hardest task, describing the complex relations between multiple elements in the puzzle. Second, each referential utterance was also coded by the methods used to accomplish the reference: Vocal denotes a case in which a participant used verbal communications to reference specific parts of the grid; Other Tool denotes a case in which a participant appropriated software features to make references; Ref Tool denotes a case in which a participant used whichever one of the three explicit reference tools to which he or she had access.

As shown in Figure 4.2, among 134 referential utterances identified, 106 indicated Single Elements in the puzzle. 17 described Indirect relationships. 11 described Direct relationships. Of the 80% of the referential utterances that indicated a single element, 57% (60) used verbal description alone. Of the 17 utterances describing indirect complex problems or relations among different elements in the puzzle, 77% (13) used an explicit reference tool.

It looks very likely that people utilize less complex methods to make simpler references and more costly methods for more complex problems. Additionally, other tools were appropriated for indication only for the simplest Single Element references and never for the more complex references.

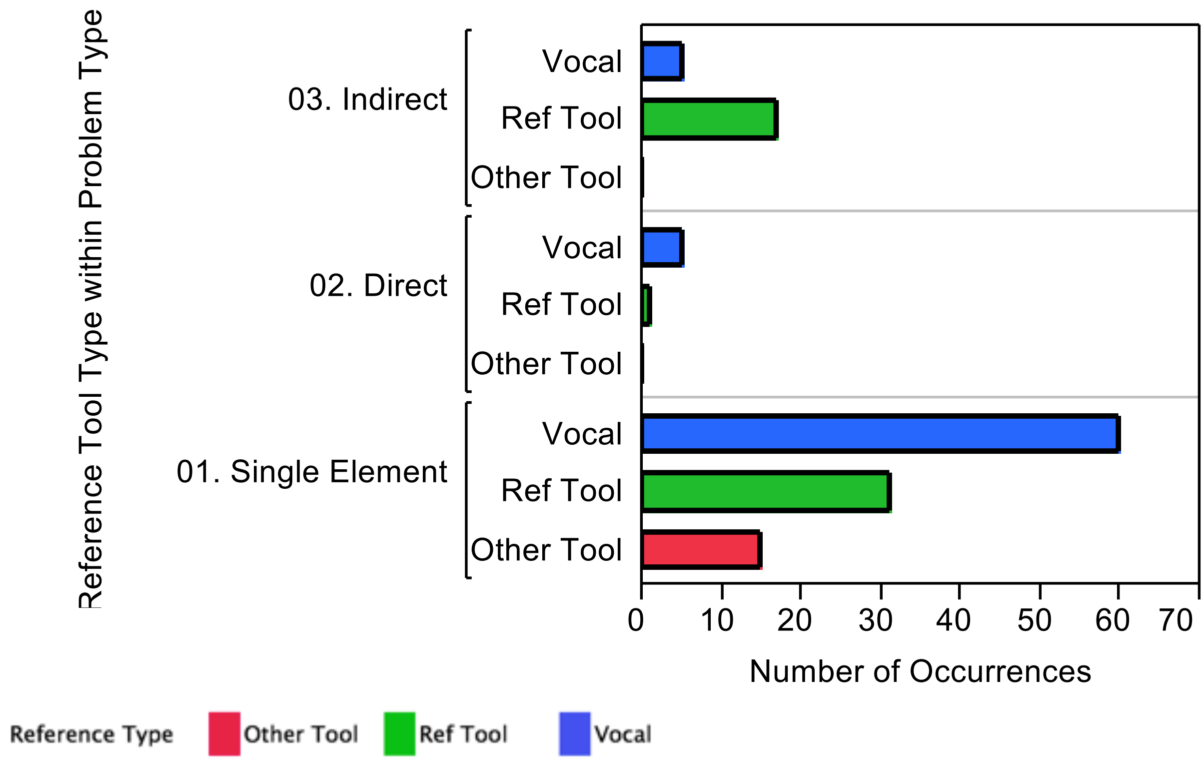

Figure 4.2: Use of Types of reference tools by difficulty of reference task

4.9. "Good Enough" Pointing

Not surprisingly, when I compared communicative turns taken before reaching referential consensus in each condition, the quantitative analysis on the efficiency of the referring process only shows statistically significant advantages for the explicit referencing tools over the no-help condition (no-help vs. shared-pointer, $F(1, 12) = 9.42$, $p < .05$, no-help vs. highlighter, $F(1, 12) = 7.27$, $p < .05$, and no-help vs. multi-pointer, $F(1, 12) = 7.80$, $p < .05$.) and did not show any statistical differences between different tool conditions.

However, the qualitative analysis clearly shows that different tool conditions entail different sets of deictic and communicative behaviors in carrying out computer-mediated joint activities. In an accordance with the principle of least collaborative efforts [36], I believe that people not only try to minimize the collaborative efforts to ground mutual understandings, but they also tend to utilize the minimally adequate reference methods or tools needed to carry out joint actions for their current purposes. ***In other words, people do not need to have perfect tools to carry out the collaborative activities effectively; instead they only need to have "good enough" tools.*** There might not be an ideal deictic tool. Context-free referencing tools are as good as context-specific referencing tools: they only encompass slightly different sets of user behaviors.

The analysis presented in this chapter does not exhaust the potential of these data or this line of inquiry. It suggests that there is substantial reason for more investigation into the design of collaborative pointing tools, especially in the realm of co-located collaboration and perhaps even in collaboration at a distance.

Studying groups larger than dyads is necessary. Furthermore, the question of whether the disambiguation of reference should be encoded in the technology or part of the social process that surrounds the technology is still outstanding. Last, the relationship between task difficulty and tool design in deixis requires more general theory.

5. Let's Talk about Not-Talking[6]

Abstract

How is it that groups of people can complete joint tasks without the expected observable markers of "successful" coordination? The relationship between *micro-level, situated* actions and broader outcomes such as opportunities for learning is under-explored. In this chapter, I report a set of findings from Study 1. In Study 1, I investigated co-located groups as they played a collaborative, problem-solving game using distributed technology on laptops. There was considerable variety in how groups accomplished the work. Some satisfied groups talked a lot but other satisfied groups did not. *Talk was diagnostic of satisfaction but lack of talk was not diagnostic of dissatisfaction.* In fact, groups that had little or no discourse differed considerably from one another. One kind of group completes the joint tasks very well without observable markers frequently associated with success. Others are less successful in the task goal but manage difficult interpersonal situations.

5.1. Introduction

HCI and CSCW studies of coordination and collaboration often focus on measuring task or process performance [3]. Even in sub-fields of CSCW where broader outcomes are acknowledged as crucial such as computer-supported collaborative learning, there is a tendency to by-pass the relationship between particular collaborative actions and broader outcomes. In the previous chapter, I have showed that even though efficiency and performances are important components of coordination, they do not provide sufficient groundwork to support design in the general case. In this chapter, I demonstrate how looking at *micro-coordination* among triads playing Sudoku in an experimental but i*n situ* context allowed me to unveil important coordinative issues.

5.2. The Study

5.2.1. Procedure

The study was designed as a between-subject experiment. The study was conducted in a small room with participants seated in close proximity to one another. Participants were introduced to one another when they came into the room. After the informed consent process, participants were asked to fill out questionnaires about demographics, prior experiences with Sudoku and with the teammates (usually none). Participants engaged in a system walkthrough and an easy warm-up game to learn how the Team Sudoku system worked. After the warm-up session, the groups were asked to work together on two Sudoku puzzles significantly more complex than the warm-up puzzle, in an order counter-balanced across groups. The groups were given 15 minutes to work on each game. After each game, questionnaires asked players about their experiences with the game and with the other players. There was also a short discussion at the end of the study. Video recordings of all the game sessions were collected as well as computer logs and screen shot movies of the games.

5.2.2. Participants

Players were recruited from the Psychology Participant pool, N>1200, at our university, and received extra credit for participation. The advertisement for participation had two components: that the study was

[6] Findings reported in this chapter have been published as a full paper in CSCW 2012.

about a collaborative game, and that participants needed to have played Sudoku before. Players played in groups of two or three.

A total of 168 (89 female, 79 male) college students enrolled in the study, in 24 groups of two and 40 groups of three. Participants' age ranged from 18 to 23 (M = 19 SD = 1.13). 17 of 168 reported that their first language was not English, but none appeared to have difficulty because of this. Almost all the participants had prior experience with Sudoku. Four reported that they did not know the Sudoku rules. When asked how often they play Sudoku on a scale of 1 (rarely) to 7 (several times a day), a majority responded that they do not play Sudoku often (M = 2.51, SD = 1.42).

But when asked how much they like playing Sudoku on a scale of 1 (not at all) to 7 (very much), a majority responded that they like playing Sudoku (M = 4.74, SD = 1.51).

Most participants responded that they had played Sudoku on paper while only a small portion of them had played Sudoku on the computer. Only 6 of 168 reported that they had played a computer version of Sudoku with other people prior to the study.

When only two participants appeared at the agreed time, we ran the game with them, resulting in 24 groups of two. In this paper, we address only the 40 three-person groups.

5.3. Coding

Three video cameras recorded each session. With each camera facing one participant, we were able to ensure that each player's facial expressions as well as bodily gestures were captured in video recordings. Due to the glitches in the recording devices, video recordings for three game sessions were severely damaged and therefore excluded from the analysis.

The 37 15-minute video recordings of the first Sudoku game for triads were transcribed using a slightly modified version of Chafe's prosodic transcription system [34], which focuses on information flow. Six researchers worked on transcribing the sessions, in three different iterations. Transcripts from audio were created in the initial iteration. Descriptions of non-verbal gestures as well as critical changes on the Sudoku board were added in the second phase. Transcripts were then arranged into intonation and conversational turn units. The final transcripts were reviewed for accuracy several times with the log files and screen-captured videos.

Open and axial coding [44] were conducted on the segmented conversational turn units, resulting in a 3-layered hierarchical coding scheme. In total, 20 codes were developed under four main categories and ten subcategories. The four main conversational categories were 'board-related,' 'game-related,' 'off-topic,' and 'other.'

Board-related utterances refer to specific elements, regions, possibilities, or problems on the Sudoku puzzle on the screen. It has four subcategories: *Statement* represents simple, unelaborated statements or fragmented ideas such as "I don't think a 2 is gonna go right in this spot..." or "Alright let's put a 5, put a 5 there." *Question* refers to incidents in which a participant expresses doubts, asks for confirmation, or demands explanation of elements on the game board such as, "are you sure this one," or "why couldn't it be eight?" *Elaboration* means the participant went a little further to explain reasons for moves, possibilities and problems rather than just stating simple facts. "Because there's an eight in that row already" is an example of *elaboration.*

A: this can't be a 4 ((Uses a reference tool to point to a note 4 on a cell 9,4)) *{statement}*

B: It could be a !4,

there's no 4 in that row *{adding dimensionality}*

Excerpt 5.1: A Coding Example: Statement and Adding Dimensionality

A particularly interesting sub-category is *adding dimensionality,* a code that captures instances in which participants built ideas on the top of previously presented ones.

An utterance was coded as adding dimensionality if it provided evidence that the person who added the dimensionality had to be giving active attention to the claim that the original person made either by testing its validity or by enumerating its consequences, as in Excerpt 5.1.

Each of these sub-categories then were again subdivided into finer categories depending on whether referents were (1) mentioning an element or a region in the puzzle, (2) suggesting possibilities not yet present in the game board such as 4 or 6 in “either 4 or 6 can go in here,” or (3) raising a problem as in “this is wrong. Something is wrong here.” We do not analyze these in this paper.

Game-related utterances are closely related to the game, but do not refer to any specifics of the game board. This category includes discussion of general game strategy, *game- specific* discourse related to the current puzzle but not to specifics of the puzzle (as in “this puzzle is hard”); *game- general* utterances coded inquiries and comments on Sudoku rules, prior Sudoku experiences, software features and research procedures.

Off-topic included utterances not directly related to the game activities (i.e., “I am hungry.”).

Inaudible, regulatory intonations (non-lexical and phrasal backchannels), and non-sentential sounds (laughs...) were coded as *Other.*

Figure 5.1 shows the distribution of utterances in the top two levels of the coding scheme. Only 1% of the conversation was off topic, suggesting that people were quite engaged in the puzzle solving activities. 26% of the utterances were back channels. 23% were simple board-related statements.

Statistics collected on the coded transcripts include the number of conversational turns and utterances each player made throughout the session. Similarly, a log analyzer was used to gather information on the total number of entries, notes, and deletions that each player made during the game.

The number of correct and incorrect entries for which each player was responsible was also counted at game end-state.

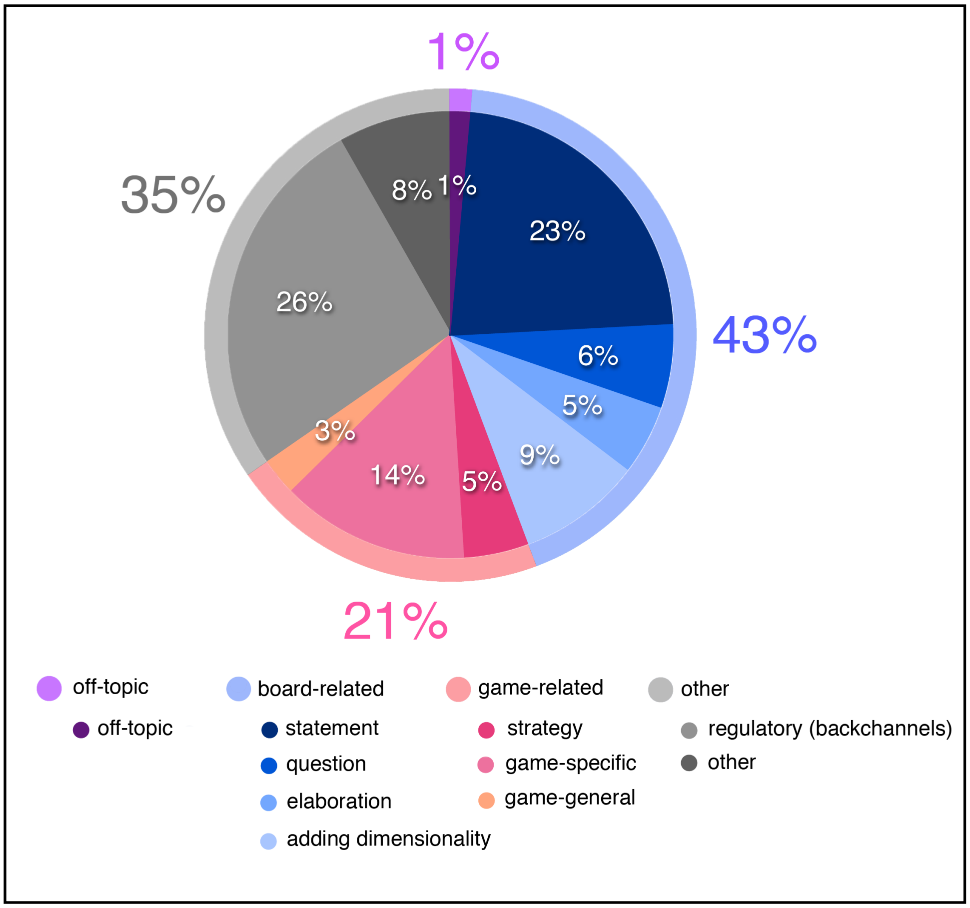

Figure 5.1: Overall Number of Utterances by Category

5.4. Amount of Activity and Satisfaction

One of the most obvious differences between groups was in activity level, either through talking or through contribution to the board. The average number of conversational turns/group was 92.8 but the standard deviation was 80.4. 11% of the groups did not have a single utterance by any- one; 24% groups had less than ten conversational turns. The distribution of kinds of utterances (Figure 5.2) also differed by group.

Individuals differed as well as groups. In three groups, two people were responsible for all the discussion. In eight of the groups that had any talking at all, 90% of the turns were taken by two of the players. Overall, the average number of turns/person was 30.9 (SD 29.2).

The number of board entries and deletions by group (Figure 5.3) also varied considerably at both the group and individual levels. The board started with 54 blank spaces and 27 pre- filled, un-erasable numbers. The average number of game entries/person was 12.5 (SD 8.9). Three participants never contributed a single number to the game board; ten had no contribution that lasted until the end state. But one group had 83 entries. Some groups had almost as many deletions as entries.

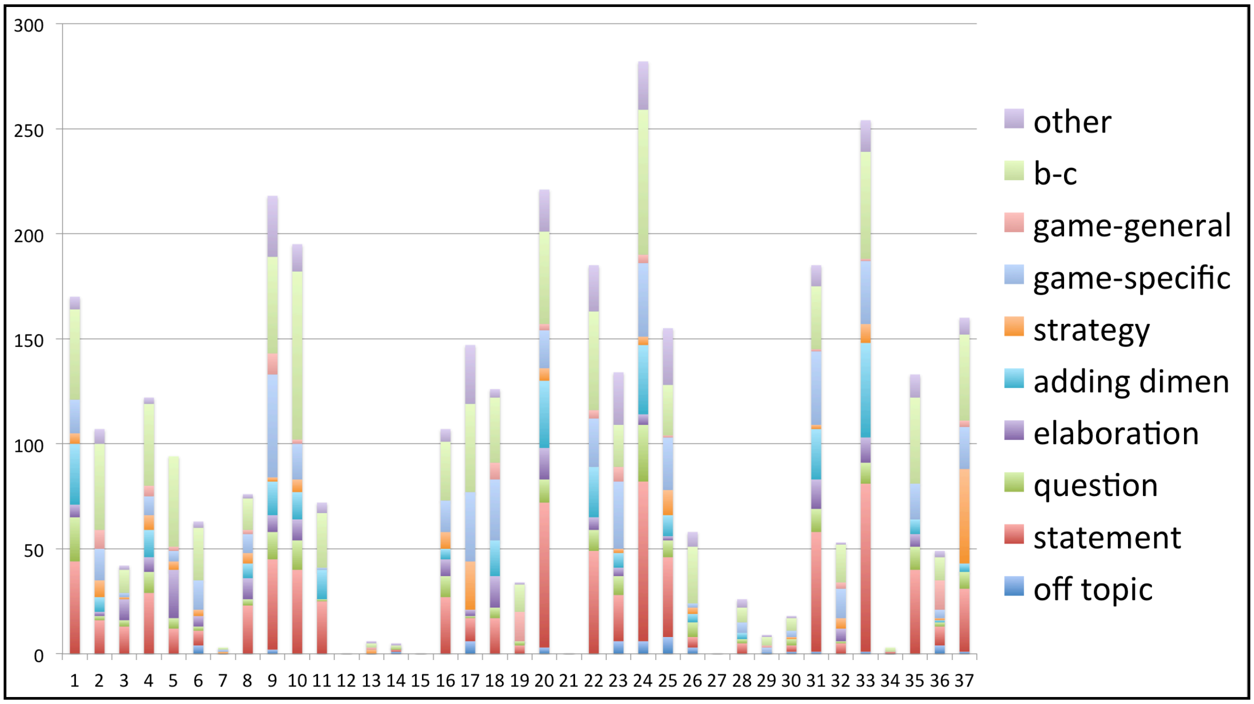

Figure 5.2: Distribution of Kinds of Utterances by Group

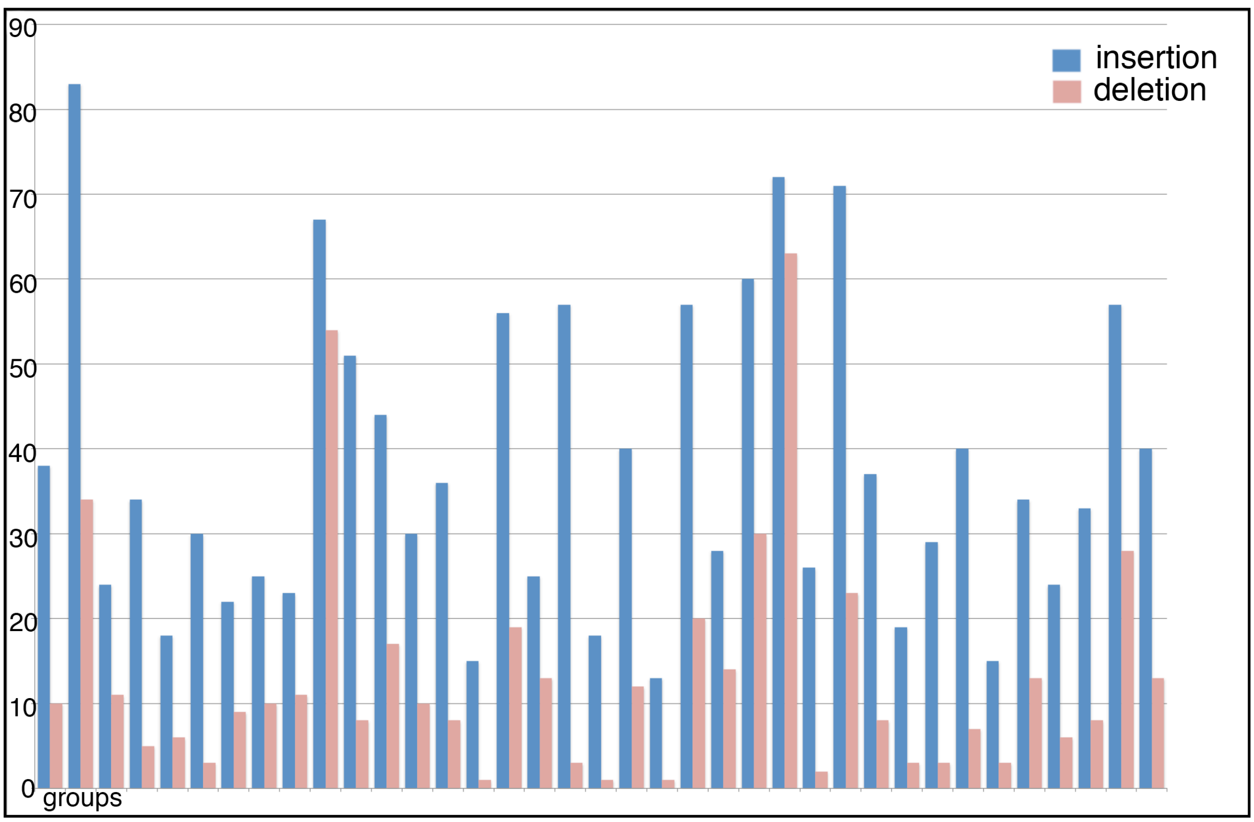

Figure 5.3: Number of Game Board Insertions and Deletions by Group

Contributing to discourse was statistically related to contribution to the game board (r= 0.27; $p < 0.005$). The more a player talked during the game, the more entries the player put on the game board. However, this was by no means an absolute relationship (Figure 5.4). Two people contributed above the mean number of utterances, but entered only two-three numbers on the board while others contributed 30-40 entries but never talked.

There was also a statistically significant difference in self- reported satisfaction related to amount of discourse in the group. Players were asked to rate how satisfied they were with the group and the way they worked together on a scale of 1 (not at all) to 7 (very much). The number of utterances each player made was significantly correlated with self- reported satisfaction (r = 0.26; $p < 0.006$). However, there was no correlation between satisfaction rate and number of game board entries (r = 0.01; p = 0.90).

Figure 5.5 shows a very interesting distribution. Satisfaction level varied more considerably amongst people who spoke very little compared to those who spoke quite a lot. Highly communicative participants tended to be satisfied. There existed no individuals who were highly communicative but fell below the middle of the scale for satisfaction. However, uncommunicative people covered the spectrum of satisfaction.

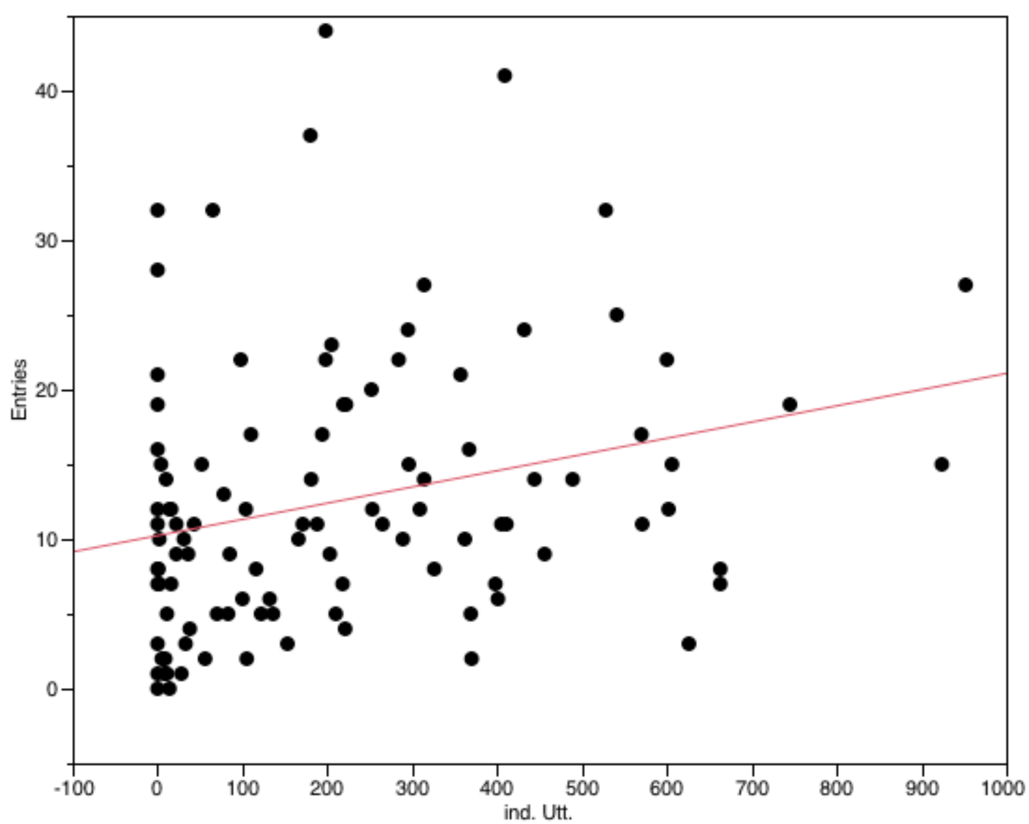

Figure 5.4: Number of entries by conversational turns by individual (r = 0.27; p < 0.005)

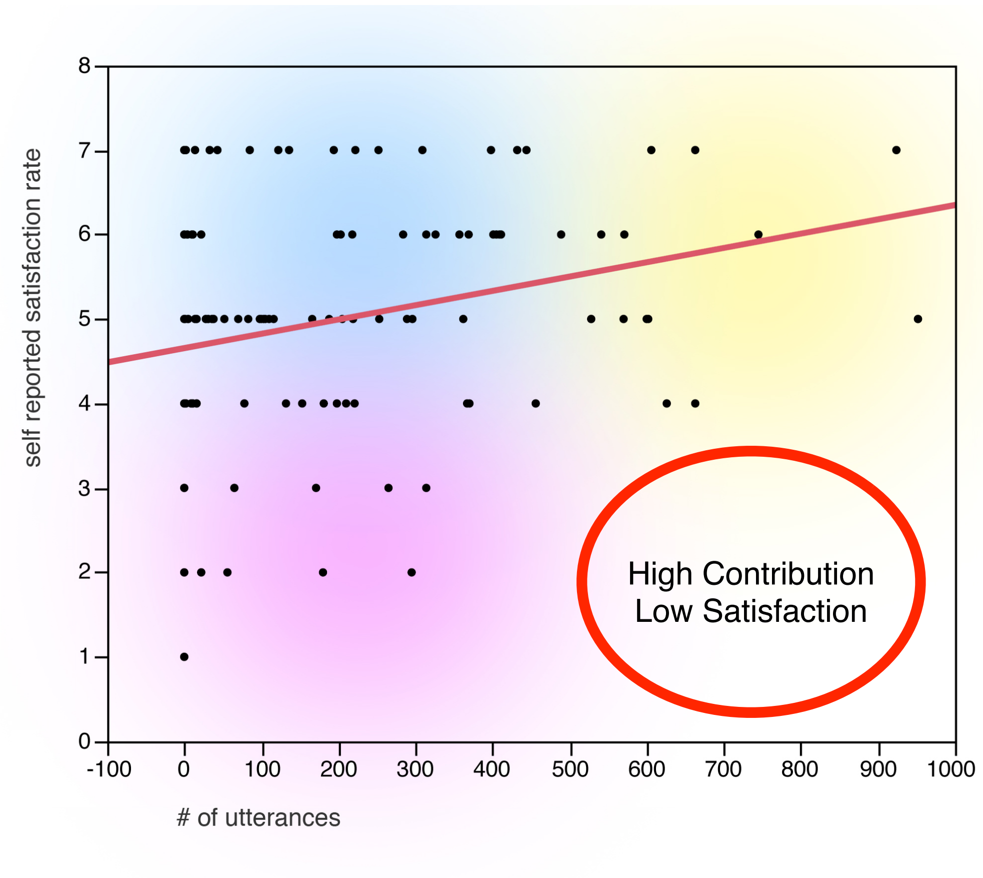

Figure 5.5: Satisfaction level by number of utterances by individual; the high contribution, low satisfaction quadrant is empty

5.4.1. Adding Dimensionality

Both amount and intensity of conversation influence how groups felt about their group activities. To investigate how intensely the group maintained focus, we divided the groups into three categories; adding dimensionality (AD) provides strong evidence of joint focus across multiple actions on specifics of the puzzle. Board related statements, questions, or elaborations (ST) illustrate fragmented one- time focus. Groups that did not have any board-related conversations were called NO. (As a note, all groups who exchanged less than 10 conversational turns belonged to NO. That is, even when they did talk, they did not talk about the board at hand.)

As we might expect, groups that maintained prolonged joint focus on the puzzle and tried to share and contribute individual ideas on top of the previously shared group knowledge were significantly more satisfied with their group activities and outcome than groups that only shared fragmented ideas and comments. That is, in pairwise t-test ($F(2,34)=2.03$), AD groups had a significantly higher rate of satisfaction than ST groups (Mean Difference = 0.873; $p < .036$).

But, curiously, there was a less uniform and consistent difference between AD groups and NO groups than between AD and ST groups. AD and NO had only a marginally significant difference (Mean Dif. = 0.720; $p = 0.057$). NO and ST were indistinguishable (Mean Dif. = 0.153, $p = 0.74$.)

5.5. “Sounds of Silence”: Varieties of Non-Talk

Thus, from a statistical perspective, we see that groups that talk a lot are more satisfied than groups that do not talk, but that this difference is driven by the fact that groups that talk a lot are not unhappy (dissatisfied) while groups that do not talk a lot may be either happy or unhappy. Furthermore, while depth of conversation is associated with increased satisfaction, lack of depth is not associated cleanly with decreased satisfaction.

These are, by themselves, important findings, but frustrating. They do not lead to clean causal claims and associated design implications (even at the level of saying “talk more and you will be more satisfied”). The immediately observable behavioral outcome (talking/not talking) has asymmetric meaning.

Even studies that focus on behavioral outcomes implicitly brand non-talking as a deteriorative behavior by showing a correlation between the nature and quality of the communication and group outcome [4,5,168]. But in our study, some groups that do not talk much claim satisfaction, thus constituting a reasonable way to engage in joint work. Other groups are both dissatisfied and silent. Following are three examples of kinds of interactions not usually associated with collaborative success. Each of these can be described to a certain extent in terms of high level constructs current in the field. And yet, they strongly suggest alternative constructs that may be more perspicuous.

Figure 5.6: Tree people playing Sudoku

5.5.1. Alone Together or Together Alone?

Juliana, Stacy and Jason (all names are pseudonyms) were situated in the dual socio-digital space. However, they solved the interactional problem by ignoring the social space. No one chose to utter a word during the whole 15 minutes. Instead, they all were intensely focused on the puzzle-solving activity. Figure 5.6 displays the intensity of players’ focus on the screen. Their eyes remained honed on their screens throughout. Even though they were not verbally communicating in the social space, every move made by one into the game space seemed to immediately be integrated into the others’ decision-making processes. This kind of digital interaction has been described as entailing a place into which players project themselves and their willful control.

The way players perceive the changes made by others in the digital space, and the way they perceive the reciprocal interactions are unknown to observers (and could differ amongst interactants). Participants could self-consciously perceive these changes as bits of inter-dependent collaborative efforts projected on to the digital space, or passively take them as external and uncontrollable changes—they may not perceive the activities as collaborative. However actively they perceive the interactions within the digital space or however tightly-coupled these interactions are, the individual players are arguably alone in their social space, having no visible interaction with their teammates. To the third person observer, they were playing the game in absolute solitude.

In Alone Together, Sherry Turkle [191] portrayed people in our current society as becoming more and more detached from face-to-face interactions and increasingly attached to machinery (even emotionally). However, what we were seeing in the case of Juliana, Stacy and Jason was something other than being "alone together." They were "together alone." They were in the same room, playing the same Sudoku game, witness to the material focus of one another. They were highly coordinated. This group did almost as well as some of the other very interactive groups, entering 27/27 numbers in the correct positions. Groups typically made 24 entries during the game and had 5 wrong entries on average.).

Sherry Turkle sees being "alone together" as a distinct and problematic characteristic of today's society in the U.S. But "together alone" may be likened to other highly coordinated performances, such as jazz improvisation, that involve telegraphic or non-existent verbal communication. We do not know the details of what Juliana, Stacy and Jason experienced, but suspect that rather than deserving deprecation, it should be celebrated as a kind of flow or group flow [48]. It is certainly coordination, rather than non-coordination and consistent with collaborative success.

5.5.2. Social Loafing, sort of

Another behavior seen in less communicative participants is to engage in off-task activities. Eden (group 89) was the quiet member of a group that had process difficulties. The other two members were voluble and at odds with one an- other. Eden constantly checked his phone, read text messages and occasionally texted during the session. Eden was not totally indifferent; he took part in the group conversation occasionally, and placed a number of entries onto the game board. But he fell into the quiet end of the spectrum. His behavior, taken in isolation, for the most part was analogous to what social scientists would call social loafing. The classical social loafing model explains the loafing behavior as people working less hard when they are working in a group as opposed to when they are working alone [101,111]. Lack of accountability is one factor traditionally associated with social loafing. Yet this is not an exact description of Eden. Eden's distracted behavior was perfectly visible to all. He was not fully engrossed with making the task at hand work, and found other things to do, as we might check our emails during meetings or listen to the radio while driving.

The meaning of Eden's behavior is evidently different than the meaning of Juliana, Stacy and Jason's quietude. It seemed that Eden was defining the situation as not requiring his full attention. He is setting a different standard than we see in most groups for "good enough" participation. Eden is not exhibiting the surface level characteristics that would make him a good collaborator. In this case, we do not know whether his allocation of attention is a good choice on his part.

5.5.3. The Simply Lost or Process Loss?

An example of another kind of less communicative player was found in group 87. Joan appeared to be less experienced in playing Sudoku than her partners. While the other two made 40 and 13 entries, she made only 1. Also, while her teammates, Hardy and Sam, took 43 and 61 conversational turns respectively she took only 9. She responded to questions directed to her with low content replies such as "mm" and "yeah," or "what?" However, she appeared to be paying attention. She continually used a software feature to demarcate a screen area on which she was focusing, presumably either to show the group that she was working on the puzzle or to aid and maintain her focus on the game. At [9:54], she said, "so five would go here?" to get a confirmation for her guess. No one replied and she never put in the number (which was correct). Toward the end of the game, when Sam looked at her to check if she was OK, she said, "yea-h- Sudoku is exactly not my game." She was simply lost and overwhelmingly left alone.

Barron reported a similar kind of behavior in her work through an example in which two students ignore a third student who was proposing a correct solution for the group problem. Barron turns analytic attention to an occasion in which smart groups fail [5].

We build on this to propose a new question. When two people ignore a third person and that third person has an idea that could lead to the correct answer, we normally con- sider this process loss for the group. But what if the third person does *not* have a good idea?

Collaborative Sudoku as well as the math problem solving task in Barron's example is a disjunctive activity in that the outcome depends on the group recognizing the best player, getting that player to share unique information and avoiding process loss [2]. To maximize group performance and efficiency, it is logical to exclude a less effective player from the group activities. From an educational point of view, this is a poor outcome because it deprives students like Joan of opportunities to learn. It may also be poor outcome from a social point of view. Joan's group does not behave as though inclusion/participation is particularly important in their definition of the situation.

5.5.4. Current Purposes, or How Process Loss Arises

It would be easy to conclude that Joan's team should include her. However, we draw a contrastive example by looking more at Eden's group.

The other two members of group 89 talked quite a bit but experienced difficulty conveying their ideas to each other. As soon as the game started, upon inserting 5 in cell (1,1), Adam said "everybody gots to saw that ..right?" As it turns out, this was an ambiguous query. It could refer either to what people saw on the board, or whether 5 was the right entry for cell (1,1). However, Bob and Eden both acknowledged Adam's inquiry with "oh yeah" and "yeah" respectively. Then, Bob asked Adam "how do you know that?" Bob elaborated by asking, "are you just guessing?" Even after Bob's elaboration, Adam answered back that he knew that everyone saw the same thing because the researcher told them they would during the walk-through session. This breakdown soon got repaired by help from Eden, who re- phrased Bob's initial question for Adam.

Bob's behavior—incrementally refining his initial question—is in accordance with the principle of least collaborative effort [36]. Bob was filling in enough to help Adam understand easily. Yet, his judgment about what was "enough" information for Adam was not in fact enough.

Later in the game, Adam became confused by all the notes Bob was entering on the board and suggested that everyone should only place only one number in the cell by assigning big numbers to one player, the first small note to the second player, the second small note to the third player. In fact, the proposed strategy would not work because there was no way in the software of assigning a note in a particular order to a player. Any one who enters a note into a cell first be- comes the owner of the first note. Bob tried to explain the difficulty, unsuccessfully.

Upon meeting with misunderstanding, Bob stopped trying to explain the difficulty and instead suggested another alternative to simplify the display. He asked the group to divide the board into sections so that each player could work on their own section. This strategy would mean that Bob could use notes his way in his cells and Adam could use notes differently. NB, like Adam's strategy, this one could not really work, at least not for long, because of the inter- twined nature of the game.

From the point of view of an outside observer, Bob had a better grasp of the game play situation than Adam. He questioned Adam's baseless guesswork at first. He tried to ex- plain issues of process. But Bob compromised his initial strategy of using notes to capture the possible numbers that could go into a cell because Adam did not understand it. Adam did not end up "simply lost" like Joan. Bob did not ignore him. Neither did the group maximize its potential achievement in the game. As we have seen, Eden opted out. The current purposes of the collaborative game play move, in effect, away from achievement towards lowering active disagreement.

5.6. Discussion

We investigated co-located groups as they played a collaborative, problem-solving game using distributed technology on laptops. There was considerable variety in how the groups accomplished the work. Some satisfied groups talked a lot but other satisfied groups did not. Talk was diagnostic of satisfaction, but *lack* of talk was not diagnostic of dissatisfaction. Additionally, groups and individuals that had little or no discourse differed considerably from one another. However, one kind of group completes the joint tasks very well without observable markers frequently associated with success. Another kind of group demonstrates problems with process but some components of these problems may represent rational choices for the participant. A third kind of group is marked by inequity—but the contrastive example shows that the design implications depend on the priorities of the setting and participants (and designers).

CSCW is like chemistry before the periodic table. We need descriptive categories for phenomena that are fine-grained enough to inform decision about how to support particular designerly values, but what seem like small differences in the situation make a huge difference in outcomes. Is it the absence of phlogiston or the presence of oxygen? Our examples are important not because of frequency but because they capture variation in the human responses to immediate conditions. That variation includes behaviors that can be interpreted as desirable or undesirable, depending on precisely what the goals are for the interaction.

In fact, to be useful, studies of micro-coordination need to incorporate a variety of conditional outcomes of different sorts. Beyond contextualizing the micro-coordination phenomena, they should set the user of the analysis's frames of interpretation. That is, they are not footnotes to results but starting points for exploring how competing (and perhaps conflicting) values will frame investigations and design results.

This argument supports our contention that the relationship between *micro-level, situated* actions and broader outcomes—including but not limited to—opportunities for learning is under-explored. A key question that follows from this analysis is: “What descriptive categories of behavior constitute the coordination and collaboration from which higher level constructs such as ‘collaborative learning’ emerge in novel CSCW/CSCL situations?”

We do not “put this question to bed,” but we:

—remind researchers and designers that it is centrally important to CSCW research,

—remind researchers and designers that one reason global measures may fail to inform is that they may ignore micro- coordination, and

—draw attention to variety in human behavior that merits design focus in CSCW work.

The assumption that people learned everything about how to collaborate productively in kindergarten [205] itself assumes that interactive technology does not place its own game-changing and possibly problematic demands on co- operative work. We note that there would be little need for research in CSCW if this were true.

Simple behavioral or design lessons such as “talk more” risk interfering with legitimate, productive styles of interaction and papering over differences between the skills required in CSCW settings and those learned in kindergarten.

6. Form Factor Matters[7]

Abstract

Study 2 investigated how different mediating technologies might affect group processes differently by comparing and contrasting three technology conditions (Paper, Laptop and Tablet). Overall, people's positive emotion rose more when they talked more about the complex relationships of the puzzle specifics. People in both computer conditions talked less about the specifics on the game board than people in the paper condition, but only people in the laptop condition experienced a significant decrease in positive emotion.

6.1. Introduction

Questions such as "would you feel more positive if you played a crossword puzzle with your friends on an iPAD as compared to playing the same game as printed in a newspaper or with a laptop?" or "would you talk more if you played *Settlers of Catan* on a laptop rather than playing it on a tablet?" might sound absurd or obvious to some people. They might ask "why would people feel or act any differently by engaging in the same kind of activities using different forms of technologies?" or they might say "I know how to use technology, so it's all the same to me." Indeed, the person who expresses doubt might, in today's culture, feel a need to apologize or qualify him- or herself as "not a technical person."

Previous research, however, has shown differences in interactive technologies can affect and change users' behaviors and their feelings toward the artifacts. For instance, people prefer a computer that flatters or diagnoses them as happy regardless of the correctness of the assessment [146]. People act politely towards computers in general [155], but not towards small computers [72].

In our study, unlike previous studies that looked at how people react to different interactive technologies, we investigate how mediating technologies affect people in group settings. In this case, we examine the role technological mediums play in influencing behaviors and emotional states in a "*triple space*" situation.

Jean Twenge documents a rise in anxiety and depression among young adults, and argues that today's children see themselves as solitary actors, untied to others in Generation Me [192]. Sherry Turkle also portrayed people in our current society as becoming more and more detached from face-to- face interactions and increasingly attached to machinery in Alone Together [191].

While a recent Pew Internet Personal Networks and Community survey reports that the extent of social isolation has not changed since 1985 [77], Klinenberg reports that more than 50% of American adults today are single and one out of every seven adults lives alone [110]. Klinenberg assesses this change positively, claiming that the rise in rates of living alone is a transformative social experience that requires us to make changes in how we view ourselves and our intimate relationships. He claims living alone does not make people any lonelier, and goes on to explain how solitude can be beneficial in reviving personal energy in a hyper-networked, always-connected culture [110]. Klinenberg does not provide evidence about unhappiness (more generally than loneliness).

While the evidence for whether Americans are becoming evermore isolated is still mixed and controversial, and the interpretation for whether the use of social media is supplementing or replacing

[7] A portion of findings reported in this chapter has been published as a short paper in CSCW 2013.

traditional interpersonal connections is debatable, it is an undeniable fact that we are living in the era of information technology, and that we do not necessarily understand all the ways that information technology affects us. For example, loneliness and unhappiness are closely related concepts but they are not identical, and questions about both may vary according to precise details in the framework in which the questions or assessments are made. We need to understand more and our understanding needs to come from many perspectives and levels of analysis. Tablets and smartphones are rapidly taking the place of desktops and laptops. However, we do not yet know what it means to use tablets and smartphones in the place of desktops and laptops.

Findings from our first study (summarized in Chapter 5) suggested a more complex interaction between technology design and user experience than had emerged clearly in prior works. In particular, we found that proxies such as "amount of talk" or even "kinds of talk" proved poor indicators of the satisfactory nature of the system.

Our second study explores the relation between talk, difference in the mediating technology and user's emotional state. It asks "How does the mediating artifact affect people's coordinative behaviors and possibly the way that people feel as they engage in joint activities?" It uses the same highly demanding Collaborative Sudoku task as in our first study, but contrasts a Paper, a Tablet and a Laptop condition. It investigates whether and how the kinds and the form factors of mediating technology affect users' behaviors and their emotional state.

6.2. The Study

To explore the possibilities of the differences in mediating technology having impacts on people's emotional states and behaviors, we asked groups of people to play Sudoku collectively on a 25 x 30.5 inch sheet (base-line, Paper Condition) and on two different form-configurations (Tablet Condition and Laptop Condition) of tablet PCs. In the paper condition (PC), researchers prepared the Sudoku game board manually on 25 x 30.5 inch sheets prior to the study and asked participants to solve the puzzles on that. In both computer conditions, groups were asked to collaboratively solve puzzles on specially designed multiplayer Sudoku software, Team Sudoku. We made an explicit decision to use a type of computer that has a twist-and-swivel display so that we could configure the same computer both as a laptop and as a tablet. For the laptop condition (LC), mice were connected to the systems as the primary input devices, while for the tablet condition (TC), stylus pens were provided as the primary input devices. Keyboard input mechanisms were disabled in the systems to maintain compatibility between the laptop condition and the tablet condition in which keyboards are hidden under the laid-down screens, inaccessible to the users.

Clearly, there are many differences between the paper and the computer conditions that are consequences of the types of sharing that they enable. However, the differences between the LC and the TC include only the configuration and the input device.

6.2.1. Procedures

The study was designed as a two-phased, between-subject experiment. During the initial sign-up process, participants were directed to an online survey site and asked to fill out questionnaires about demographics, prior experiences with Sudoku as well as five personality self-report inventories (Big Five [98], Circumplex Scales of Interpersonal Values [119], Circumplex Scales of Interpersonal Efficacy [120], Beck Anxiety Inventory [8] and Beck Depression Inventory [9]). Only the participants who filled out the online questionnaires were allowed to sign-up for phase 2. When participants reported that they did not have prior Sudoku experience, they were directed to a web site that had both descriptions of the Sudoku rules and sample Sudoku games.

In phase 2, participants were brought into a small room and seated in close proximity to one another. They were introduced to one another when they came into the room. After the informed consent process, participants were asked to fill out a pre-game questionnaire (Q1) including questions about their experiences with the game and with the other players, and also the 20-item Positive and Negative Affect Schedule (PANAS) [197] that measures how people are feeling in the moment. After filling out Q1, researchers briefly went over Sudoku rules (in all conditions) and conducted a software walkthrough (in LC and TC) in order to familiarize participants with the Team Sudoku tool features. The groups were then asked to work together on two Sudoku puzzles, in an order counter-balanced across groups. The groups were given 20 minutes to work on each game. After each game, participants filled out post-game questionnaires (Q2 and Q3), including retaking the PANAS. In Q3, we also asked them to rate how much they were satisfied with the group and the way it worked together on a scale of 1 (not at all) to 7 (very much). There was also a short discussion at the end of the study. Video and audio recordings of all the game sessions were collected as well as computer logs and screen shot movies of the games.

6.2.2. Participants

Players were recruited from the Psychology Participant pool, and received extra credit for participation. A total of 138 (75 female, 63 male) college students enrolled in the study, in 24 groups of two and 30 groups of three. Participants' age ranged from 18 to 41 (M = 19 SD = 2.28). 10 of 138 reported that their first language was not English, but none appeared to have difficulty because of this. Almost all the participants had prior experience with Sudoku. 15 reported initially that they did not know the Sudoku rules, but researchers confirmed that these 15 people were at least fully familiar with the Sudoku rules when they came in for the on-site experiment. Overall, participants reported playing Sudoku quite often (M = 5.35, SD = 1.51) on a scale of 1 (rarely) to 7 (several times a day). If only two participants appeared at the agreed time, the game was run with them, resulting in 24 groups of two. In this paper, however, we only address the triads.

6 pairs out of 90 participants knew each other before coming to the study. There were no groups in which all three participants knew each other, and the six pairs were relatively well spread out among the three conditions: 1 in PC, 3 in LC, and 2 in TC. Indeed, a Chi-square test for independence indicated no significant association between the condition and acquaintance status, $\chi2(2, n=90) = 3.75$, $p = .15$, Cramer's V =.2. However, when we ran an independent-samples t-test to compare the changes in participants' positive emotions for groups that had pairs who knew each other (M = 4.11, SD = 6.77) and groups that did not (M = 0.68, SD = 6.09), two groups were significantly different ($t (88) = 2.09$, $p = .04$, two-tailed). In other words, after playing the first Sudoku game together, groups that had people who knew each other previously felt significantly happier than groups that did not know each other. So we excluded these 6 groups from the analysis to ensure that there would exist no interfering effect between the acquaintance status and the groups' behaviors.

6.3. Methods

Four video cameras recorded each session. With three cameras facing each participant and one capturing the entire group, we were able to ensure that each player's facial expressions as well as bodily gestures were captured in the video recordings. An additional audio recorder was also used to capture the participants' conversations.

The 24 20-minute video recordings of the first Sudoku game for triads were transcribed using a slightly modified version of Chafe's prosodic transcription system [34], which focuses on information flow. Five researchers worked on transcribing the sessions in three different iterations. Transcripts from audio were created in the initial iteration. Descriptions of non-verbal gestures as well as critical changes on the Sudoku board were added in the second phase. Transcripts were then arranged into intonation and conversational turn units. The final transcripts were reviewed for accuracy several times with the log files and screen-captured videos.

6.3.1. Measuring Performance

While Sudoku puzzles typically have only one correct solution, it is not easy to definitively assess an unfinished game. That is, Sudoku is an all or nothing game in that a group that has two incorrect entries after 10 moves is not necessarily performing any worse than a group that has four incorrect entries at the same stage.

In our case, only 2 out of 30 groups finished the puzzle (Game1) within the given time. Fully acknowledging the arbitrariness of the assessment metrics, for practical reasons, we used the number of correct/incorrect entries and the number of filled/left-empty cells to measure relative performances among the groups. The formula we used is as follows.

$$Score = \alpha * X + \beta * Y + \Upsilon * Z$$

X denotes the number of correct entries, Y the number of incorrect ones, and Z the number of left-empty cells. α, β, ϒ are weight variables, and we used values, 30, -20, and -10 respectively. The formula penalizes both empty and incorrect entries, but does so more heavily for the incorrect entries, while rewarding the correct ones. The scores for the groups ranged from -560 to 1620 (M = 366.25 and SD = 615.76).

6.3.2. Measuring Amount of Talk

The counts for the conversational turns as well as the utterances were extracted and computed from the transcripts. The number of conversational turns each player took during the game ranged from 11 turns to 247 turns (M = 78.58, SD = 55.38). The number of utterances ranged from 41 to 1676 (M = 522.97, SD = 378.66).

6.3.3. Measuring Kinds of Talk

Transcripts from 24 triad sessions were coded using the 3-layered hierarchical coding scheme developed in Study 1. The coding scheme consists of 20 codes under four main categories and ten subcategories. The four main conversational categories are 'board-related,' 'game-related,' 'off-topic,' and 'other.'

Board-related utterances refer to specific elements, regions, possibilities, or problems on the Sudoku board. It has four subcategories. *Statement* represents simple, unelaborated statements or fragmented ideas such as "uh oh the six has to go there." *Question* refers to incidents in which a participant expresses doubts, asks for confirmation, or demands an explanation of elements on the game board such as "why does it have to be on the bottom?" *Elaboration* means the participant went a little further to explain reasons for moves, possibilities and problems rather than just stating simple facts. *Adding* *dimensionality* is a code that captures instances in which participants built ideas on top of previously presented ones. In coding *adding dimensionality*, we added one more constraint to the original adding dimensionality category in order to prevent one person dominantly adding new ideas one after another, resulting in an over-estimated number for the adding dimensionality category. In order to be considered as adding dimensionality, (1) segments of utterances needed to add new ideas to the group conversation, and (2) the person contributing the new ideas should not have contributed the immediately preceding new ideas. If a participant contributed two new ideas in a row, we considered the person to be leading the flow of the conversation, and marked the second new idea as board-related statement, question or elaboration based on the nature of the utterance.

```
Adam: I'll put like little fives here {statement}

Caitlin: but you still need

    like a five in that row though

    and it can't go anywhere else

    in that [row] {adding dimensionality}

Adam:    [why] do you need a five in that row {question}

Caitlin: ((begins to explain the reasons)) {statement}
```

Excerpt 6.1: Coding Example – statement, question and adding dimensionality

In Excerpt 6.1, for instance, we code Adam's first turn as *statement* because Adam, by saying he will make changes to the game board, starts a new segment of discourse isolated from previous conversation. Caitlin adds a new perspective to Adam's proposed move by proposing other possibilities. Therefore, we code Caitlin's first turn as *adding dimensionality*. In his second conversational turn, Adam asks Caitlin why she said what she said, but adds no new perspective to the specifics of the game board. We code Adam's second turn as *question*. In her second turn, Caitlin adds previously unmentioned ideas to the group conversation. However, this time, we consider Caitlin to be taking over the flow of the conversation since she adds two consecutive new ideas, and code the turn as *statement*.

Game-related utterances are closely related to the game, but do not refer to any specifics of the game board. This category includes discussion of *game strategy*, *game-specific* and *game-general* discourses. *Game-specific* is discourse related to the current puzzle but not to specifics of the puzzle (as in "this puzzle is hard"). *Game-general* utterances code inquiries and comments on Sudoku rules, prior Sudoku experiences, software features and research procedures.

Off-topic included utterances not directly related to the game activities. Inaudible, regulatory intonations (non-lexical and phrasal backchannels), and non-sentential sounds (laughs...) were coded as *Other*.

Figure 6.1 shows the distribution of utterances in the top two levels of the coding scheme. Only 0.86% of the conversation was *off-topic*, suggesting that people were quite engaged in the puzzle solving activities. 28.22% of the utterances were back channels. 36.76% were simple *board-related* statements.

Statistics collected on the coded transcripts include the number of conversational turns and utterances each player made throughout the session. Similarly, a log analyzer was used to gather information on the total number of entries, notes, and deletions that each player made during the game (only in LC and TC).

The number of correct and incorrect entries for which each player was responsible was also counted according to the sate of game board when the time was up. (in all three conditions).

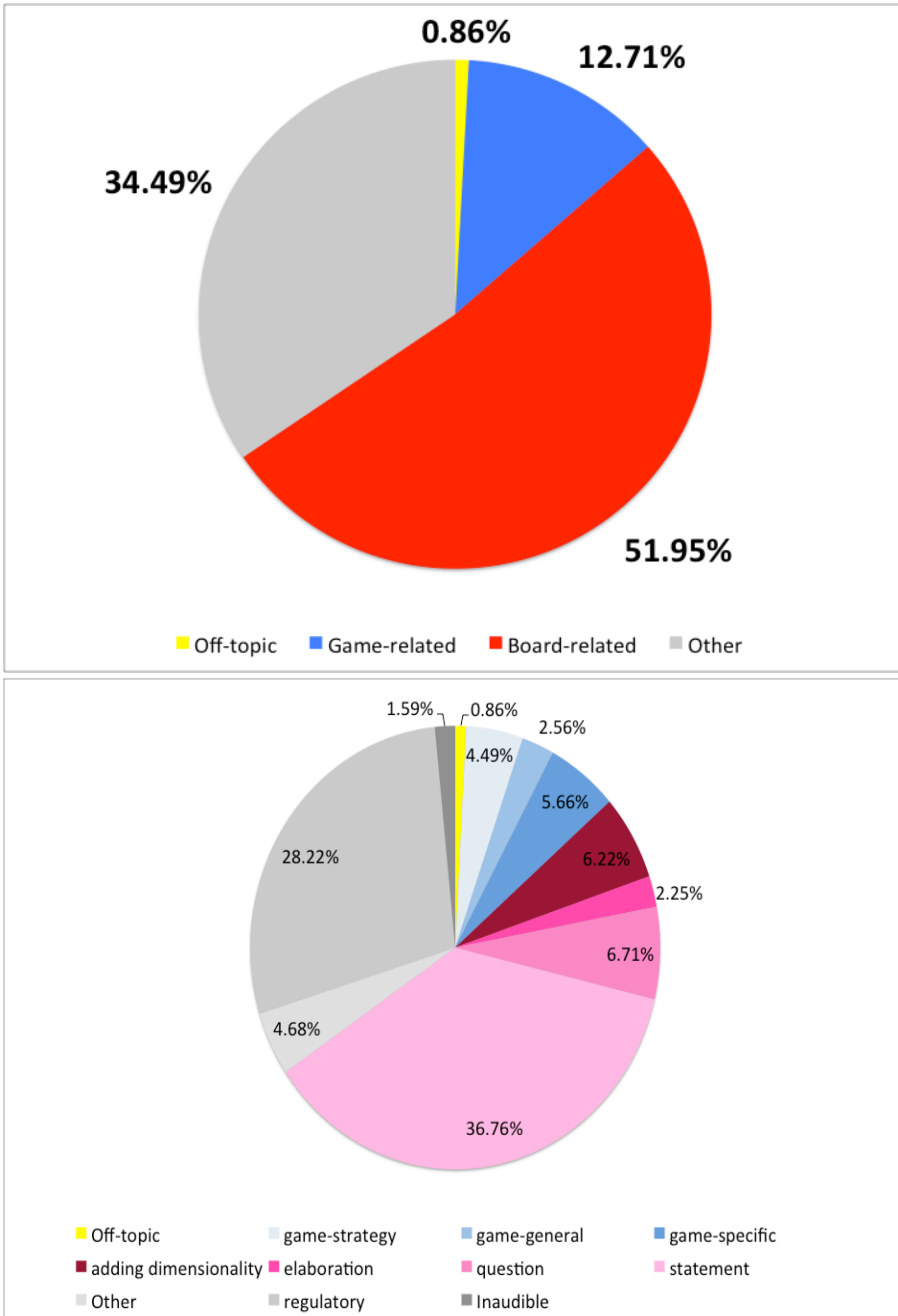

Figure 6.1: Overall Number of Utterances by Category.

6.4. Findings

6.4.1. How the difference in the technological medium influences participants' self-reported satisfaction

One of the most obvious differences among the triads playing collaborative Sudoku was in activity level, either through talking or through contribution to the board. In investigating triads collaboratively playing Sudoku, our previous investigation (Study 1) showed that contributing to discourse was statistically related to participants' self-reported satisfaction. We were able to partially replicate the results in Study 2.

In Study 2, the average number of conversational turns/group was 235.75, and the standard deviation was 140.38. Overall, we observed a statistically significant difference in self-reported satisfaction related to the amount of discourse in the group. Players were asked to rate how satisfied they were with the group and the way they worked together on a scale of 1 (not at all) to 7 (very much). The number of conversational turns each player took was significantly correlated with self-reported satisfaction ($r = 0.281$; $p = 0.017$). *The more a player talked during the game, the higher satisfaction rate s/he reported.* However, there was no correlation between satisfaction rate and the number of entries individuals contributed to the game board ($r = 0.12$; $p = 0.45$). Nor was satisfaction rate correlated with Sudoku scores ($r = 0.054$; $p = 0.65$).

When we ran the correlation tests by mediating technology conditions, the correlation between the self-reported satisfaction and the amount of talk was only evident in PC ($r = 0.448$; $p = 0.019$), but not in LC ($r = 0.237$; $p = 0.30$), nor in TC ($r = -0.146$; $p = 0.49$). However, one-way ANOVA showed no significant differences among the three conditions ($F(2,69) = 1.04$, $p = 0.36$). This suggests that even though there exists correlation between self-reported satisfaction and the amount of conversational turns each individual took during the game session, no significant differences exist in the satisfaction rate among the three conditions. In other words, the differences in mediating technology seemed not to affect how individuals said they felt after playing Sudoku together.

6.4.2. How the difference in the technological medium influences participants' emotions

The first mood state (PANAS) questionnaire was given before the first puzzle, the second between the first and the second puzzle, the third after the second puzzle. As usual, the sum of scores for the Positive Affect (PA) items and the sum of scores for the Negative Affect (NA) items were calculated for each PANAS test. Differences in scores were calculated to monitor the mood changes after playing each game, but we only focus on the first game in this investigation.

Overall, the group average of the differences in members' positive emotional states (ΔPA^{group}) were positively correlated with the average of members' contributions to discourse ($r=0.40$; $p=0.05$). That is, groups that had participants who took more conversational turns overall tended to exhibit a higher rise in positive emotions. Correlation between ΔPA^{group} and Sudoku scores also neared significance ($r=0.39$; $p=0.06$). However, ΔPA^{group} was not correlated with the contribution to the board. Note that we used the group averages instead of individual ΔPA scores ($\Delta PA^{individual}$) or the number of conversational turns taken by individuals, since the groups were the experimental units, not individuals. Sudoku scores were already a group attribute. Throughout this paper, we used group average over sub-samples (individuals) in our analyses.

More interesting correlations were between ΔPA^{group} and different kinds of talk that groups held during the game. In general, a significant positive-correlation existed between ΔPA^{group} and the number of conversational turns marked as adding dimensionality (r=0.41; p<0.05) or as board-related (r=0.44; p<0.05). There also existed a marginal negative-correlation between ΔPA^{group} and the number of conversational turns coded as game strategy (r=-0.36; p=0.08). In other words, the more the groups talked about the complex relationships of the puzzle specifics and added new perspectives to other people's contributions, the higher the rise in the average of group members' positive emotions. The more they talked about game strategy, the less positive they felt. No correlation was found between the differences in people's negative emotional states (ΔNA) and any of the metrics we used in this investigation.

A one-way between-groups analysis of variance was conducted to explore the impact of the technological conditions on the average of the changes in positive emotions (ΔPA^{group}). Since Levene's test for homogeneity of variances showed unequal variances among the three conditions (p=0.15), we used Welch's Robust ANOVA. The result reported that differences existed in ΔPA^{group} among the conditions ($F(2, 13.53) = 4.37$, $p < 0.05$) in which PA scores showed a gain of the most positive affect in PC, a gain of only a bit in TC, and a loss in LC (Table 1). The effect size for ΔPA^{group}, calculated using eta-squared, was 0.23. In Cohen's terms, this effect is considered large. (p.284-287, [42]).

Drilling down, post-hoc comparisons using the LSD test indicated that participants in PC had a significantly higher rise in PA scores than participants in LC (Mean Dif. = 4.29; $p < 0.05$). Those who used paper were quite a bit happier than those who used the laptop. Subtle, but more surprising was the difference between TC and LC. The difference in ΔPA^{group} between TC and LC was marginally significant (Mean Dif. = 2.64; p = 0.15). Instead of Laptop and Tablet resembling one another, Paper and Tablet were more aligned on this outcome measure. Furthermore, the mean value for LC (M = -1.81) decreased after the game, while the mean value for TC (M=0.83) and PC increased (M = 2.48).

In sum, our data shows that the incremental changes in people's positive emotional states are associated with the properties of the medium. These differences are associated not only with the large and obvious differences between PC and the computer conditions, but also with the more subtle differences between LC and TC. The difference between LC and TC shows that not only the differences in mediating technology, but also the differences in form factor, affect people's emotional states differently.

Condition	N	Mean	Std. Err
Paper	9	2.48	1.56
Tablet	8	0.83	0.98
Laptop	7	-1.81	0.69

Table 6.1: Group Average of Positive Affect Change Before to After First Game.

6.4.3. How the difference in the technological medium influences participants' contributions to group discourse

Overall, the number of conversational turns individuals took differed from one technological condition to another (P1-to-P2, $F(2,87) = 5.86$, $p < .004$). People in the paper condition took significantly more conversational turns than individuals in either the LC (Mean Dif. = 33.73; p = 0.01) or the TC (Mean Dif. = 41.47; $p < 0.01$).

Moreover, statistical differences existed not only in the overall amount of talk, but also in the distribution of kinds of utterances. The amount of board-related conversation ($F(2,21) = 3.40$; p=0.05) differed by group. Post-hoc comparisons showed that participants in PC talked significantly more about the specifics of the game board than people in TC (PC vs. TC: Mean Dif. = 115.08, $p < 0.05$) and marginally more than people in LC (PC vs. LC: Mean Dif. = 87.33, $p = 0.08$).

It is, perhaps, not very surprising that participants talked more in PC compared to participants in the other two conditions. The more the participants talked, the more likely they were to talk certain kinds of conversation. However, more interesting differences lay in the proportional comparisons for the different kinds of talk. When we looked at the percentage of different discourse categories, participants in PC not only had proportionally more conversation marked as board-related ($F(2,21) = 5.81$, $p < 0.01$) than people in the other conditions, but also people in PC had proportionally less conversation coded as game-strategy ($F(2,21) = 4.03$, $p < 0.05$). Table 6.2 shows the post-hoc analysis between the pairs.

Kinds of Conversation	Condition Pairs	Mean Dif.	p-value
board-related (%)	PC vs. TC	0.20	< 0.01
board-related (%)	PC vs. LC	0.14	< 0.05
game-strategy (%)	PC vs. TC	0.04	< 0.05
game-strategy (%)	PC vs. LC	0.04	< 0.05

Table 6.2: Post-hoc analysis for kinds of talk/total conversational turns taken by group

In other words, ***participants in PC talked more about specifics of the game-board, but less about the game strategy than people in the other two conditions in both absolute and relative terms.***

From a statistical perspective, our data tells us that the differences in mediating technology affect participants' emotional states and verbal behaviors differently, but neither the game scores nor self-reported satisfaction is influenced by the conditions.

These statistical differences are, by themselves, important findings, but at the same time they are frustrating. They do not lead to clean causal claims and associated design implications. First, we do not know why people in PC would talk more about specifics on the game board. As we mentioned earlier, some might just say it is trivial that people in PC would just talk more since, both in LC and TC, all the game entry moves are automatically logged, and therefore people do not need to exchange information about the game entries. But is it really trivial?

Second, we cannot definitively tell why people who used tablets were less susceptible to the changes in positive emotions. When participants used laptops, they talked significantly less about specifics on the game board, and had a considerable decrease in their positive feelings than people who used paper. But when participants used tablets, the changes in their positive feelings weren't statistically different from the people in the paper condition, even though people who used tablet also talked significantly less about specifics on the game board. We still do not know why people using tablets had higher positive emotions than people using the laptop. The fact that these two groups of people used exactly the same computers, but in different form configurations just hints to us that the form factor of technological medium might affect changes in people's emotional states differently.

In order to explore these issues, we conducted a contextualized analysis to develop fuller understandings of how the groups conducted their joint activities.

6.5. How Groups Differ

We first ranked groups based on Sudoku scores and ΔPA^{group} into two ranking systems, and then grouped them into high (above the 3rd quartile), mid (below the 3rd and above the 1st quartile), and low (below the 1st quartile). We then identified 6 sample groups based on the cross tabulation of the two ranking scales (Table 6.3). We base our qualitative discussions on these 6 groups.

	High Score	Low Score
High ΔPA^{group}	G14(PC)	G38(TC), G40(PC)
Low ΔPA^{group}	None	G34(TC), G44(PC), G46(LC)

Table 6.3. Cross Tabulation (ΔPA^{group} x Score)

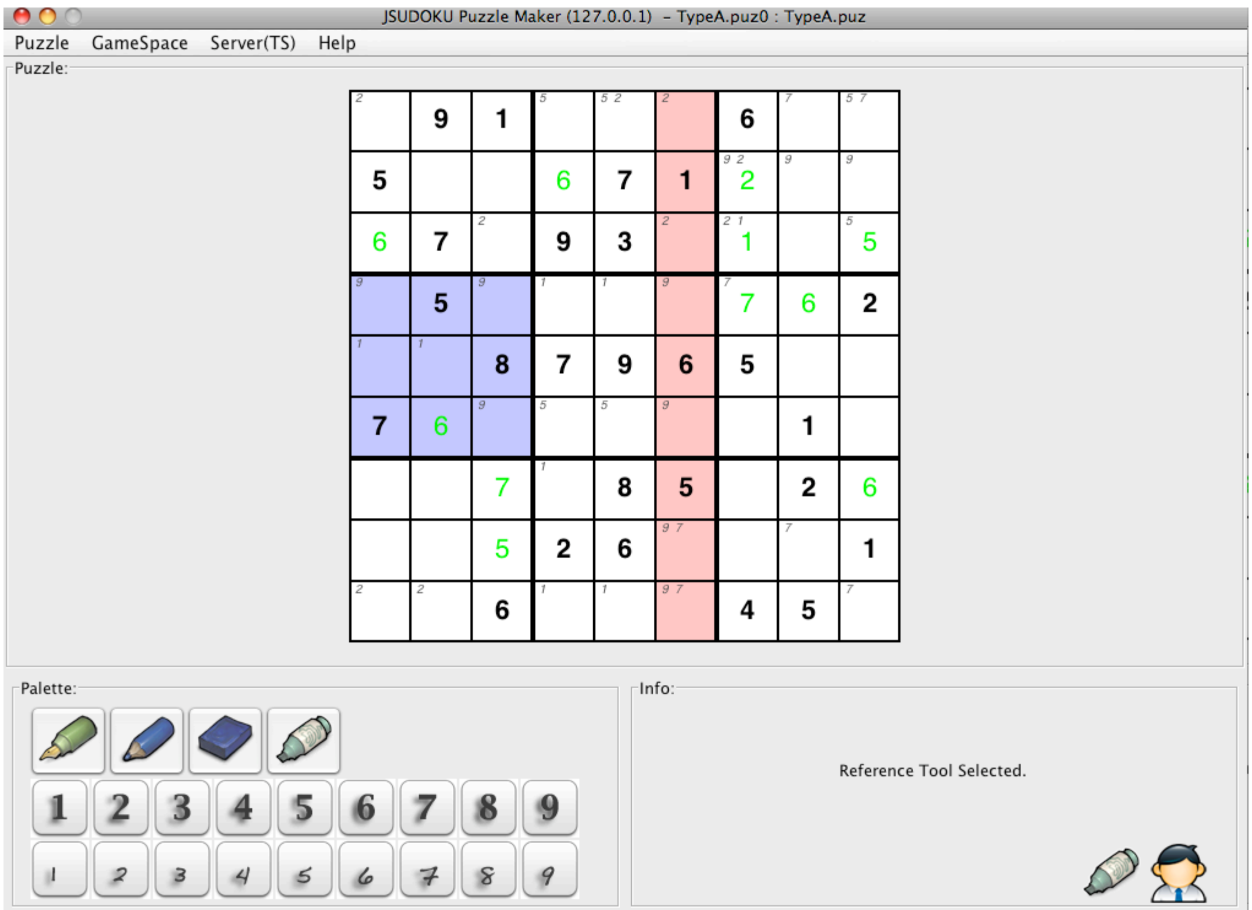

Figure. 6.2: High ΔPA^{group}, High Score Group14 (Paper Condition)

The most salient difference between the high score, high ΔPA^{group} group (group14) and three low score, low ΔPA^{group} groups was how groups managed to maintain group focus.

Throughout the session, Ann, Bill and Cook (group14) maintained the group focus by utilizing not only verbal communication, but also physically putting their hands on the paper board. As shown in Figure 6.2, these three players constantly pointed to same area on the puzzle board while speaking to each other. In this group, Ann worked as the dedicated entry marker for the team. She was the only one who marked down entries on the game board. Yet, the other two players also constantly pointed and kept their hands around the focused region of the game board.

Group14 resembled a case of three boys that Brigid Barron described as “coordinated coconstruction” in her study [5] in that both groups maintained joint attention throughout the session and collaboratively worked towards solving the given tasks. However, unlike Barron’s three boys, the joint activity as well as the group discussions in group14 were only led by two dominant players, Ann and Cook. In that sense, group14 also resembled “two’s company” [5] since the group activity was led by two dominating participants. However, while the two dominating students in Barron’s case ignored the less outspoken one, Ann and Cook, who contributed to 43% and 52% of the group discourse respectively, were always responsive to Bill’s contributions. (Even though Bill only contributed to 5% of the group’s discussion.)

```
Adam: like one of us could take the first three= and then= just keep lookin

    and see if anybody filled in anything

Charles: well I usually just like= do it like=

    .. all at once so like we can all just think together .. really

Adam: alright

Bobby: alright
```

Excerpt 6.2: Talking Strategy (Group44 – Paper Condition)

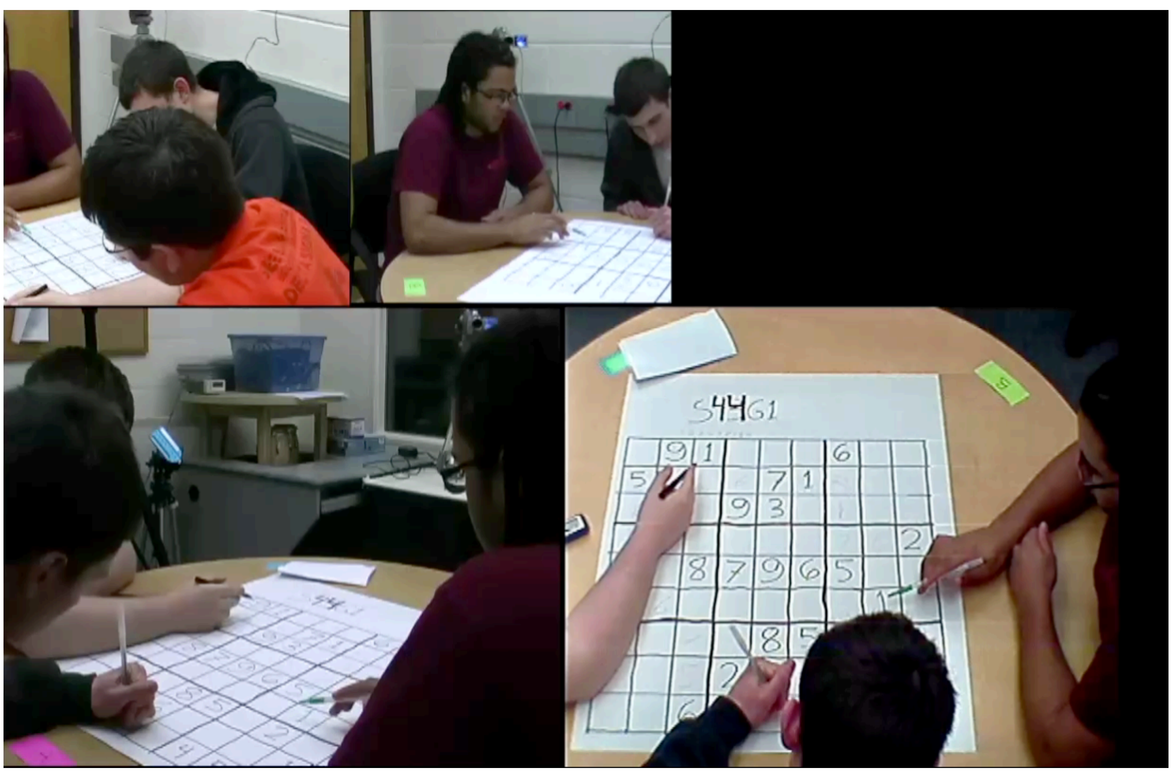

Figure. 6.3: Low ΔPA^{group}, Low Score Group44 (Paper Condition)

On the contrary, group44 (also in PC) showed a distinctively different set of behaviors. Three male participants, Adam, Charles and Bobby, started their group activity by discussing how they would go about solving the puzzle. In Excerpt 6.2, Charles suggests they "do it like= all at once" (maintain group focus together) and "think together." However, what they did during the session was the exact opposite. Even though they sporadically focused on the same specifics on the game board and tried to talk through the solutions, they mostly remained silent, working individually. These three participants mostly kept their hands off the paper board. When they pointed to or wrote on the game board, they tended to work on separate regions as illustrated in Figure 6.3. When multiple people needed to point to the same region, these three participants were hesitant to put their hands on the region already occupied by another player. Instead, they waited until the other player retracted his hands. This was quite distinctive from group14. In group14, both Ann and Cook continually approached the regions already occupied by other people's hands without any hesitation. Figure 6.2, indeed, shows Ann placing her left hand onto the cell to which Cook is already pointing.

Groups in both the Tablet and the laptop conditions obviously could not use their hands to point to the puzzle regions to indicate their focus. Even though we provided a deictic tool that could highlight different puzzle elements, people in both computer conditions used the tool much less frequently than people in the paper condition used their hands. Two notable shortcomings in the deictic tool were (1) it only supported highlighting one element at a time per player, while participants in PC had two hands per person, and (2) the deictic tool required activation (users needed to activate the highlighter to highlight and deactivate it to fall back into writing mode), while people's hands were readily available.

Different technology mediums afford different sets of behaviors and also have different constraints. Problems pertaining only to the paper condition exist. For example, since three people shared one big piece of paper, the game board was only oriented toward one person. The two other players had to look at the game board upside-down or side-ways. Participants hand-wrote the entries as well as small notes on the paper using pens. Some had difficulties reading their teammates' handwriting. However, even with all these shortcomings in the mediating technology, people in the paper condition experienced a rise in their positive emotional states. Sharing a physical game board might have helped people feel more connected than when they were sharing a digital game board. The digital mediums, by supporting surrogated interactions, might be pulling people away from more direct, social interactions. We cannot decisively tell what caused people in PC to feel significantly better than people in the other two conditions. Yet, it is most probable that different affordances in the mediating technology as well as in the deictic mechanism enabled different sets of behaviors, which impacted how people felt toward their group activities.

```
John: Go ahead and highlight it

Tom: How do you highlight?

     Do you [just-]

John: [Uhm] you press the highlighter and then press that

Tom: Alright
```

Excerpt 6.3: Discussion about a Tool Feature

Although the statistical differences between TC and LC were not as prominently contrastive as the difference between PC and the computer conditions, there clearly existed subtle but important differences. Among the noticeable behavioral differences between TC and LC was that some participants in TC tried to glance at other players' screens during the sessions while none in LC exhibited such behavior. For instance, in Excerpt 3, Tom asks John how to use the highlighter tool. As John explains how to enable the tool, Tom glances at John's screen very briefly (this moment is captured in Fig. 6). Even though players shared the same information on their own screens, participants might have felt more connected by having a chance to physically share what they considered to be their private resources. This conjecture might also help in explaining the highest mean numbers in positive affect changes in PC, in which participants had a large shared resource. In LC, upright-positioned screens might have acted as physical barriers between players, whereas in TC, laid-down screens could have helped people to feel enhanced social presence by providing increased immediacy for social interactions [199].

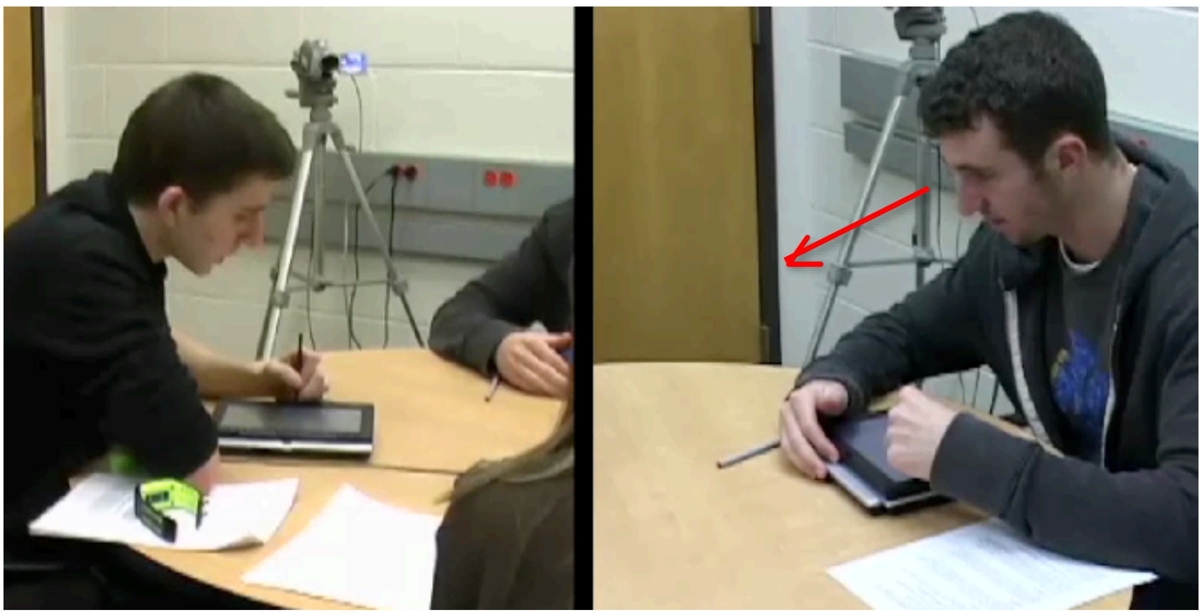

Figure 6.4: Glancing at Other Player's Screen (Tablet condition)

6.6. Discussion

Our quantitative analysis shows statistically significant differences in the amount of particular kinds of talk among the three mediating technology conditions. People not only talked significantly more when they shared a big piece of paper to collectively work on a Sudoku puzzle, but they also talked proportionally more than people in the two computer conditions about the complex relationships of the puzzle specifics, adding new perspectives to other people's previous contributions.

Our data also show that people's positive feelings rose more when they talked more about the specifics of the game board in general. However, people who used tablets were less susceptible to the changes in positive emotions than people who used laptops. When participants used laptops, they talked less about the game contents than people who used paper, and their positive feelings decreased significantly. But when participants used tablets, the changes in their positive feelings weren't statistically different from the people in the paper condition, even though participants in the tablet condition also talked significantly less about the game contents than people in the paper condition.

Close examination of the group interactions revealed that participants in high performing groups in the paper condition utilized verbal communication as well as their hands to maintain group attention on specific regions of the game board throughout the session. Subtle behavioral differences also existed between the two computer conditions. Participants in the tablet condition sometime glanced at other players' screens, while no such behavior was witnessed in the laptop condition. We conjecture that not only would having the shared visual space help collaborators understand the current state of their tasks better [112], but also having the mere possibility of sharing certain visual information would impact how people feel toward their group work. We suppose that future research comparing technologies with different screen sizes will help us further test our hypothesis that having physically less obtrusive technologies can cause an increase in positive emotional states.

Our findings tell us that differences in technology medium do not necessarily beget different user behaviors, but only enable users in different ways. We believe the way groups act in these different technology conditions makes actual differences. Putting people in the paper condition does not make the group talk more, but it only nudges [189] the group in a certain direction. After all, it is the people who decide what they do in the group setting, and how they act in the group setting makes a difference in how they feel toward their group work.

7. Sounds of Silence: A Study on Non-Responses

Abstract

Previous research reports a number of independent variables that affect group processes. Many empirical studies have explored group work on an interactional level, reporting various coordinative properties of joint activities. Yet much attention is given only to linguistic and paralinguistic features of interaction; most previous studies focus on examining *what people say* or *do* in interactions, and seldom look at *what people do not say*, or *do not do*. *Silence* has always been considered as background, or a void needing to be filled with interactions. This research is a study of *silence*. In this work, I examine how silence affects group processes in "*triple space*" situations. In particular, I look at a specific kind of silence: *non-responses*.

7.1. Introduction

My research explores what most other studies consider a background in interaction: *silence*. Much research that looks at moment to moment interactions, whether it stems from psycholinguistics, conversation analysis, or sociolinguistics, invariably focuses on examining *what people say* and *do* during the interactions, and seldom looks at *what people do not say* or *do not do*. Indeed research on coordination is built on the premise that cooperative group work requires a certain minimal level of communication [116]. *Talking* has always been at the center of the interaction analysis. I also believe that both linguistic and paralinguistic features of interactions are important factors in understanding how individuals conduct joint activities. In my research, however, I try to bring the background to the fore, and give full attention to *what people do not say*.

In Study 1, I explored a general issue of how people solve the problem of interacting in triple space and came to notice that silence is not just a background for talking, nor a void that needs to be filled with interactions; instead it is as equally important a construct of joint activities as talking or gestures. In Study 2, I investigated how *silence* plays a role among talking groups at an interactional level. In particular, I looked at a specific kind of silence: *non-response*. While I was conducting both studies, on many occasions, I observed that participants sometimes did not respond to what other players said. In order to systematically examine how non-responses affect groups processes, and how mediating technology conditions influence the way people do not respond to others, this chapter uses Clark and Schaefer's Contributions to Conversations model [39,40] in analyzing the data from Study 2.

7.2. Contributions to Conversations

Clark and Schaefer [39,40] argue that people in conversation speak to make contributions to the social process they are engaged in. They see that contributions to conversation are achieved through content specification and grounding. Through speaking and listening, interlocutors in conversation collectively try to establish mutual understandings [36,39,41]. In order to accomplish such kinds of mutual understandings, conversants collaboratively create units of conversation called contributions. Contributions are "stretches of speech and the grounding of the contents (p37, [39])."

The model of contributions says contributing to conversation occurs in two phases—content specification and grounding. In content specification phase, a speaker presents stretches of speech for the groups to consider. In grounding phase, conversants seek to establish the mutual belief that everyone has good enough understandings of what is being said and presumably of the group processes in which they are currently engaged for their current purposes [39,40].

Even though Clark and Schaefer [39] do not imply that the model of contributions is only applicable to dyads, they only use examples of dyadic interactions drawn from a very confined context—directory inquires to a telephone company. In this section, we attempt to clarify how the model would apply to triads, and slightly modify the model to analyze our triadic interaction data.

First, the model of contributions states that the process of making contributions consists minimally of three parts (p22, [39]) in the case of dyadic interactions:

(a) A presents *u* for B to consider.

(b) B accepts *u*.

(c) A accepts that B accepts *u*.

This process can easily be applied to triads (A,B and C). The process for triads would consist minimally of five parts:

(a) A presents *u* for B and C to consider

(b) B accepts *u*.

(c) C accepts *u*.

(d) A accepts that B accepts *u*.

(e) A accepts that C accepts *u*.

Note that in this triadic interaction, neither B nor C needs to accept that the other understood *u*. While the categorical rendition of the 'mutual belief' that everyone has good enough understandings of *u* would include both that B accepts that C accepts u and that C accepts that B accepts u, I find these two parts exorbitant as well as unsubstantial. That is, in conversation, listeners do not typically seek to understand if other listeners have understood what the speakers have said.

Second, the model of contributions claims that the model cannot be reduced to the notion of repair and repair opportunity (as in [164]) because the model not only helps to define troubles—which only occur at specific points in interactions—but also helps to delineate how people achieve goals in interaction through grounding processes [39]. Yet the model does not fully explain that there could exist multiple goals in joint activities, and that some goals can still be achieved even without always making successful contributions to conversations. For instance, in Study 1, we saw that groups can still successfully solve a puzzle without making any contributions to conversations. In directory inquires, if a customer and an operator fail to achieve mutual understandings of each other, it automatically means a failure of the main and the only task—getting necessary information. On the other hand, in Sudoku (and in many other triple space tasks), occasional failures of achieving mutual understandings do not decisively mean a failure of the task. On multiple occasions in my study, many attempted contributions were, in fact, ignored. That is, when a participant presented an utterance *u* for the other two to consider, instead of going through an acceptance (grounding) phase, the utterance *u* did not get any response back from the other players.

Third, unlike most previous models of discourse which either assume that the content of each utterance is automatically added to common ground or that the content is added to common ground unless there exists negative evidence of understanding, the model of contributions argues that each participant in conversation must take positive steps to mutually establish beliefs that the content is understood by everyone. The model of contribution mandates positive evidence of understanding. Clark and Schaefer listed five different types of positive evidence: *continued attention*, *initiation of the relevant next contribution*, *acknowledgement*, *demonstration,* and *display* [40].

Among these five types of positive evidence, however, I found *continued attention* to be possibly ambiguous. Clark and Schaefer argue that when a participant does not show changes in his/her "attentive demeanor or eye contact (p267, [40])," we should consider the participants as giving positive evidence of understanding. Yet conducting tasks in *triple space* requires participants to concurrently perform multiple functions, and it becomes almost impossible to tell if participants' attentive demeanors mean they are attending to social interactions or to the problem solving task. A majority of our participants mostly kept their gazes on their computer screens throughout entire gaming sessions, even while talking to each other. When a participant did not display any behavioral changes, we could not tell if the participant was attending to what other players had said, or was too immersed in the problem solving task to even hear other participants. So we made a strategic decision not to consider *continued attention* as positive evidence of understanding. This modification to the original *contributions to conversations* model was necessary to operationally discern a *non-response* from passively displaying an evidence of understanding by not doing anything.

7.3. The Study

7.3.1. Procedures

Study 2 was designed as a two-phased, between-subject experiment. In Study 1, even though the participant recruiting advertisement explicitly asked for people who had prior Sudoku experiences, I still had participants come to the study without knowing how to play the game. So I made Study 2 two phased in order to discourage participants from coming to the study without knowing the rules.

In phase 1, participants were asked to fill out online questionnaires about demographics, prior experiences with Sudoku, and five personality self-report inventories (Big Five [98], Circumplex Scales of Interpersonal Values [119], Circumplex Scales of Interpersonal Efficacy [120], Beck Anxiety Inventory [8] and Beck Depression Inventory [9]). When participants reported that they did not have prior Sudoku experience, they were directed to a web site that had both descriptions of the Sudoku rules and sample Sudoku games.

In phase 2, participants were brought into a small room and seated in close proximity to one another. They were introduced to one another when they came into the room. After the informed consent process, participants were asked to fill out a pre-game questionnaire (Q1) including questions about their experiences with the game and with the other players, and also the 20-item Positive and Negative Affect Schedule (PANAS) [197] that measures how people are feeling in the moment. The groups were asked to work together on two Sudoku puzzles, in an order counter-balanced across groups. The groups were given 20 minutes this time to work on each game. I added 5 more minutes to each game, hoping to see more interaction and more talking. After each game, participants filled out post-game questionnaires (Q2 and Q3), including retaking the PANAS. In Q3, I also asked them to rate how much they were satisfied with the group and the way it worked together on a scale of 1 (not at all) to 7 (very much).

7.3.2. Participants

Players were recruited from the Psychology Participant pool at Virginia Tech, and received extra credit for participation. A total of 138 (75 female, 63 male) college students enrolled in the study, in 24 groups of two and 30 groups of three. Participants' age ranged from 18 to 41 (M = 19 SD = 2.28). Almost all the participants had prior experience with Sudoku. 15 reported initially that they did not know the Sudoku rules, but researchers confirmed that these 15 people were at least fully familiar with the Sudoku rules when they came in for the on-site experiment. Overall, participants reported playing Sudoku quite often (M = 5.35, SD = 1.51) on a scale of 1 (rarely) to 7 (several times a day). If only two participants appeared at the agreed time, the game was run with them, resulting in 24 groups of two. Again I only address the triad sessions in this chapter.

Six pairs out of 90 participants knew each other before coming to the study. There were no groups in which all three participants knew each other, and the six pairs were relatively well spread out among the three conditions: 1 in PC, 3 in LC, and 2 in TC. Indeed, a Chi-square test for independence indicated no significant association between the condition and acquaintance status, $\chi 2(2, n=90) = 3.75$, $p = .15$, Cramer's V =.2. However, I excluded these 6 groups from the analysis to ensure that there would exist no interfering effect between the acquaintance status and the groups' behaviors.

7.4. Methods

Four video cameras recorded each gaming session. With three cameras facing each participant and one capturing the entire group, we were able to ensure that each player's facial expressions as well as bodily gestures were captured in video recordings.

The 24 20-minute video recordings of the first Sudoku game for triads were transcribed using a slightly modified version of Chafe's prosodic transcription system [34]. Five researchers worked on transcribing the sessions, in three different iterations. Transcripts from audio were created in the initial iteration. Descriptions of non-verbal gestures as well as critical changes on the Sudoku board were added in the second phase. Transcripts were then arranged into intonation and conversational turn units. The final transcripts were reviewed for accuracy several times with the log files and screen-captured videos.

In order to identify non-response places, researchers first applied the Contributions to Conversations model to the data and coded each conversational turn for Pr (Presentation) and Ac (Acceptance). Researchers went through the transcripts and video recordings in three iterations. During the initial iteration, researchers marked non-response places based solely on verbal evidence. For example, if participant A highlighted a cell and said, "I think a 3 goes here," and no other participants showed any verbal evidence of understanding such as "OK" or "yeah," we marked participant A's turn as having no response from B and C. In the second iteration, researchers revisited all the non-response places and looked for evidence of any gestural responses. For instance, if participant B nodded back when A said, "I think a 3 goes here," we re-marked A's turn as having a response from B, but not from C. During the third iteration, we revisited all the non-response places again, and checked for evidence of understanding within the digital space. So if we saw that participant C inserted a 3 into the cell to which A was referring immediately after A said, "I think a 3 goes here," we re-marked the turn as having responses from both B and C. This initial coding enabled me to pick out dangling presentation turns, that is, all the Pr turns that have either no matching Ac or just one matching Ac.

After marking the non-response places, I randomly selected 5 groups per condition (15 in total) and went over the non-response places in the transcripts to develop a coding scheme for different kinds of non-responses. I then went through the transcripts multiple times, and conducted open and axial coding [44]. The coding scheme consisted of 8 codes under 3 main categories. The three main categories are '*talking-to-oneself*,' '*interrupted-and-delayed contributions*,' and '*P1R-and-P2R*.'

7.4. Different Kinds of Non-Responses

7.4.1. Talking-to-Oneself

The first noticeable kind of non-response was a '*talking-to-oneself*.' This category includes 3 sub-categories: *Thinking-out-loud*, *Talking-to-Things*, and *Self-Answering*.

Thinking-out-loud represents situations in which a speaker murmurs, making the utterances almost incomprehensible to others. Oftentimes participants seemed to narrate (or mark off) possibilities for entries as in "two three four… can't be 3… can't be 2 ((speaker mutters))." In such cases, the utterances did not usually get responses back from the other two players. *Talking-to-Things* refers to incidences in which a participant seemed to talk to inanimate objects such as computers. *Self-Answering* codes occasions in which a participant utters a question, and subsequently self-answers it before anyone else has a chance to respond.

For instance, in Excerpt 7.1, A first presents a contribution (c1) by asking the group if it would be possible to put an eight in a cell to which he is pointing. Both B and C accept c1 by saying "m=hm=" and "yeah." A then goes on to make the next relevant contribution (c2), showing that A has accepted that both B and C understood c1. At this point, the group attains a mutual belief that everyone understood the content, c1. Yet in presenting the second contribution (c2), A self-answers his own contribution by saying "nope ok," depriving others of a chance to reply. It is possible for B or C to still reply to what A has said, but in this case, no one responds to A. Therefore I coded the case as a *self-answering* (*talking-to-oneself*) kind of non-response.

```
// Paper Condition
line01- A: can't be six seven                                    -- Pr (c1)
line02-     but it can be eight?
line03- B:   m=hm=                                               -- Ac
line04- C:   yeah                                                -- Ac
line05- A:   and                                                 -- Ac, Pr (c2)
line06-     what about nine? ((asking a question))
line07-     nope ((self answering the question))
line08-     ok
```

Excerpt 7.1: Non-Response - Self-Answering

7.4.2. Interrupted-and-Delayed-Contributions

In conversations involving more than two people, not all *Presentations* are intended to be understood by all the others [37]. Pairs sometimes create communicative sub-channels within three person groups. One person can also be involved in more than one communicative sub-channel. Moreover different participants can concomitantly present multiple Presentations, creating possible interactional conflicts. *Interrupted-and-Delayed-Contributions* category represents incidences of such conflicts. For instance, in Excerpt 7.2, A presents a contribution (c1), but C, immediately following A, presents another contribution (c2) in an assertive manner, masking out c1. The group picks up c2 instead of c1, and continues to talk about the content presented in c2. Since c2 and c1 are not closely related topics, I do not see c2 as *the relevant next contribution* [40] of c1, and do not consider it as accepting c1. I see such cases as having two different conflicting contributions. In this case, c1 gets interrupted by c2. Sometimes participants who initiate interrupted contributions, try to re-present the contributions at a later time as A re-presents c1 in line14 ~ line15. When initially interrupted contributions get re-presented at later times, I coded that instance as "*delayed-contribution*," if not, I coded it as "*interrupted-contribution*."

// laptop condition

line01- A: should we keep it like that and move on to like the next ones and then like= **-- Pr (c1)**

line02- C: wait **-- Pr (c2)**

line03- you can put three in this one

line04- [this is the only place that three fits]

line05- B: yeah it's the only [one that=] **-- Ac, Pr**

line06- yeah

line07- so put three there

line08- A: ok **-- Ac, Pr**

line09- go head

line10- well hauh is that because that's the only one in that order?

line11- …

line12- ***((the group continues to talk about putting in a 3))***

line13- …

line14- A: should we just n like move onto the next **-- Pr (c1')**

line15- and keep doing what we're doing?

Excerpt 7.2: Non-Response - Delayed Contributions

7.4.3. P1R (Presentation with 1 missing Response) and P2R (Presentation with 2 missing Responses)

After coding non-response places for ‘talking-to-oneself’ and ‘interrupted-and-delayed-contributions,’ I was still left with a number of non-response places that did not belong to either category. For reasons that I could not tell, on many occasions, participants still remained non-responsive to other people’s utterances. That is, I could not find any positive evidence that shows the listeners (people other than the one presenting the contribution) understood what had been uttered by the presenter (person who presents the contribution). I coded these cases as either P1R or P2R: P1R represents cases in which a presenter fails to get a response back from one listener. P2R represents cases in which a presenter fails to get any response back from both listeners.

7.5. Groups are Happier When They Have Low Rates of Non-Responses

In the data, 8.70% of *Presentations* had no matching *Acceptances* from both players, and 43.69% of *Presentations* did not have a matching *Acceptance* from one player. That means, in some cases, people still can conduct joint activities without fully establishing the mutual belief that everyone has understood the contents of conversations. In many cases, participants only needed to establish at least one dyadic mutual belief with one other player: a belief that a pair consisting of a presenter and a listener has understood the conversational contents well enough. In other words, in triad interactions, people do not usually seek positive evidence of understanding from all the other participants. About half the time, participants in my case only needed positive evidence of understanding from one player.

Interestingly enough, the group’s average of differences in individual members’ positive emotional states (ΔPA) were negatively correlated with the ratio of non-responses per total conversational turns per group. That is, groups tended to feel happier when they had a lower non-response rate. This correlation is illustrated in Figure 7.1. Dots represent 15 randomly selected sessions. Blue dots represent 5 tablet sessions, pink dots represent 5 laptop sessions, and black dots represent 5 paper sessions.

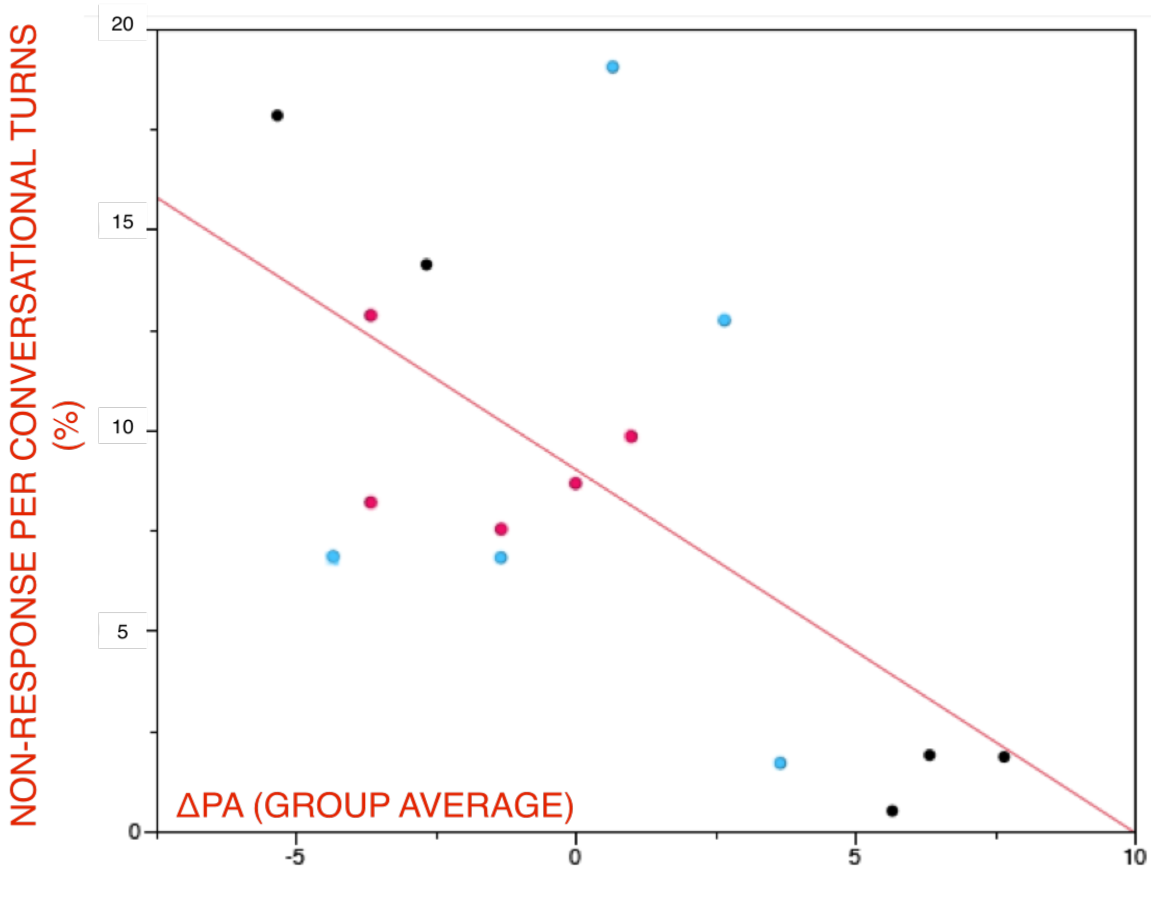

Figure 7.1: Non-Response per Total Conversational Turns by Changes in Positive Affect

7.6. Mediating Technology Does Matter

In order to see whether and how the choices in mediating technology affected the ways non-responses were manifested in group interactions, I selected and compared groups that had more than 20 places in which *Presentations* did not have any matching *Acceptances* from the other two players. I decided to pick groups that had more than 20 non-responses because I used the ratio of the number of certain types of non-response over the total number of non-responses in comparing groups. For groups that had very small total number of non-responses, the ratio does not really enable meaningful interpretation. In total, 4 groups were selected and compared (Table 7.1).

session #	condition	# of non-response	"P2R" type non-response	"talking-to-oneself" type non-response
44	Paper	25	68%	28%
45	Paper	38	84%	13%
8	Laptop	25	36%	60%
4	Tablet	28	39%	54%

Table 7.1: Groups that had more than 20 non-response places in which Presentations did not get any Acceptance from any other players

Even though I am basing the discussions solely on these 4 groups, it is worth noting that in both computer conditions, most non-responses were *'talking-to-oneself'* kind of utterances, whereas in paper condition, most non-responses were the *P2R* type. This suggests that participants who used personalized devices tended to talk more to themselves than people who shared a paper. Maybe it is the computing technology that nudges us to encapsulate ourselves in a very private personal space around the digital artifacts. By going into these private spaces, we might feel more detached from social interactions and find it easier to talk to ourselves.

In addition, close examination of groups in paper condition revealed that *Presentations* coded as *P2R* were typically accompanied by presenters' making modifications on the physically shared game board. Having a physically shared space, and acting on the shared medium might have given the presenters a certain sense of assurance that other people have seen and heard what has been acted and uttered by the presenter. So in a sense, people in paper condition might have felt it was easier to actually utilize *continued attention* as evidence of understanding, even though I did not consider *continued attention* as positive evidence in my analysis.

These findings are interesting in the sense that they show how technology not only might affect the ways we behave around the technology, but also influences the different ways that we do not behave.

7.7. Listening to "Sound of Silence"

In my research, I have examined how silence affects group processes in increasingly pervasive "*triple space*" situations. The data showed that silence does not necessarily mean poor performance or degraded satisfaction, even though much previous CSCW research brands non-talking as a deteriorative behavior. In addition I also saw that not all non-responses are the same. Different mediating technologies afford different types of non-responses. I contend that the imposition of simple behavioral or design lessons such as "*talk more*" might risk interfering with legitimate, productive styles of interactions.

Even though my analysis is solely based on a limited number of groups, I believe that my findings warrant further investigations. In the current study, I mainly compared a paper condition to two computer conditions, and many questions on how different kinds of silence manifest themselves in triple space tasks still remain to be answered. I think comparing technologies with different screen sizes (tabletops, desktops, laptops, tablets and mobile phones) will help me further investigate different coordinative issues related to *silence*.

PART III: DESIGN

8. Design (Interlude)

In previous chapters, we have seen that the differences in mediating technology affect interactions in *triple space*. Even subtle changes in the mediating technology design—whether the differences are in the variations of the software tools or in the form factors—clearly have consequential impacts not only on participants' behaviors but also on their emotions. The quantitative and qualitative inquiries presented in previous chapters did not limit the analyses as to efficiency or performance, but tried to provide insight into various interactional issues by illustrating the different interactional choices participants made in *triple space.*

The assorted behaviors observed in various groups do not necessarily yield a clean causal relationship between design and outcome. Instead they represent how different technologies provide different *interactional possibilities* (or different situations of *thrownness* [82]—an extended discussion of Heidegger's term, *thrownness* and technology design is well provided in [207]) for people. That is to say with my quantitative and qualitative analyses I do not make bold and futile claims such as "using a highlighter tool will make users collaborate more efficiently," or "making people talk more will make the group perform better." Instead, I illustrate the interactional choices people made in the presence of given technological conditions and how their choices eventuated in *triple space* (e.g., some participants chose not to talk during the game, but non-talking was not always associated with degraded performance).

In designing technology, thoughtful designers [121] have to acknowledge that not only do *technologies* and users interactionally define one another [183,201], but *activities* and users also mutually determine one another [100] in the moment of enactment. In other words, as I have shown in earlier chapters, users sometimes appropriated note-entries as indicators (an example of a user redefining a tool), and highlighter tools enabled users to demarcate a region on the game board (an example of a tool determining user actions). Similarly I have also noted that not all non-talking behaviors were the same and the meaning of users' non-talking behaviors could only be understood interactionally in situ (an example of activities defining user behaviors) and that what a user decided to do (talk or not talk) in a group setting influences not just the actor but all other players' experiences as well (an example of a user influencing group activities).

In *triple space*, technologies, people (as individuals and also as codependent members within a group), and activities (what people choose to do in the moment) mutually define and determine one another, creating unforeseeable interactional possibilities. How do we as designers then create and design technologies for triple space interaction? When we technology designers create interventions in triple space, we are not just making changes in the things we design, but creating ripple effects that permeate the entire TripleSpaceFS. Thoughtful designers should look at the different ways that the designs can affect all other components in TripleSpaceFS (technologies, individuals, groups and interactions among and between these three).

In concluding this document, as a final piece of my research, I address the question of design in triple space. In the next chapter, I discuss *processlessness* as an idea for preparing designs that are open to multiple interactional possibilities, and *nudgers* as an idea for enabling and aiding users to create and design their own situated experiences.

9. Design: Processlessness and Nudger[8]

Abstract

In this chapter, I present the notion of *processlessness* as a design value and propose *processless design* as an important alternative to existing design thinking. *Processless design* argues that by intentionally leaving out processes, or minimally embedding processes in system design, designers might be able to come up with systems that are more open to different interactional possibilities. An example of an afternoon gaming club illustrates how the absence of process in mediating artifacts can make room for users to discover, construct, and reconfigure context through and around their technologies. In addition, I propose *customizable processes* and *appropriable opportunities* as two key design ramifications of the *processlessness* concept. I present *ESL Password* as an example of *processless design,* and illustrate how *processless design* concepts support constructing more spontaneous, opportunistic and meaningful experiences for the users *in situ*. I also argue that processlessness is the key in designing educational technologies for increasing student learning, and in making it possible during the design time to account for promoting teacher adoption.

In addition, I propose the notion of *nudgers* as a design concept for enabling and aiding users to create and design their own situated experiences. By building on the idea of *nudge* [189] (designs that influence user behaviors) and *participatory design* [18,102,175], I show how *nudgers* enable users to actively design their own interactions in situ by providing opportunities to influence each other through technologies.

9.1. Introduction

Years ago, Weiser predicted a future in which technologies would become so pervasive and ubiquitous that they would disappear into the fabric of everyday life [200]. Today, in fact, the use of technologies is no longer bounded in workplaces, but is increasingly integrated into every aspect of our lives. Consequently, context becomes critical in system design. How system designers view context and how they account for ever-changing context in system design is becoming a key focus of design discourse [55].

In response to this, researchers and designers have been trying to design systems to be open for appropriation and interpretation. For instance, Höök et al. suggest making the representation of systems' internal mechanisms transparent to users as a way to enable user appropriation [88]. Dourish lists three approaches for supporting continually manifested and interactionally defined context in system design [55]. He argues for making systems that display their context and support "deep customization" at the architectural level. In addition, he proposes separating information from the structure in which the information is organized.

In this chapter, I provide two additional ways of thinking about designing technology that is open to multiple interpretations and appropriations.

First, in opposition to the long established computer science tradition of system design that values the full capture and automation of processes, I argue for supporting an alternative. At least on some occasions, the intentional omission of process can open up new possibilities for interactions and experiences.

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[8] A subset of this chapter has been published as a short paper in DIS 2012.

Processlessness in this sense can afford a wider range of contextualized meaning-making opportunities than process enforcement. Instead of making processes visible to the users [55,88] and creating internal mechanisms to enable deep customization [55], I add another alternative; I argue that leaving out automation and minimally embedding processes into the system are viable design approaches that designers should consider.

Drawing on the teaching of Tao Te Ching, "practice not doing, and everything will fall into place [209]," and *Zensign*, the idea that what we leave out of a design is as important as what we put in it [188], I propose *processless design* as an important alternative to existing design thinking.

Second, I propose the notion of *nudgers* as a design concept for enabling and aiding users to create and design their own situated experiences. By building on the idea of *nudge* [189] and *participatory design* [18,102,175], I show how *nudgers* enable users to actively design their own interactions in situ by providing opportunities to influence each other through technologies.

9.2. Education Technology Design

Over the years, an increasing number of educational technologies have been designed, developed and deployed by designers and researchers, yet the discussion of whether or not the technology is beneficial to education is still inconclusive. Technologies proven to produce positive increases in student learning in experimental settings have shown limited success in actual classroom adoption [29,208]. Longitudinal studies also report incompatible findings. For instance, Dynarski et al. [59] report that they did not find either an increase or decrease in student learning after a year-long study testing the effectiveness of Reading and Mathematics software in classrooms whereas Roschelle et al. [159] report strong classroom learning gains from a large-scale, multi-year investigation of deploying SimCalc in multiple classrooms.

Noticing such discrepancies, Dickey-Kurdziolek and Tatar [51] assess the difficulties in educational technology design, and point out that a strategy of "design(ing) for student learning, and then find(ing) ways to increase teacher adoption later [51]" is bound to produce ineffective classroom technologies. They suggest that technology designers need to consider the design tensions [186] between "designing for the student experience" and "designing for teacher adoption" in design time. Roschelle et al. [159] contend that the key to the successful deployment of classroom technology is not just about designing novel technologies, but is more about creating "interventions that deeply integrate professional development, curriculum materials, and software in a unified curricular activity system (p.874, [159])." Yet, neither Dickey- Kurdziolek and Tatar [51] nor Roschelle et al. [159] explicitly show how to design educational technologies that can increase student learning while promoting teacher adoption, or that can easily be integrated with the professional development and curriculum materials.

Every school, every classroom and every teacher is unique and probably has very different demands and requirements for technology use in the classroom. This multifarious nature of classroom context makes designing classroom technologies which can easily be integrated to a number of different existing curricula while meeting individual teacher's local needs a formidable task. Furthermore, even for the same school, same classroom and same teacher, the use of technologies is always being continually defined and negotiated in the classrooms in the moment. That, in turn, makes context not only illusive and slippery, but also central and critical in interactive system design [55]. In a similar vein, context is central and critical in educational technology design as well.

I argue that processlessness is the key in designing educational technologies for increasing student learning, and in making it possible to account for promoting teacher adoption during the design time. I present *ESL Password* as an example of *processless design,* and demonstrate how the design embodying processlessness can eventuate in an increased adoptability for multiple educational settings.

9.3. Processless Design

What do I mean by *processless design*? Imagine that you sit down to play a game of cards—physical cards, not digital ones. You start dealing a game of *Solitaire*, but you could very well take up a game of *Gin Rummy* with a friend or even make up your own card game. You choose to deal the cards and play according to your favorite house rules, and sometimes you choose to break those rules. In a different scenario, consider that you sit down to a computer to play cards, in which case you likely have to choose between a game of *Solitaire* or *Gin Rummy* by explicitly selecting the appropriate program. The digital card deck will be dealt for you, the cards can only be moved according to strictly encoded/embedded/implemented rules that cannot be negotiated or changed mid-game, you will be told when the game ends and if you have won or lost, etc. The difference between these scenarios is what concerns this chapter.

The design of the physical card deck provides affordances that allow the player to appropriate the cards in the deck flexibly. The game begins and ends, proceeds by rule or against it, and takes on meaning for which you, the user, are largely responsible. In contrast, the designers of the digital card game often encode, embed or somehow implement—and therefore solidify—the process of the game into the digital artifact, such that by playing with the cards you are subscribing to the rules, processes and world the designers have created for the users.

Physical card decks allow the values of the user to be brought to bear on such open questions as “what is (are) the purpose(s) of this game?” and “what rules should I follow and when?” These questions can be asked and answered in the context of playing the game. But in digital context, the answers to these questions are largely fixed and enforced.

Processless design does not suggest that interactional process is located solely in the artifact, and hence fully defined by the artifact’s built-in features. Process as a larger phenomenon is always interactionally defined, managed, negotiated and recreated in the moments of use. People and artifacts co-define process as they constantly reconfigure each other in situ [182,183,201]. Yet, by trying to encode and rigidify the processes at design time, designers might be depriving individuals of opportunities to create more diverse, tailored, and appropriate processes in situ. In this sense, processless design is not about removing processes from holistic human-nonhuman interactions, but rather it is about redistributing some of the process-making activity to the users, times and places in which the artifacts are enacted.

As I describe in more detail in future sections, there is no such thing as pure processless design; all artifacts impose some form of process and meaning on their use. I am instead suggesting that there are degrees to which process can be embedded in a design. The notion of processlessness is proposed as design vocabulary that can help designers evaluate existing designs and inspire new ones.

9.4. Processlessness in Action

This section details a field report from an observational study that inspired me to envision processless design.

After school game club

In the winter and spring of 2008, I conducted an observational study at a local middle school in an effort to explore and compare the interactional properties of playground-like games [188] and computer-based ones. While these exploratory field observations served as a small-scale, complementary addition to my dissertation work which investigated varying issues of computer-mediated coordination among co-located people, the study provided me with an important opportunity to learn the rich, multifaceted nature of face-to-face interaction. With permission from the school and a supervising teacher, two researchers (including myself) attended the extra-curricular gaming club sessions once or twice a month for 6 months to observe and investigate how middle school students play various types of board/card games. The gaming club was held every Wednesday after school hours. A typical session lasted an hour and a half to two hours. About 20 students regularly attended the gaming club. Students ranged from 11 years old to 16 years old, and from sixth grade to tenth grade. With help from the supervising teacher, we were able to get parents' consent and children's assent to video record the gaming sessions.

During a typical session, students were divided into three to four groups and played games of their choice. Groups were spread out and set up at different tables or seating areas in the classroom. In an attempt to construct the study in a minimally obtrusive manner, researchers refrained from engaging in any formal interactions with the students. By placing and fixing one video camera faced at one gaming area and leaving all other areas free from the recording, researchers ensured that students who did not want to be video recorded could still participate in the gaming club.

Figure 9.1: Students and a teacher playing *Settlers of Catan*

A boy who kept playing the game

One afternoon, Aaron, Dale, Olivia and the supervising teacher decided to play a board game, *Settlers of Catan*. In this game, players take on the role of settlers, each trying to expand one's colony by building settlements, roads, and cities by acquiring and trading resources. Players are rewarded victory points as their colony grows, and the first player to acquire a pre-agreed number (typically ten) of points wins. A typical game board represents a hexagonal island composed of multiple hexagonal tiles of different land types that produce different types of resources.

Aaron, Dale and the teacher had previously played the game but Olivia seemed new to it. She asked the boys about the rules at the beginning of and throughout the session. The boys and the teacher helped her with the rules and strategies throughout the game. Players sat on a couch around a coffee table (Figure 9.1).

Towards the end of the game, by acquiring the longest road card, a card worth two victory points, from Olivia, the teacher reaches 10 points for a win and declares that he has won. However, as the teacher declares his winning, Dale challenges the teacher by showing the teacher and the group that he had already won the game five turns ago. Amused by Dale's lighthearted deception, the teacher says, "look at this guy," and the group laughs all together. This scene is portrayed in the transcription in Excerpt 9.1.

Strictly speaking, the game should have ended when Dale earned 10 victory points. Yet, Dale kept playing the game without announcing his winning, which in the end created a fun and extended game playing experience for the team. Even when the teacher says “chu chu chu ch=eater=”, he says it in a playful tone, evidence that the group or at least the teacher was enjoying the extended gameplay. It is clear that for this group, winning was not the sole goal of playing the game. This becomes even more evident when the teacher asks Olivia if she wants to play one more turn. Again, at this moment, everyone in the group knows that the game has ended. Yet, the decision to play one more turn was left up to the group. The processes of computing the victory points and determining the end of the game were not embedded into the gaming artifacts, but left to the players to negotiate and decide.

Observing this group of players shifting and tweaking the rules of the game made us think about the limitations that digital games often impose on players. By encoding and enforcing the rules—those for keeping track of victory points, managing resource distribution, and determining the winner—into the system, we can certainly automate the entire process to make it faster, more efficient, and more accurate. Indeed, an online version of *Settlers of Catan* does keep track of victory points, manage resource distribution, and determine the winner. However such a *processful* system would not have given Dale a chance to conceal his win and continue playing the game. The purpose of playing the game is not just bound to determining the winner, but encompasses a wider range of possibilities. For Dale, whether it was for his own sake or for that of others, continuing the game play until someone declared his/her winning and countering the legitimacy of the winner was clearly another purpose of playing the game at the moment.

Teacher: I will build a road

..and I will

..turn in two more for another brick

..and build another road

..which unfortunately means that I get the longest road for the moment

((Teacher takes a longest road card from Olivia))

Teacher: wait two four six eight nine

..nine ten ((Teacher counts his victory points))

Dale: I beg to differ

Teacher: what do you mean

you already won?

Dale: yeah I won like five turns ago

Teacher: well you didn't declare it then

you didn't win officially

Dale: oh but.. we tie then

Teacher: look at this guy

((Everyone laughs))

Olivia: <X inaudible X>

Teacher: I guess that's the game

..probably perfectly timed too

..cause we need to we need to clean up

..did you want to take one more turn though?

((Teacher looks at Olivia))

Olivia: no

Teacher: ok let's go ahead

we just need to put our pieces away

Teacher: chu chu chu ch=eater=

Dale: haha what I.. I let you.. I let you guys

Teacher: cheater land

((Everyone laughs))

Excerpt 9.1 : Transcript of Settlers of Catan gameplay

9.5. Processless Design: Explained

Can one build an artifact fully processless? Most probably not. By definition, any digital artifact operates in predefined ways according to the coded design intentions of its programmers. For that matter, neither are a physical deck of cards or a *Settlers of Catan* board game completely devoid of process. These artifacts have constraining affordances that (in Don Norman's [148] sense of the word) suggest certain modes of interaction and (in Gibson's [68] sense of the word) physically enable and disable other interactions.

The matter of being processless as opposed to processful is one of degrees. How can we as technology designers go about designing digital artifacts processlessly? This is a question that I am addressing in this section.

9.5.1. Customizable Processes

While processless design values removing processes from digital artifacts as the primary design principle, building technologies devoid of any process at all is not practical, if not entirely infeasible. That is, when designers design digital artifacts, even in the processless way, they are destined to put a certain amount of processes into the design. In that respect, I contend that the subsequent auxiliary principle in processless design is the user customizability of the embedded processes. Designers need to provide ways in which users can replace or supplement any built-in processes.

Dourish points out that, in information technology design, it is important to separate information from the structure in which the information is organized [55]. On top of that, processless design proposes separating processes from the structures in which processes are organized. By modularizing processes and making processes replaceable and customizable, designers can incorporate processes into the digital artifacts in the processless way.

9.5.2. Appropriable Opportunities

By minimally embedding processes in digital artifacts, and preparing the embedded processes to be easily customizable, designers not only create interaction technologies, but also fabricate new possibilities for user interactions around the built artifacts. Designers, especially educational technology designers, however, also need to take a step further and attempt to design holistic user experiences. With what they provide or do not provide through technology designs, educational technology designers need to create interventions that integrate (1) individual teacher's needs, (2) existing curriculum materials and (3) different use practices.

When leaving out processes in technology design, designers are not delegating their responsibilities to the users. "Whatever designers leave out, the users will fill in" is not the philosophy of processlessness. Designers should always consider what it means to leave out certain processes in technology design, and think about how users will or will not be able to appropriate interactional possibilities created by the design. Thus when leaving out any processes in design, designers should not consider themselves as practicing not-designing, but instead see themselves as designing interactional possibilities beyond the artifacts as well as the affordances for unfolding users' activities.

In sum, designers practicing processless design should consider putting minimal processes in the digital artifacts. When embedding any processes, they should consider making the processes easily customizable. When leaving out any process, they should consider the consequences of not embedding the process.

9.6. ESL Password: An Example

In this section, I present ESL (English as a Second Language) Password as a sampler applique of ESL class activities, and demonstrate how the three processless design concepts—*processlessness*, *customizable processes*, and *appropriable opportunities*—are embodied in technology design.

9.6.1. Software

ESL Password is a multi-user parallel distributed game activity. It resembles a television game show from the 60's in which a presenter is given a target word or phrase and asked to use words that would get the guesser to say the target. For example, a presenter can say "it's raining cats and ...?" to make the guesser say "dogs." Guessers are allowed to ask presenters questions and actively engage in the game. If the guesser cannot guess the word, the presenter may "pass" or move on to the next word. Thus, the original game involves two roles, that of the presenter, who knows the word or phrase, and that of the guesser, who does not. These roles are filled by exactly one person at a time. There is also a third role, that of audience, filled by many people. The audience is told the target word or phrase and is therefore presumably more allied with the presenters' than the guessers' experiences. Although the audience role is tacit in the game description, this role is quite important. The original T.V. game was arguably designed as much or more for the audience as for the players. (Indeed to whom else would a television show be targeted if not for the studio audience and for home viewers?)

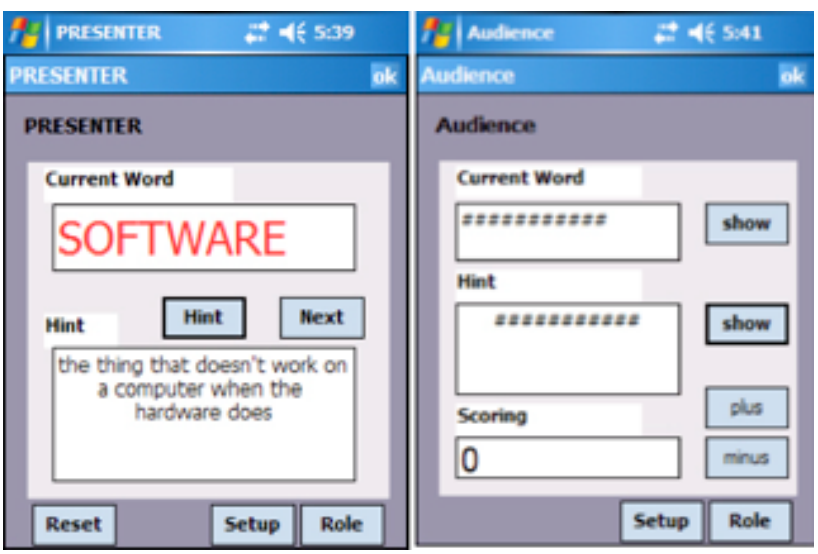


Figure 9.2: ESL Password - PDA Version

Inspired by the fact that the rules of the game obligate participants to speak, I developed ESL Password (Figure 9.2) for people learning English as a second language. Users can choose to take one of three roles. Different helping mechanisms were added to help ESL students with their roles.

The system is used to deliver words/phrases for the players as well as to provide hints. Presenters can fetch words or phrases on their devices as well as retrieve a dictionary definition of the word. Guessers can access six different kinds of hints from the system. These are machine-generated hints such as an anagram, the length of the word, or the revelation of random letters.

In order to grant the audience access to the information available to presenters and guessers, the audience mode has an option to display both the given words and the hints given for the guessers. In addition, in order to nudge the audience to take an active role in the game play, the audience is given an option to keep track of the scores for the current game.

9.6.2. Embedding Minimal Processes

Two main processes embedded in the software are hinting mechanisms and a word-delivery system with built-in English dictionary. These two functionalities represent two embedded processes that automate different user tasks in the non-digitized version of the gaming activity. For instance, a word-delivery system is a substitute for a flashcard that displays different words/phrases. I could have designed the activity to require one dedicated player to flip the flashcard for the presenter. The design rationale for automating the flashcard and the card flipping task is rather obvious; the flashcard flipping task requires an additional role without adding any value to the game. Hinting systems provide mechanisms for balancing task difficulty levels for non-native speakers.

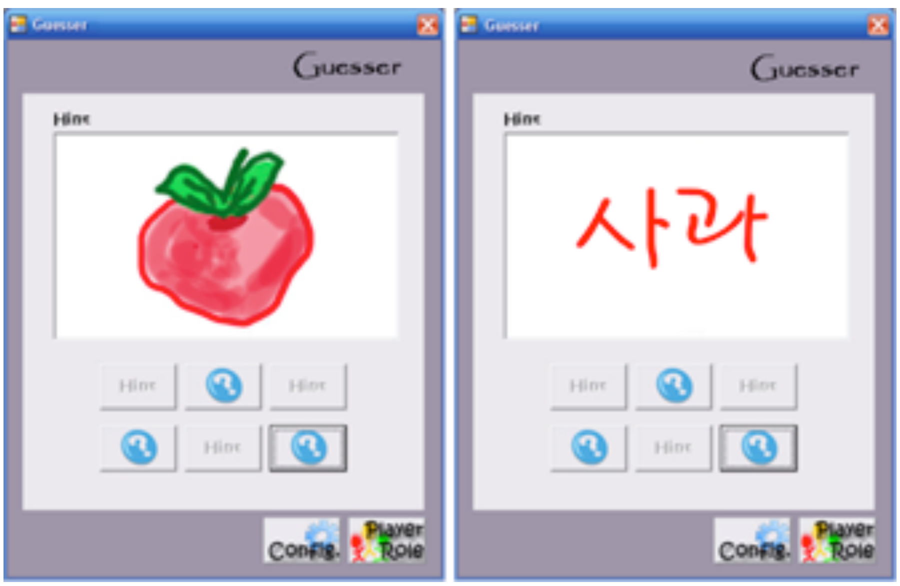


Figure 9.3: Pictorial & Korean Guesser Hints from Children's Version

9.6.3. Customizable Contents

Two embedded processes in ESL Password are both user customizable. Users can replace the built-in dictionary with custom built ones. This is a key feature in ESL Password since teachers would need to customize the words list, and possibly the presenter hints prior to using ESL Password in the classroom. Similarly, the hinting mechanisms for the guessers are also user customizable. Users can either use computer generated hints, or author textual, auditory, and pictorial hints. For instance, one can use a series of pictures depicting the given word or even a translation of the given word in the guesser's native language. Figure 9.3 shows a pictorial hint and a Korean translation of the word, 'apple' from the children's version of the game.

9.6.4. Designing Appropriable Opportunities

ESL Password is designed to include only processes that are essential to the game play. For instance, without a word-delivery system, the ESL Password activity itself regresses to the non-digitized form of the gameplay. Without hinting systems, ESL Password is no more than an automated flashcard. Two features I intentionally left out in designing ESL Password are scoring and encoding user roles. While I have user interface for marking, increasing and decreasing scores, no process has been embedded in the software. In addition, even though the game supports three user roles by providing different user interfaces for the different roles, I do not explicitly encode the roles in the software. Users can always switch to different user modes at any given time. The enacting and regulating of user roles is left to the users to decide, manage and negotiate in the course of acting out the gameplay.

9.7. ESL Password in Action

ESL Password has been deployed on multiple occasions and tested with a variety of student groups and settings. In this section, I report on two occasions in which ESL Password was used in distinctively different ways.

9.7.1. English Language Institute

Figure 9.4: ESL Password Session at English Language Institute

As a first attempt to deploy ESL Password in a classroom setting, researchers conducted three game sessions with students at the English Language Institute at Virginia Tech on three different days. With help from the teachers at the institute, we were able to get consent from students to video record the sessions. The vocabulary lists as well as the logistics of the game were modified to accommodate class curriculum and schedule.

The teachers administered ESL Password activities in three different ways. Some teachers, prior to using ESL Password, had used a whiteboard as a medium for the game activity. Students were asked to pair up with another student. The pairs were then asked to play the traditional version of the game. Guessers were seated in the front row facing backwards while presenters were seated in the second row facing the whiteboard. When a teacher wrote a word on the board, all the presenters tried to explain the word to their partner guessers. The pair who got the correct answer first won a game-point (It was up to the teacher to decide whether to wait for other pairs to finish guessing the word or to continue on to the next word).

When teachers used ESL Password, students were asked to form presenter/guesser/audience triplets or quadruplets (two audience participants). As with the traditional game mode, teachers in this setting also controlled the game play. They decided when to move on to the next word and also changed dictionaries if needed.

When a teacher initiated the game play, a randomly selected word from a dictionary was displayed on all the presenters' PDA screens. Instead of looking at the whiteboard for a word, presenters were able to use their handheld devices to look at the given word. All the presenters tried to explain the word to their partner guessers. The team that got the correct answer first was given a game point. The teacher clicked on the next-word button when she decided to go on to the next word.

9.7.2. Women in Computing Day

Figure 9.5: Password Session at Women in Computing Day

The Association for Women in Computing (AWC) is a student-run, non-profit organization at Virginia Tech. Every year, AWC holds a keystone event, Women in Computing Day (WCD) in which AWC invites local junior high school female students and introduces various computing technologies to inspire them to pursue computing careers.

As a part of the event, I held four Password gaming sessions. Each session lasted about 45 minutes and included 8 to 11 students. Students were first briefed on the game rules, and PDA devices were distributed. Students were free to choose their roles (presenter, guesser or audience). One of our research team members, supervised the game play sessions.

Since students were native English speakers, I prepared a special dictionary designed for the event. The dictionary consisted of 55 words and each word had a definition and two guesser hints.

When I deployed the system, students quickly adapted and created their own versions of the game. Instead of having one presenter, one guesser and several audience members, students divided into groups of presenters and guessers. Multiple presenters usually took turns explaining, while teams of guessers shouted out possible answers. It was notable that the students were able to appropriate their own activities without the supervision of a teacher (or, in our case, of a supervising researcher).

9.8. Processlessness: Staying Open to Interactional Possibilities

It is not just the *structure* of information, as Dourish suggests, that "emerges in the course of a users' interaction, rather than having to be specified all at once or in advance (p.27, [55])." I have shown that *processes* around the artifacts also emerge in the course of users' interaction.

Processless design is related to Sengers and Gaver's idea of staying open to interpretation [167], and Gaver and Beaver's idea of viewing ambiguity as a resource for design [67], in that they all support leaving room for multiple interpretations of the designed artifacts. Yet, the idea of processless design differs from the other two in at least three ways. First, processless design does not necessarily draw attention to the limits of the system's interpretation and includes no explicit call for reflection or differentiated experience on the part of the user. Second, processless design describes the mechanism by which designers can encourage user participation in meaning-making—by explicitly leaving out process. Third, processless design is not just about the interpretative relationship between the user and the artifact; it is also about appropriation, or how individuals create and negotiate activities around the artifacts.

Contrary to intuition and somewhat paradoxically, by adding more features to computational systems, designers might actually be removing interactional possibilities. I believe that *processless design* can support the ability of users to construct more spontaneous, opportunistic and meaningful experiences.

Moreover I also believe that *processlessness* is the key in designing educational technologies for increasing student learning, and in making it possible to account for promoting teacher adoption during the design time.

9.9. Nudgers: Re-liberating Users

How do we design for user appropriation? How do we design technologies so that users can discover, construct, and reconfigure context through and around the designed technologies? In addition to the idea of *processless design*, I propose *nudgers* as an additional way of enabling and aiding users to create and design their own situated experiences. By building on the idea of *nudge* [189] and *participatory design* [18,102,175], I show that how *nudgers* enable users to actively design their own interactions in situ by providing opportunities to influence each other through technologies.

In his 1980 article, "Do Artifacts Have Politics?," Langdon Winner pointed out that no design is free from embedding designers' beliefs—designs inevitably represent designers' cultural, political, philosophical, religious, ethical, or aesthetic values [206]. No design is value neutral and the act of designing is a form of articulating the designers' constant efforts to configure user activities (and users). Throughout the chapters in Part II, we have also seen how the differences in technologies impacted the participants' behaviors as well as their emotions. With or without knowing it, designers always bring their own set of beliefs and morals into building artifacts [206]. Designers have power over users. As such, designers are destined to shape users' experiences in one way or the other. This unequal relationship between designers and users creates an important space for design discourse. Different design professionals and researchers have tried either to enforce and embrace this inequality or to ameliorate it through different design practices.

On one hand, for example, stemming a Marxist commitment to democratize workplaces and empower workers, participatory design engages users in the design process [175]. Participatory design aims to democratize the design process and offset the unequally distributed power between designers and users by endowing users with opportunities to affect design decisions [18,102,175].

On the other hand, the authors of "Nudge: Improving Decisions About Health, Wealth, and Happiness", drawing from social science findings, argue that people oftentimes make bad decisions—"decisions they would not have made if they had paid full attention and possessed complete information, unlimited cognitive abilities, and complete self-control (p.5, [189])." Based on this premise, they advocate the idea of *a choice architect*, whose responsibility it is to create designs that can *nudge* people into making better decisions. While distancing their idea of *nudge* from *coercion*, the authors introduce a term, *Libertarian Paternalism* and point out that *Libertarian Paternalism* is a weak, soft and nonintrusive way of guiding people's behaviors [189]. The notions of *nudge* and *Libertarian Paternalism* are, however, intrinsically rooted in an evangelistic dualism which supposes two distinct strata among individuals, their values, and their roles; the superior and the inferior; ones that need to be embraced and ones that need to be reformed; the role of designers and the role of users. The idea of nudge not only fully acknowledges that designers have power over users, but also carefully encourages designers to act as a *paternal* figure, strengthening (in a supposedly positive way) the inequality between designers and users.

While these two opposing approaches differ in how they view and accommodate the dichotomous roles of users and designers, they both inherently differentiate design practices from use practices. Such separation between "the setting of design (design time) and the setting of use (use time)" is often thought of as a by-product of the design industrialization [122]. *Design time* is seen as belonging to the design professionals whose job it is to create completed design artifacts, while *use time* is associated with unpredictable situations in which the artifacts are deployed into the ever-changing user context [122]. *Participatory Design* aims to reform the relationship between the designer and the user by shifting user involvement from *use time* into *design time,* whereas *Libertarian Paternalism* focuses on the designers' responsibilities in *design time*.

As opposed to the design praxis and theories that differentiate *design time* and *use time*, it has also been argued that design does not end when designers produce designed artifacts, but encompasses the entirety of use practices in which the designed artifacts are taken, appropriated, redefined and reconfigured by the users. Users and designed artifacts co-define and constantly reconfigure each other in situ [183,201]. Design in this sense is always an on-going process in which users are a legitimate part of design processes. Yet, such a view of design only provides a retrospective, interpretative account of what design is, but does not tell how designers can actively aid users' design involvement in *use time.*

My approach builds on the ideas of *nudge* and *participatory design*, taking a situated perspective in understanding design praxis. I, too, try to provide ways to influence users as with *nudge*. Yet, unlike *nudge,* I aim to provide users with *interaction disruptors* that I call *nudgers*. Users can use *nudgers* to disrupt *seamless* interactions and create *seamful* moments. By appropriating these moments, users nudge each other in interaction. By providing nudgers, I place users back into the center of design as in participatory design. Yet, unlike participatory design which mostly concerns putting users into *design time*, I provide *nudgers* that users can use in *use time* to create and design their own interactions.

If designers design *nudges*, whatever the designers might envision as consequences of their "nudge/design" might produce unforeseen complications. However, designers only provide design opportunities when designing *nudgers,* but do not design actual interactions. Designers of nudgers do not try to nudge users, but provide tools that users can use to nudge each other.

9.10. Nudgers: Sample Design

This section illustrates two sample examples of *nudger* design. By activating these different interaction disruptors, users can create seamful moments in their interactions, and try to appropriate the moments to initiate desired social interactions. These designs are not intended to enforce certain kinds of user behaviors (e.g., talking), but only provide users opportunities to create seams in interaction. Users can use these disruptors to shape their interactions and influence other people’s behaviors.

9.10.1. Reverse Highlighter

The first example of interaction disruptors is a reverse-highlighter. When activated, a reverse highlighter dims all the un-highlighted parts in the software on everyone’s screen.

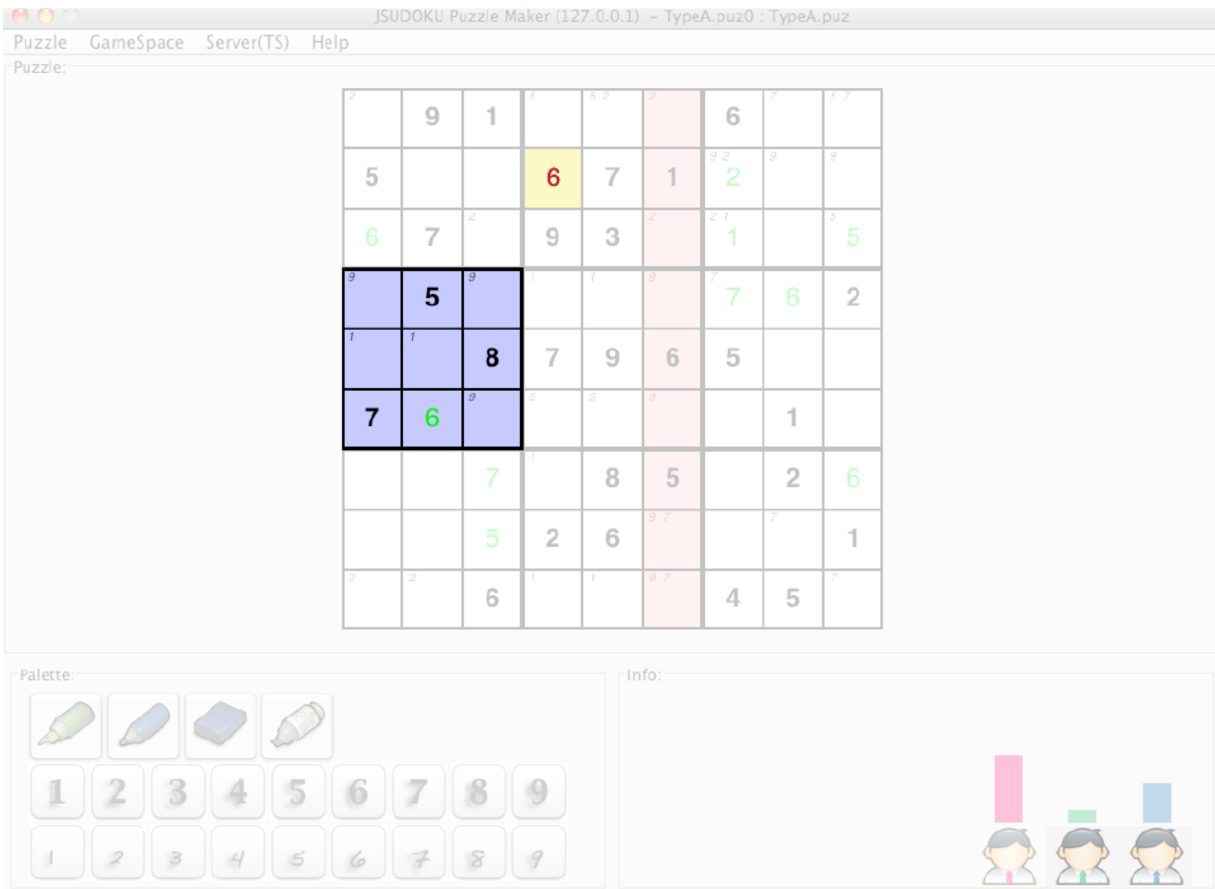


Figure 9.6: Reverse Highlighter Implemented in Team Sudoku

9.10.2. Control Disabler

The second example is a control disabler. When activated, this feature will temporarily disable all the controls in everyone else's devices.

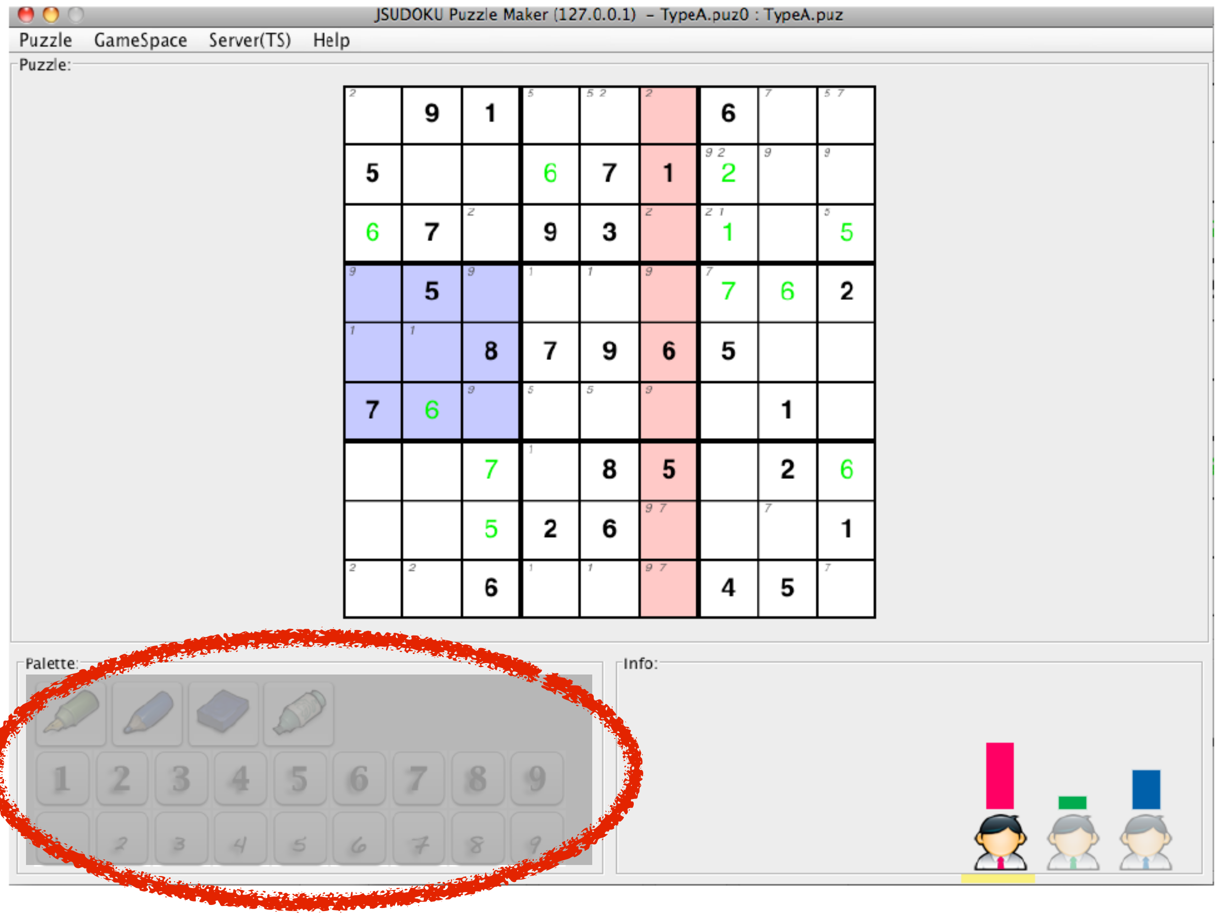


Figure 9.7: Control Disabler Implemented in Team Sudoku

9.11. Discussion: Processlessness, Nudgers, Claims and the Design Tension

In this chapter, I have presented *processlessness* as an idea for preparing designs that are open to multiple interactional possibilities, and *nudgers* as an idea for enabling and helping users to create and design their own situated experiences. I provide these two ideas as possible conceptual guides for designing collaborative systems. Yet, these two design ideas are mutually contradictory; by creating *nudgers*, designers inevitably embed processes into the system; by removing processes (that is, practicing *processlessness*), designers are forgoing opportunities to provide *nudgers.*

However, these two design ideas should not be understood as design axioms that must be practiced unconditionally. Nor should they be seen as constituent parts of possible design solutions in an ontological morphological design box (see [30]). Choosing to practice *processlessness* does not necessarily mean not designing nudgers, and designing nudgers should not be seen as refraining from *processlessness*. Instead, *processlessness* and *nudgers* should be understood as incommensurate dichotomous design concepts that constitute a *design tension* [186] between the two. In other words, the tension between the two competing ideas of *processlessness* and *nudgers* "conceptualize design not as problem solving but as goal balancing” (p.415, [186]). The acts of designing in this sense are designers’ continual efforts and praxes to find a proper equilibrium within the continuum of two opposing design forces (see Figure 9.8).

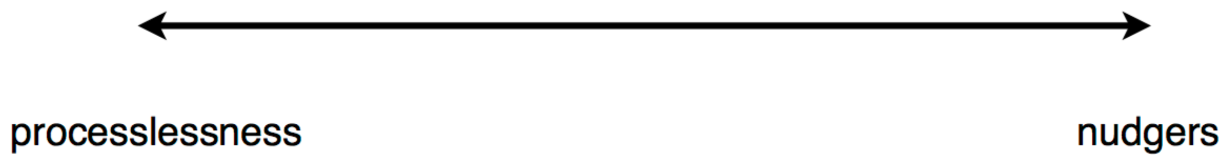


Figure 9.8: Design Tension between *Processlessness* and *Nudgers*

How then can designers go about balancing two contending design goals and design collaborative systems? The design tension between processlessness and nudgers does not provide bullet-listed design implications, but only works as a conceptual guide for design. It offers designers space to consider the different interactional possibilities their designs enable (or disable) in the moment of use. In addition, the idea of tension is not tied to any specific design methodology and can indeed be easily incorporated into many existing design methods. For instance, the conceptual tension between processlessness and nudgers can be handled effectively by *scenario-based design* which has been known to provide “simultaneously concrete and flexible” ways of handling the “complex [and] uncertain nature of design” (p. 26, [128]). *Claims* that augment the scenario-based design process by providing *critical parameters* for design choices can also provide an effective way to put the tension ideas into practice. *Claims* also can help designers capture their design practices of using the tensions into a reusable knowledge base (see [128] for in depth descriptions of *claims* and *critical parameters*). By requiring designers to generate design tradeoffs (*upsides* and *downsides*), *Claims* help designers to recognize the different interactional possibilities their design (what they put in or what they leave out) can create or hinder. Figure 9.8 shows an example of a typical *claim* for a control disabler feature.

control disabler
+ users can initiate disabling process to forcefully capture other people’s attention
+ users can appropriate the seamful moment created by the control disabler to design desired social interaction
- control disable can be an annoyance
- control disable can be a distractor

Figure 9.8: Claim for Control Disabler

By embracing and augmenting *Zensign*, the idea that what we leave out of a design is as important as what we put in it [188], I proposed *processless design* and *nudgers* as an important alternative to existing design thinking. These two ideas constitute a design tension which in turn can help to create designs that are *open to multiple interactional possibilities.* Yet, designers also have to acknowledge that even with such designs, they cannot anticipate the innumerable ways that users and the designed artifacts can interact. Users and designed artifacts reform, reformulate and redefine each other. This in turn mandates research on how users behave around the newly designed artifacts. This is a dialectic relationship in which studies in qualitative research and studies in design research affect each other and trigger reformation on both sides iteratively. My research so far illustrates just one iteration of this continual circle.

"A designer knows he has achieved perfection not when there is nothing more to add, but when there is nothing left to take away." - Antoine de Saint-Exupéry

Appendix

Appendix A - Questionnaires

Appendix B - Research Notes

Appendix D - Transcription Coding Rules

Appendix E - IRB Approval Letters

Appendix A-1 : One-day pilot Pre-game Questionnaire

Pre-Study Questionnaire

1. Age: _________ yrs

2. Gender: ☐ Female ☐ Male

3. Year: ☐ Freshman ☐ Sophomore ☐ Junior ☐ Senior ☐ Graduate

4. Major:

5. First Language: ☐ English ☐ Non-English

6. Nationality:

7. Ethnicity:
   - ☐ Asian or Pacific Islander
   - ☐ African American
   - ☐ Caucasian
   - ☐ Hispanic
   - ☐ Native American or Alaskan Native

8. How often do you solve puzzles of any kind?
   - ☐ Several times a day
   - ☐ Several times a week
   - ☐ Several times a month
   - ☐ Less than once in a month
   - ☐ At least once a day
   - ☐ Once a week
   - ☐ Once a month

9. Rate how much you like to solve any kind of puzzle. Circle your choice.
   1 - Don't like at all 7 - Like it very much.
   1 2 3 4 5 6 7

10. How often do you solve Sudoku?
    - ☐ Several times a day
    - ☐ Several times a week
    - ☐ Several times a month
    - ☐ Less than once in a month
    - ☐ At least once a day
    - ☐ Once a week
    - ☐ Once a month

11. Rate how much you enjoy solving Sudoku puzzles. Circle your choice.
    1 - Don't like at all 7 - Like it very much
    1 2 3 4 5 6 7

12. What do you think about solving puzzles or sudoku?
    - ☐ Relaxing
    - ☐ Fun
    - ☐ Competitive
    - ☐ Other. Specify: _______________________________

Appendix A-2 : One-day pilot Post-game Questionnaire

Post-Study Questionnaire

Please help us understand your experience today in solving the sudoku as a team by answering the following questions. Your answer is very important in analyzing our results. So take time to answer these questions and provide as much details as possible.

Circle your choice whenever appropriate.

1. How interesting did you think solving the game was?
1 - Not at all interesting 7 - very interesting
1 2 3 4 5 6 7

2. How much did you enjoy playing Sudoku today?
1- Didn't enjoy it at all 7 - Enjoyed it very much
1 2 3 4 5 6 7

3. How much were you satisfied with the group and the way it worked together?
1 – Not at all satisfied 7 – very satisfied
1 2 3 4 5 6 7

4. How much were you interested in participating in the group?
1 – Not at all interested 7 – very interested
1 2 3 4 5 6 7

5. Did anything stop you from participating in the group?
☐ Yes ☐ No

6. If you answered yes, what stopped you from participating?
☐ Puzzle difficulty
☐ Tool difficulty
☐ Group difficulty
☐ Other reasons. Please explain: ____

____

____

7. How much did you enjoy working with the other people?
1- Didn't enjoy it at all 7 - Enjoyed it very much
1 2 3 4 5 6 7

8. How hard were the puzzles?
1- Very hard 7 – Very easy
1 2 3 4 5 6 7

9. How much was your participation welcomed by others in your group?
1 – Not at all 7 - very welcomed
1 2 3 4 5 6 7

10. How obvious was it to figure out what other people were doing?
1- Not at all obvious 7 – completely obvious
1 2 3 4 5 6 7

Appendix A-2 : One-day pilot Post-game Questionnaire (cont.)

11. Were there ever times when you were bewildered?
 ☐ Yes ☐ No

12. If you answered yes, please explain what confused you (as well as you can)
____
____

13. Did you ever have any difficulty in explaining what you were talking about while solving the puzzle?
 ☐ Yes ☐ No

14. If you answered yes, please explain the difficulty
 ☐ Tool was hard to use
 ☐ Did not know how to use the tool
 Other reasons, please explain: ______________________________
____
____

15. Did you ever have any difficulty in understanding what someone else was talking about while solving the puzzle?
 ☐ Yes ☐ No

16. If you answered yes, please explain the difficulty
____
____
____

17. How often did you use the pointing feature?
1 – Did not use 7 – Whenever I had to explain something
1 2 3 4 5 6 7

18. To what extent did the pointing feature help you to point at specific parts of the game board?
1 – Not at all helpful 7 – very helpful
1 2 3 4 5 6 7

19. To what extent did the pointing feature help you to explain your thoughts to the group?
1 – Not at all helpful 7 – very helpful
1 2 3 4 5 6 7

20. How much confidence did you have that other people understood what you explained?
1- Not at all confident 7 – very confident
1 2 3 4 5 6 7

21. How much confidence did you have that you understood what other people explained?
1- Not at all confident 7 – very confident
1 2 3 4 5 6 7

22. The pointing tool was easy to use.
1 – Strongly disagree 7 – Strongly Agree
1 2 3 4 5 6 7

Appendix A-3 : Study 1 Pre-Game Questionnaire

Study on Collaborative Gaming

post

POET Lab, Computer Science Department, Virginia Tech

Date ___________________

Please help us understand your experience today in solving the sudoku as a team by answering the following questions. Your answer is very important in analyzing our results. So take time to answer these questions and provide as much detail as possible.

SECTION I

Circle your choice whenever appropriate.

1. How much did you enjoy playing the game?

did not enjoy it at all — enjoyed it very much

1 2 3 4 5 6 7

2. How much did you enjoy playing the game with your team members?

did not enjoy it at all — enjoyed it very much

1 2 3 4 5 6 7

3. How difficult was the puzzle?

very easy — very hard

1 2 3 4 5 6 7

4. How interesting did you think solving the puzzle was?

not interesting — very interesting

1 2 3 4 5 6 7

5. Sudoku software was easy to use.

strongly disagree — strongly agree

1 2 3 4 5 6 7

Appendix A-3 : Study 1 Pre-Game Questionnaire (cont.)

12. How often do you try puzzles of any kind?

rarely	once a month	several times a month	once a week	several times a week	at least once a day	several times a day

13. How often do you try to solve puzzles with your friends?

rarely	once a month	several times a month	once a week	several times a week	at least once a day	several times a day

14. How often do you play Sudoku?

rarely	once a month	several times a month	once a week	several times a week	at least once a day	several times a day

15. How often do you play Sudoku on computers, cell phones, or other electronic devices?

rarely	once a month	several times a month	once a week	several times a week	at least once a day	several times a day

16. How often do you play Sudoku using pencil and paper?

rarely	once a month	several times a month	once a week	several times a week	at least once a day	several times a day

17. How much do you enjoy playing computer games?

Not At All						Very Much
1	2	3	4	5	6	7

18. How much do you enjoy playing puzzle games?

Not At All						Very Much
1	2	3	4	5	6	7

Appendix A-3 : Study 1 Pre-Game Questionnaire (cont.)

19. How much do you enjoy playing Sudoku games?

Not At All — Very Much

1 2 3 4 5 6 7

20. How much do you enjoy playing Sudoku games on computers or other electronic devices?

Not At All — Very Much

1 2 3 4 5 6 7

21. How much do you enjoy playing Sudoku games with pencil and paper?

Not At All — Very Much

1 2 3 4 5 6 7

22. Did you ever play a Sudoku game with others?
☐ Yes ☐No (*Go to # 23*)

22-A. If yes, have you played the game on computer or with pencil & paper?
☐ On computer ☐ With pencil & paper

22-B. If yes, do you prefer playing Sudoku alone or with others?
☐ Alone ☐ With Others

23. Do you prefer playing Sudoku with pencil and paper or on Computer?
☐ Pencil & Paper ☐ On Computer

24. What do you think about solving puzzles or Sudoku? (Check all that apply)
☐ Relaxing
☐ Fun
☐ Competitive
☐ Personal Challenge
☐ Other. Specify: ________________________________

Appendix A-4 : Study 1 Post-Game Questionnaire

Study on Collaborative Gaming *post*

POET Lab, Computer Science Department, Virginia Tech

Date ____________________

Please help us understand your experience today in solving the sudoku as a team by answering the following questions. Your answer is very important in analyzing our results. So take time to answer these questions and provide as much detail as possible.

SECTION I

Circle your choice whenever appropriate.

1. How much did you enjoy playing the game?

did not enjoy it at all — enjoyed it very much

1 2 3 4 5 6 7

2. How much did you enjoy playing the game with your team members?

did not enjoy it at all — enjoyed it very much

1 2 3 4 5 6 7

3. How difficult was the puzzle?

very easy — very hard

1 2 3 4 5 6 7

4. How interesting did you think solving the puzzle was?

not interesting — very interesting

1 2 3 4 5 6 7

5. Sudoku software was easy to use.

strongly disagree — strongly agree

1 2 3 4 5 6 7

Appendix A-4 : Study 1 Post-Game Questionnaire (cont.)

6. Do you prefer playing Sudoku alone or as a team?
   ☐ Alone ☐ As a team

7. Would you use this tool (Sudoku software) again?
   ☐ Yes ☐ No

8. Would you play Sudoku with others again?
   ☐ Yes ☐ No

9. Do you prefer playing Sudoku with pencil and paper or this software?
   ☐ Pencil & Paper ☐ This software

   Why?
   ____
   ____

SECTION II

10. How much were you satisfied with the group and the way it worked together?

not at all satisfied — very satisfied

1 — 2 — 3 — 4 — 5 — 6 — 7

11. How much were you interested in participating in the group?

not at all interested — very interested

1 — 2 — 3 — 4 — 5 — 6 — 7

12. How much did your team talk to each other while playing the game?

less than I'd have liked — way too much

1 — 2 — 3 — 4 — 5 — 6 — 7

13. Did anything stop you from participating in the group activity?
   ☐ Yes ☐ No (*Go to #14*)

   13-A. If you answered yes, what stopped you from participating? (Check all that apply)
   - ☐ Puzzle difficulty
   - ☐ Tool (Sudoku software) difficulty
   - ☐ Group difficulty
   - ☐ Personal reasons.

   Please explain:
   ____
   ____

Appendix A-4 : Study 1 Post-Game Questionnaire (cont.)

14. How much did you enjoy working with the other people?

did not enjoy it at all — enjoyed it very much

1 2 3 4 5 6 7

15. How much was your participation welcomed by others in your group?

not at all — very welcomed

1 2 3 4 5 6 7

16. Was it fun to play the game as a team?

not at all — very fun

1 2 3 4 5 6 7

17. Do you think you got to know your team members better after playing the game?

not at all — very much

1 2 3 4 5 6 7

18. Compare to your previous experience playing Sudoku, what was the main difference in playing the puzzle as a team? ____

____

____

SECTION III

19. While you were talking to other team members during the game, did you ever wanted to refer to certain parts of the puzzle?

☐ Yes ☐ No

20 If you answered yes, how did you convey your ideas to others?

____

____

____

21. How obvious was what other people were doing?

not at all obvious — completely obvious

1 2 3 4 5 6 7

Appendix A-4 : Study 1 Post-Game Questionnaire (cont.)

22. Did you ever have any difficulty in explaining what you were talking about while solving the puzzle?

☐ Yes ☐No (*Go to #23*)

22-A. If you answered yes, please explain the difficulty

☐ Reference tool was hard to use
☐ Did not know how to use the reference tool
☐ It's just hard to specify parts of a Sudoku puzzle
☐ Other reasons, please explain:

____

____

23. Did you ever have any difficulty in understanding what someone else was talking about while solving the puzzle?

☐ Yes ☐No (*Go to #24*)

23-A. If you answered yes, please explain the difficulty

____

____

24. How often did you use the reference feature?

did not use — whenever I had to explain something

1 2 3 4 5 6 7

25. How much confidence did you have that other people understood what you were talking about?

not at all confident — very confident

1 2 3 4 5 6 7

26. How well did you understand what other people explained?

not at all — completely

1 2 3 4 5 6 7

27. The reference tool was easy to use.

strongly disagree — strongly agree

1 2 3 4 5 6 7

28. How much did you like the reference tool?

strongly disagree — strongly agree

1 2 3 4 5 6 7

Appendix A-5: Study 2 Pre-Session Questionnaire

Pre-Session Questionnaire (before game 1)

Date and Time:________________________

Part 1.

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you feel this now. Use the following scale to record your answers.

1	2	3	4	5
Very slightly or not at all	A little	Moderately	Quite a bit	Extremely

_______interested _______irritable

_______distressed _______alert

_______excited _______ashamed

_______upset _______inspired

_______strong _______nervous

_______guilty _______determined

_______scared _______attentive

_______hostile _______jittery

_______enthusiastic _______active

_______proud _______afraid

(continue on next page)

Appendix A-5: Study 2 Pre-Session Questionnaire (cont.)

Part 2.

Please think about your attitudes right now, knowing what you know now and feeling what you feel now. Here are some questions about your willingness to engage in future interaction with the other members of your group. For each question, please circle the number reflecting your feelings.

1. Would you like to play Sudoku with your team in the future (after today)?

-3	-2	-1	0	+1	+2	+3
Definitely Not			Neutral			Definitely Yes

2. Would you be willing to ask your team members for advice in solving Sudoku?

-3	-2	-1	0	+1	+2	+3
Definitely Not			Neutral			Definitely Yes

3. Would you be willing to sit next to your group members on a three-hour bus trip?

-3	-2	-1	0	+1	+2	+3
Definitely Not			Neutral			Definitely Yes

4. Would you be willing to invite your group members to your house?

-3	-2	-1	0	+1	+2	+3
Definitely Not			Neutral			Definitely Yes

5. Would you be willing to work with your team members on a job?

-3	-2	-1	0	+1	+2	+3
Definitely Not			Neutral			Definitely Yes

6. Would you be willing to admit your team members to your circle of friends?

-3	-2	-1	0	+1	+2	+3
Definitely Not			Neutral			Definitely Yes

(continue on next page)

Appendix A-5: Study 2 Pre-Game Questionnaire (cont.)

Part 3.

We would like to know whether you already know the other people in today's session. Please mark two and leave the other blank:

Participant A

1	2	3	4	5	6	7
Never meet before						Very close friend

Participant B

1	2	3	4	5	6	7
Never meet before						Very close friend

Participant C

1	2	3	4	5	6	7
Never meet before						Very close friend

(end)

Appendix A-6: Study 2 Between-Game Questionnaire

Between-Games Questionnaire (after game 1 and before game 2)

Date and Time:________________________

Part 1.

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you feel this now. Use the following scale to record your answers.

1	2	3	4	5
Very slightly or not at all	A little	Moderately	Quite a bit	Extremely

_______interested

_______distressed

_______excited

_______upset

_______strong

_______guilty

_______scared

_______hostile

_______enthusiastic

_______proud

_______irritable

_______alert

_______ashamed

_______inspired

_______nervous

_______determined

_______attentive

_______jittery

_______active

_______afraid

(continue on next page)

Appendix A-6: Study 2 Between-Game Questionnaire (cont.)

Part 2.

Please think about your attitudes right now, knowing what you know now and feeling what you feel now. Here are some questions about your willingness to engage in future interaction with the other members of your group. For each question, please circle the number reflecting your feelings.

1. Would you like to play Sudoku with your team in the future (after today)?

-3	-2	-1	0	+1	+2	+3
Definitely Not			Neutral			Definitely Yes

2. Would you be willing to ask your team members for advice in solving Sudoku?

-3	-2	-1	0	+1	+2	+3
Definitely Not			Neutral			Definitely Yes

3. Would you be willing to sit next to your group members on a three-hour bus trip?

-3	-2	-1	0	+1	+2	+3
Definitely Not			Neutral			Definitely Yes

4. Would you be willing to invite your group members to your house?

-3	-2	-1	0	+1	+2	+3
Definitely Not			Neutral			Definitely Yes

5. Would you be willing to work with your team members on a job?

-3	-2	-1	0	+1	+2	+3
Definitely Not			Neutral			Definitely Yes

6. Would you be willing to admit your team members to your circle of friends?

-3	-2	-1	0	+1	+2	+3
Definitely Not			Neutral			Definitely Yes

(end)

Appendix A-7: Study 2 Post-Session Questionnaire

Post-Session Questionnaire (after game 2)

Date and Time:________________________

Part 1.

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you feel this now. Use the following scale to record your answers.

1	2	3	4	5
Very slightly or not at all	A little	Moderately	Quite a bit	Extremely

_______interested _______irritable

_______distressed _______alert

_______excited _______ashamed

_______upset _______inspired

_______strong _______nervous

_______guilty _______determined

_______scared _______attentive

_______hostile _______jittery

_______enthusiastic _______active

_______proud _______afraid

(continue on next page)

Appendix A-7: Study 2 Post-Session Questionnaire (cont.)

Part 2.

Please think about your attitudes right now, knowing what you know now and feeling what you feel now. Here are some questions about your willingness to engage in future interaction with the other members of your group. For each question, please circle the number reflecting your feelings.

1. Would you like to play Sudoku with your team in the future (after today)?

-3	-2	-1	0	+1	+2	+3
Definitely Not			Neutral			Definitely Yes

2. Would you be willing to ask your team members for advice in solving Sudoku?

-3	-2	-1	0	+1	+2	+3
Definitely Not			Neutral			Definitely Yes

3. Would you be willing to sit next to your group members on a three-hour bus trip?

-3	-2	-1	0	+1	+2	+3
Definitely Not			Neutral			Definitely Yes

4. Would you be willing to invite your group members to your house?

-3	-2	-1	0	+1	+2	+3
Definitely Not			Neutral			Definitely Yes

5. Would you be willing to work with your team members on a job?

-3	-2	-1	0	+1	+2	+3
Definitely Not			Neutral			Definitely Yes

6. Would you be willing to admit your team members to your circle of friends?

-3	-2	-1	0	+1	+2	+3
Definitely Not			Neutral			Definitely Yes

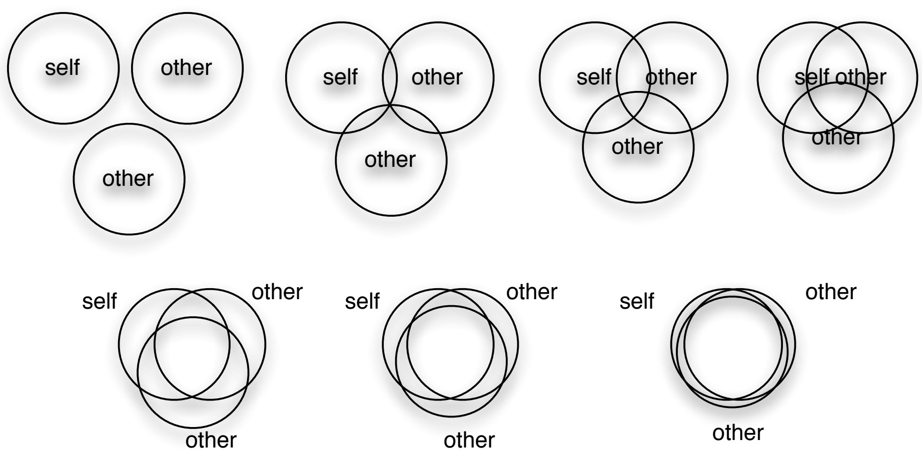
Appendix A-7: Study 2 Post-Session Questionnaire (cont.)

Part 3.

Please answer each of the following questions according to how you personally feel about your team members and the relationship you now have with the team members.

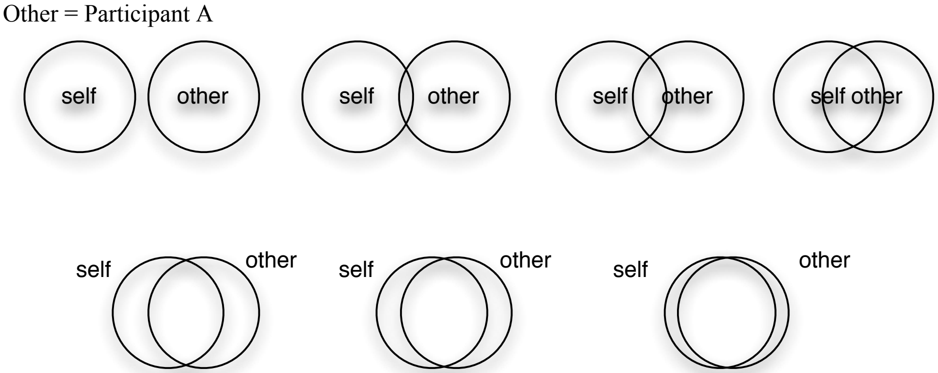
Your answers are anonymous and confidential. Other members of the team will never see them. Please answer honestly.

A. (CLOSENESS): Please circle the picture which describes how you feel about your group and the way your group worked the problem (solved puzzles) together.



B. (CLOSENESS): Please circle the picture which describes how you feel about other players in your group and the way your worked the problem (solved puzzles) with that person. (Answer 2 and leave 1 blank)

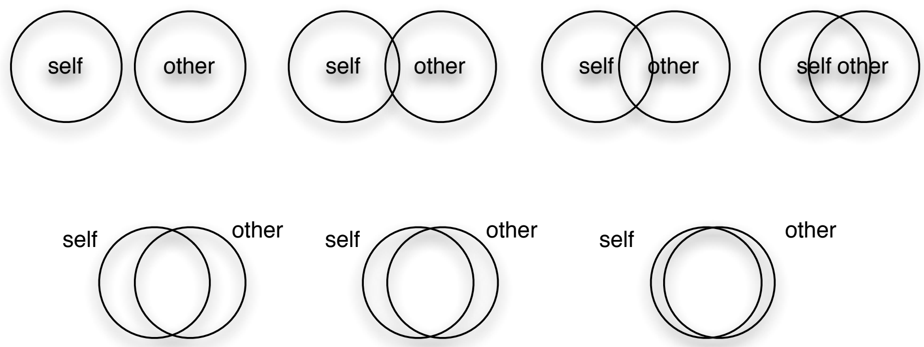
Other = Participant A



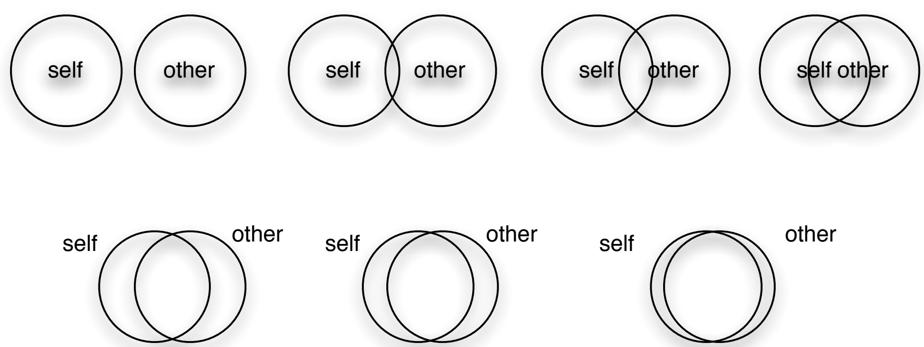
(continue on next page)

Appendix A-7: Study 2 Post-Session Questionnaire (cont.)

Other = Participant B



Other = Participant C



(continue on next page)

Appendix A-7: Study 2 Post-Session Questionnaire (cont.)

Part 4. Circle your choice whenever appropriate.

1. How interesting did you think solving the game was?

1 - Not at all interesting — 7 - very interesting

1 2 3 4 5 6 7

2. How much did you enjoy playing Sudoku today?

1 - Didn’t enjoy it at all — 7 - Enjoyed it very much

1 2 3 4 5 6 7

3. How much were you satisfied with the group and the way it worked together?

1 – Not at all satisfied — 7 – very satisfied

1 2 3 4 5 6 7

4. How much were you interested in participating in the group activities?

1 – Not at all interested — 7 – very interested

1 2 3 4 5 6 7

5. How much did you enjoy working with the other people?

1- Didn’t enjoy it at all — 7 - Enjoyed it very much

1 2 3 4 5 6 7

Appendix A-7: Study 2 Post-Session Questionnaire (cont.)

6. Overall, how much did you contribute to the group work?

1- None — 7 – As much as possible

1 2 3 4 5 6 7

7. Who contributed the most to solving the puzzle?

Participant A	**Participant B**	**Participant C**	**Everyone**	**No One**

8. Who lead the group activity?

Participant A	**Participant B**	**Participant C**	**Everyone**	**No One**

9. Who talked the most?

Participant A	**Participant B**	**Participant C**	**Everyone**	**No One**

10. Who decided on the group strategy?

Participant A	**Participant B**	**Participant C**	**Everyone**	**No One**

(end)

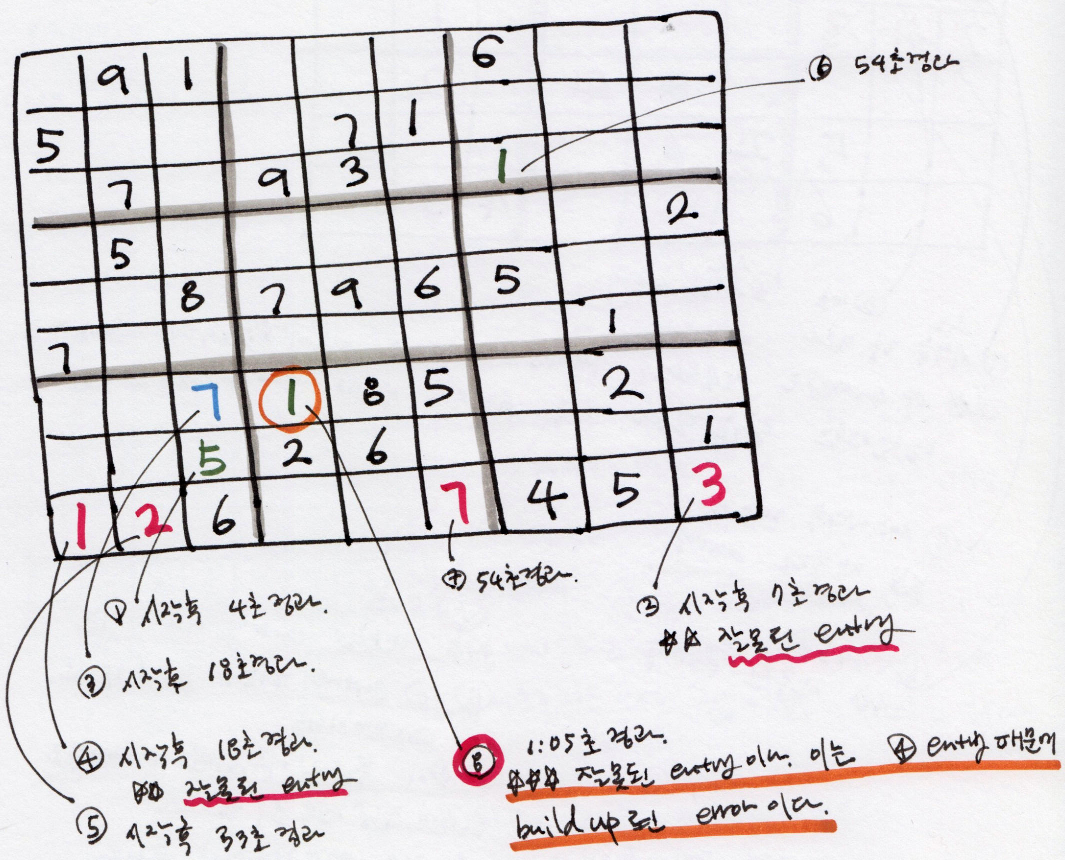
Appendix B: Sample Research Notes - Study 1

session 29.
condition : Basic
Game : Type A

Ⓐ RED - 백인남자
Ⓑ BLUE - 백인여자
Ⓒ GREEN - 동양인남자

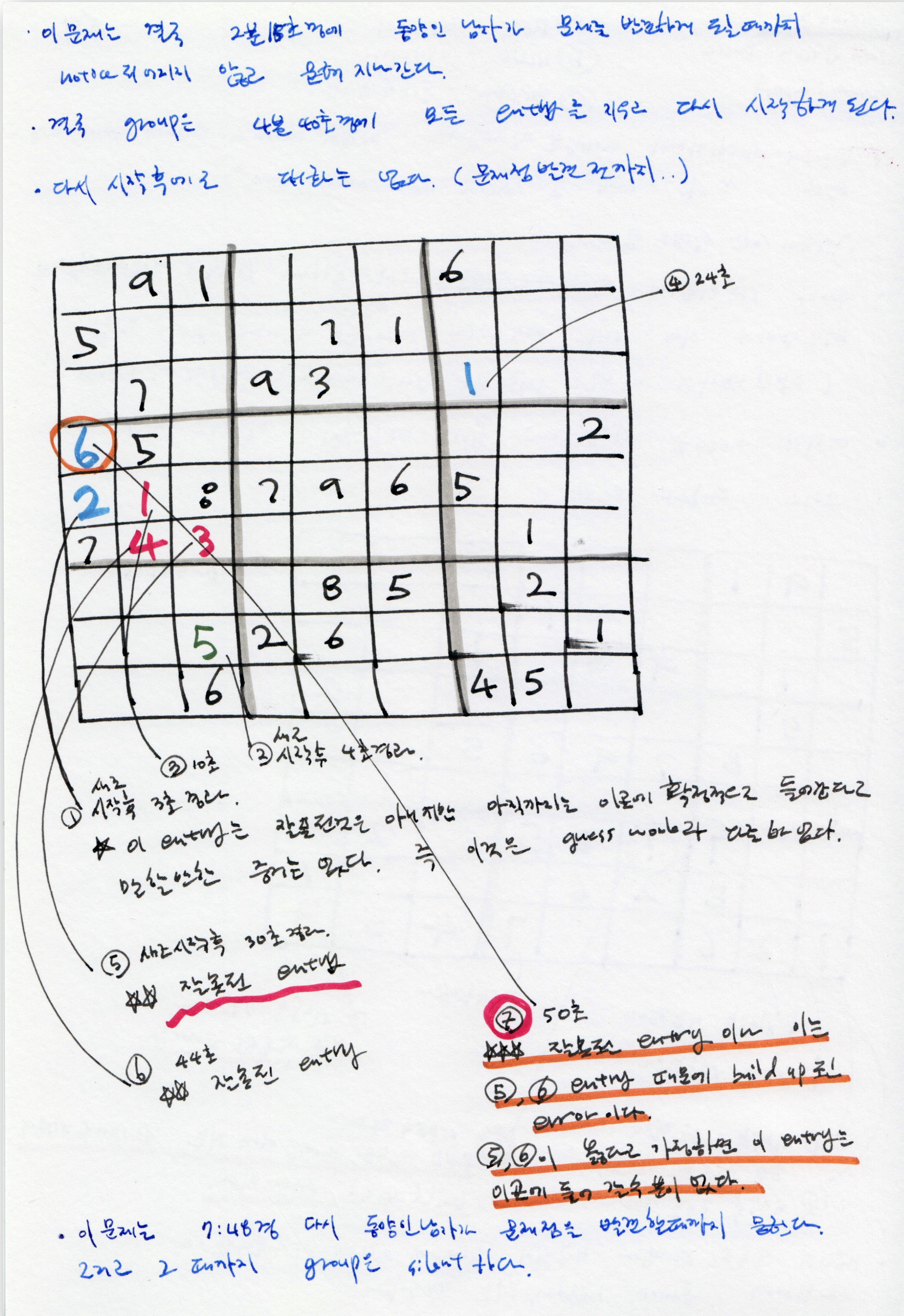
69

- 동양인이 시작하자마자 entry를 집어넣으면서 자신의 move에 대하여 announce를 한다. "ok well I found five over here".
  이유에 대한 설명은 없다.
- 여자가 다른 이들에게 ~~잘하는지를 물어본다~~. 나는 잘 못하기에 너희들이 잘 하면 좋겠다고 말한다.
  백인남자가 이에 나는 여기 오기 전 rule을 읽어보고 왔다고 말함.
  (백인 남자는 이 말로 미루어 보아 sudoku rule에 대하여 잘 모르는 듯).
- 여자가 note를 사용하냐고 묻자 백인남자가 아니라고 대답.
- 그러고 대화가 없다.



- RED의 잘못된 entry가 검증없이 group에 의하여 받아들여졌으며 그로 인하여 문제가 build up되는 경우이다.

Appendix B: Sample Research Notes - Study 1 (cont.)



Session 80 <u>493</u>

Condition: Basic

Game: Type A

Ⓒ 남자 (Green)
Ⓑ 여자 (Red)
Ⓐ 회리여자 (Blue)

	notes	entries	end state
A	31	5	4
B	29	17	11
C	58	3	0

filled	15
empty	39
correct	15
incorrect	0

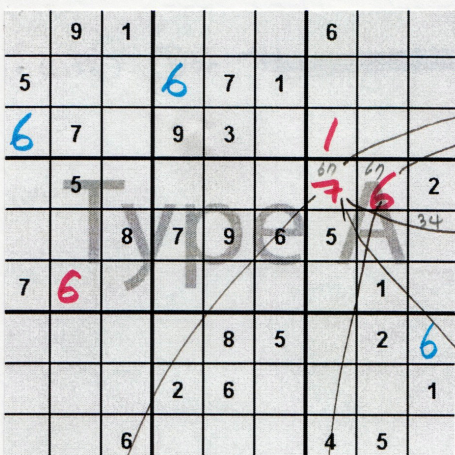
- 초반 남자 Ⓒ가 strategy 제안.

Ⓑ가 얼굴을 찡그리며 Ⓒ의 의견에 회의적인 반응을 보임. ⇒ 즉 나누어 하는 것은 문제가 있다라고 말함.

Ⓑ가 그냥하라고 하고 Ⓒ는 줄가는 줄의 예를 들며 자신의 전략방법을 보여주려 함.

Ⓑ는 Ⓐ와 Ⓒ가 넣은 entry들이 확신한 것이냐 질문

⇒ Ⓐ와 Ⓒ는 yes 라고 답변.



~~보고~~

① B가 notes 넣음.

② B가 notes 넣음.

③ B가 이곳에 6이 들어갈수 없다는 사실을 발견 "oh, wait" 이라고 말한다.

④ 이에 Ⓐ는 "can't be a 6 in that row" 라고 말하고 Ⓑ도 동의. 자신이 실수를 한 이유를 짧게 설명 notes를 지운다.

⑤ B가 7을 넣는다

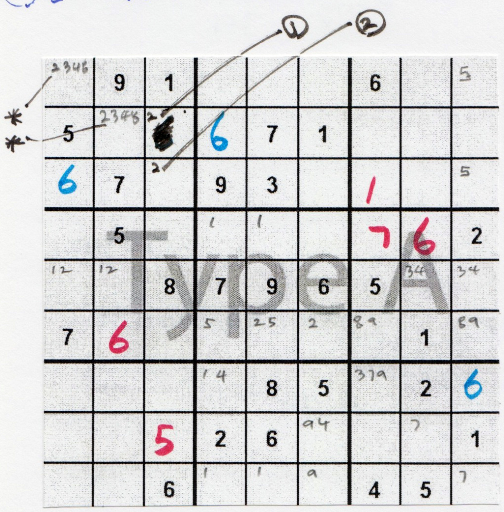
⑥ B가 6을 넣는다. 그리고 notes를 지운다.

Appendix B: Sample Research Notes - Study 1 (cont.)

이 경우 잘못된 entry는 아니나 notes끼리도 서로 혼선하는 모습을 보인다.

Ⓐ는 Ⓑ가 시작한 말을 대신 끝낸다. (잘못된 것은 Ⓑ가 발견하였으나 Ⓐ가 먼저 말하는 꼴이 된다.)

• Ⓒ는 자신이 notes들을 더한다고 말함



• Ⓑ가 [3:56] 초경.

Ⓒ가 넣은 notes ★에서 2는 들어갈 수 없다고 지적.

이유를 설명하면서

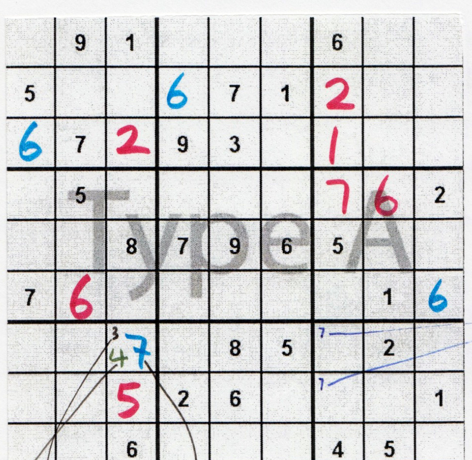
① 에 note 2를 추가

② 에 note 2를 추가

하며 이 두 곳 중 하나가 2여야

★에는 2가 들어갈 수 없다 설명한다.

Ⓑ는 자신의 move에 대하여 announce를 한다. (항상은 아니다.)



① Ⓑ가 notes를 넣으면서 7은 이 두 곳 중에 하나라고 말함.

⇒ 잘못된 것임.

② Ⓒ가 추가

③ Ⓒ가 Green 4 추가.

④ Ⓐ가 Green 4를 Blue 7으로 overwrite한다.

Appendix C-1: Transcript Analyzer

trans_process.py

trans_process.py 〉 No Selection

```
import board_info

path ='/Volumes/FreeAgent Drive/00. Sudoku Study/06a. Transcription/'

filename = 'S_S36G1'


in_filename = path + filename + '.txt'
first_level_out_filename = path + '01. processed/' + filename + '_out1.txt'
second_level_out_filename = path + '02. processed/' + filename + '_out2.txt'
third_level_out_filename = path + '03. processed/' + filename + '_out3.txt'


infile = open(in_filename)
outfile = open(first_level_out_filename, 'w', 0)


utteranceTotal = utteranceA = utteranceB = utteranceC = 0
countTotal = countA = countB = countC = 0

found_start_point = False
found_end_point = False
prev_user = 'no_one'

for line in infile.readlines():
    # this portion takes out text lines before the beginning of the transcription
    if (found_start_point == False):
        m1 = re.match(r".*cleaned transcription.*", line)
        if (m1):
            print "found the starting point..."
            found_start_point = True
            continue
        else:
            continue

    # this portion takes out text lines after the end of the transcription
    if (found_end_point == False):
        m2 = re.match(r".*original transcription.*", line)
        if (m2):
            print "found the end point..."
            found_end_point = True
            break

    # this portion takes out all timestamps
    line = re.sub(r'\[\d\d:\d\d:\d\d\.\d\d\]','', line)
    line = re.sub(r'\[\d\d:\d\d:\d\d\:\d\d\]','', line)
    # this portion takes out all coding info
    line = re.sub(r'\{\$.*\$\}','',line)

    # this portion takes out all coding info
    line = re.sub(r'\{\d\}','',line)

    # this portion takes out all non-verbal info
    line = re.sub(r'\(\(.*\)\)','',line)

    # this portion takes out all "(PAUSE)"
    line = re.sub(r'\(PAUSE\)','',line)

    # this portion replaces all '...' and '..' with a whitespace
    line = re.sub(r'[\.\.\. | \.\.]', ' ', line)

    # this portion deletes all '[' and ']'
    line = re.sub(r'[\[]', '', line)
    line = re.sub(r'[\]]', '', line)

    #print "prev_user is " + prev_user
    m3 = re.match(r"^(?P<user>[ABC])\s*:", line)
    if m3:
        user = m3.group('user')

        prev_user = user
        if (user == 'A'):
            countA = countA + 1
        elif (user =='B'):
            countB = countB + 1
        elif (user == 'C'):
            countC = countC + 1

        countTotal = countTotal + 1

    print prev_user + " says " + line
    for word in line.split():

        if word == 'A:' :
```

Appendix C-1: Transcript Analyzer (cont.)

transAnal2.py

transAnal2.py 〉 No Selection

```
        in_filename = path + filename
        third_level_out_filename = out_path + 'out_' + filename


        infile = open(in_filename)
        outfile = open(third_level_out_filename, 'w', 0)


        utteranceTotal = utteranceA = utteranceB = utteranceC = 0
        countTotal = countA = countB = countC = 0

        found_start_point = False
        found_end_point = False
        prev_user = 'no_one'

        for line in infile.readlines():
            # this portion takes out text lines before the beginning of the transcription
            if (found_start_point == False):
                m1 = re.match(r".*cleaned transcription.*", line)
                if (m1):
                    print "found the starting point..."
                    found_start_point = True
                    continue
                else:
                    continue

            # this portion takes out text lines after the end of the transcription
            if (found_end_point == False):
                m2 = re.match(r".*original transcription.*", line)
                if (m2):
                    print "found the end point..."
                    found_end_point = True
                    break

            # this portion takes out all timestamps
            line = re.sub(r'\[\d\d:\d\d:\d\d\.\d\d\]','', line)
            line = re.sub(r'\[\d\d:\d\d:\d\d\:\d\d\]','', line)
            # this portion takes out all coding info
            line = re.sub(r'\{\$.*\$\}','',line)

            # this portion takes out all coding info
            line = re.sub(r'\{\d\}','',line)

            # this portion takes out all non-verbal info
            line = re.sub(r'\(\(.*\)\)','',line)

            # this portion takes out all "(PAUSE)"
            line = re.sub(r'\(PAUSE\)','',line)

            # this portion replaces all '...' and '..' with a whitespace
            line = re.sub(r'[\.\.\. | \.\.]', ' ', line)

            # this portion deletes all '[' and ']'
            line = re.sub(r'[\[]', '', line)
            line = re.sub(r'[\]]', '', line)

            #print "prev_user is " + prev_user
            m3 = re.match(r"^(?P<user>[ABC])\s*:", line)
            if m3:
                user = m3.group('user')

                prev_user = user
                if (user == 'A'):
                    countA = countA + 1
                elif (user =='B'):
                    countB = countB + 1
                elif (user == 'C'):
                    countC = countC + 1

                countTotal = countTotal + 1

            print prev_user + " says " + line
            for word in line.split():

                if word == 'A:' :
                    continue
                if word == 'B:' :
                    continue
```

Appendix C-2: Log Analyzer

test2.py

test2.py 〉 No Selection

```
            msg ='\t' + user + ' is inserting a new value ' + str(val) + '\n\n'
            outfile.write(msg)

            num_overwrite = num_overwrite + 1

        board[index].owner = user
        board[index].cell_val = val

        if (user == 'A'):
            A_entry_num = A_entry_num + 1
        elif (user == 'B'):
            B_entry_num = B_entry_num + 1
        elif (user == 'C'):
            C_entry_num = C_entry_num + 1

        if (board[index].cell_val != answer[index]):
        # answer validity check
            msg = "\t " + user + " inserted " + str(val) + " into a cell (" + str(index) + ")\n"
            outfile.write(msg)
            msg = "\t WRONG Entry - correct answer is " + str(int(answer[index])) +"\n\n"
            outfile.write(msg)

#---------------------------------------------

    m3 = re.match(r"\[\d\d:\d\d:\d\d]\s+(?P<user>[A,B,C]) deleted a guess entry at cell\((?P<cell>\d\d?)\) with value (?P<val>\d).", line)
    if m3:
#-------------- guess (note) deleted by a user-------------

        if (m3.group('user') == 'A'):
            A_dguess_num = A_dguess_num + 1
        elif (m3.group('user') == 'B'):
            B_dguess_num = B_dguess_num + 1
        elif (m3.group('user') == 'C'):
            C_dguess_num = C_dguess_num + 1

#---------------------------------------------

    m4 = re.match(r"\[\d\d:\d\d:\d\d]\s+(?P<user>[A,B,C]) deleted an entry at cell\((?P<cell>\d\d?)\) with value (?P<val>\d).", line)
    if m4:
#-------------- entry deleted by a user-------------
        user = m4.group('user')
        cell = int(m4.group('cell'))
        index = cell - 1
        val = int(m4.group('val'))

        outfile.write('-----------------\n')
        outfile.write(m4.group() + '\n')

        if board[index].owner != 'E' and board[index].owner != user:
        # deleting other's entry
            msg = '\t-- cell (' + str(index) + ') had a value ' + str(board[index].cell_val) + ' written by ' + board[index].owner + '\n'
            outfile.write(msg)

            msg ='\t' + user + ' is deleting the cell (val = ' + str(val) + ' )\n\n'
            outfile.write(msg)

            num_delete_others = num_delete_others + 1

        board[index].owner = 'E'
        board[index].cell_val = 0

        if (user == 'A'):
            A_dentry_num = A_dentry_num + 1
        elif (user == 'B'):
            B_dentry_num = B_dentry_num + 1
        elif (user == 'C'):
            C_dentry_num = C_dentry_num + 1

#---------------------------------------------

msg =  "A guess num is " + str(A_guess_num)
print msg
outfile.write(msg)
outfile.write("\n")

msg =  "B guess num is " + str(B_guess_num)
print msg
```

Appendix C-2: Log Analyzer (cont.)

test3.py

test3.py 〉 No Selection

```
        val = int(m1.group('val'))
        hour = int(m1.group('hour'))
        min = int(m1.group('min'))
        sec = int(m1.group('sec'))

        if (include_notes == True):
            outfile.write('-----------------\n')
            outfile.write('\t\t' + m1.group() + '\n')
            if (print_elapsed_time):
                if (start_time_flag == True):
                    time_str = "03/06/05 " + str(hour) + " " + str(min) + " " + str(sec)
                    start_time = time.strptime(time_str, "%m/%d/%y %H %M %S")
                    outfile.write('!![00:00:00]\n')
                    start_time_flag = False
                else:
                    time_str = "03/06/05 " + str(hour) + " " + str(min) + " " + str(sec)
                    current_time = time.strptime(time_str, "%m/%d/%y %H %M %S")
                    elapsed_time = time.mktime(current_time) - time.mktime(start_time)
                    outtime_str = "[" + str(int(elapsed_time / (60*60))) + ":" + str(int(elapsed_time/(60))) + ":" +
                        str(int(elapsed_time%60)) +"]"
                    outfile.write(outtime_str)

        if (user == 'A' or user == 'a'):
            A_guess_num = A_guess_num + 1
        elif (user == 'B' or user == 'b'):
            B_guess_num = B_guess_num + 1
        elif (user == 'C' or user == 'c'):
            C_guess_num = C_guess_num + 1

#---------------------------------------------

    m2 = re.match(r"\[(?P<hour>\d\d):\d\d:\d\d]\s+(?P<user>[A,B,C,a,b,c]) entered an entry at cell\((?P<cell>\d\d?)\)
        with value (?P<val>\d).", line)
    if m2:
#-------------- entry entered by a user-------------
        user = m2.group('user')
        cell = int(m2.group('cell'))
        index = cell - 1
        val = int(m2.group('val'))
        hour = int(m2.group('hour'))


        outfile.write('-----------------\n')
        outfile.write(m2.group() + '\n')

        if board[index].owner != 'E' and board[index].owner != user:
        # overwriting other's entry

            msg = '\t-- cell (' + str(index) + ') had a value ' + str(board[index].cell_val) + ' written by ' + board
                [index].owner + '\n'
            outfile.write(msg)

            msg ='\t' + user + ' is inserting a new value ' + str(val) + '\n\n'
            outfile.write(msg)

            num_overwrite = num_overwrite + 1

        board[index].owner = user
        board[index].cell_val = val

        if (user == 'A' or user == 'a'):
            A_entry_num = A_entry_num + 1
        elif (user == 'B' or user == 'b'):
            B_entry_num = B_entry_num + 1
        elif (user == 'C' or user == 'c'):
            C_entry_num = C_entry_num + 1

        if (board[index].cell_val != answer[index]):
        # answer validity check
            outfile.write ('hour is ' + str(hour))
            msg = "\t " + user + " inserted " + str(val) + " into a cell (" + str(index) + ")\n"
            outfile.write(msg)
            msg = "\t WRONG Entry - correct answer is " + str(int(answer[index])) +"\n\n"
            outfile.write(msg)

#---------------------------------------------

    m3 = re.match(r"\[\d\d:\d\d:\d\d]\s+(?P<user>[A,B,C,a,b,c]) deleted a guess entry at cell\((?P<cell>\d\d?)\) with
```

Appendix D: Transcription Coding Rule

TEAM SUDOKU
Coding Book - Version 0.3
Spring 2010

1. Transcription System

We are going to use a simplified version of the transcription system described by DuBois, Schuetze-Coburn, Cumming and Paolino (1993). Extra elements such as InqScribe time stamps, Transcribers Interpretative notes on the facial expressions of the participants, indicative marks for degree of the loudness of participants' utterances, and descriptions of the changes on the game board were added to the system. (Full description of the system will follow in a later section.)

Intonation Units

The body of the transcript should consist of lines with intonation units on them. An **intonation unit** is a stretch of speech uttered in a single coherent intonation contour, "in a go" as it were. In English, intonation units are signaled by pauses and shifts upwards in pitch at the beginning and lengthening of the final syllable. An intonation unit is signaled by a return after the end.

A **capital letter** signifies the beginning of a new intonation unit or of a restart to an incomplete one. Ends of intonation units are more complex, see below.

Words and Non-words

We will be making sure that **every word** within the intonation unit is transcribed. Every word is an intonation unit, even if it is the only thing in that intonation unit, including when people repeat what they have said. We will also be transcribing **non-word sounds produced by mouth, throat and lungs**, especially uhms, ers, sharp breaths, "tsks", "whoas", coughs, sneezes, and so forth. All words and non-word sounds have a space after them.

An **incomplete word** is signaled with a – (a dash), as in "I wond-" and we'll never know what I wondered… (Joking)

Single parentheses surrounding a description in capital letters indicate a non-word noise e.g. (COUGH), (LAUGH), (TSK)

Turns and Overlaps

Speakers can utter several intonation contours in a row, or just one, or even part of one.

A set of intonation units constitutes the speaker's turn at talk. A turn at talk is signaled by the label "**PARTICIPANT' ID: .**" Usually, one speaker succeeds another. However, in some cases, a person may follow themselves as a speaker (especially if there is a long silence). Additionally, in some cases, people may be talking at once.

Transcripts were parsed into **turns**; each was defined as a segment of speaker-continuous speech. If an interruption stopped the speaker from speaking, then the turn was considered completed, even if the content of the turn was resumed later. If the student did not stop talking even though some- one else was speaking, then all of the content was considered to be part of that same turn. Backchannel responses, such as "yes," "uhm," and so on, were also considered as turns.

(Adapted from Brigid Barron, *When Smart Groups Fail, 2003*)

We will use a combination of **indentation** and **square brackets** to indicate overlaps in speech. Here's a pretty complicated example with lots of overlaps:

B: Nobody wants to [to leave].
A: [They don't] move [[out]].
S: [[Berkeley]] just keeps [[[getting]]] bigger
B: [[[Yeah]]],

(Adapted from duBois et al., p.51)

Ends of Intonation Units

Intonation units are different from sentences. However, we will use punctuation that looks familiar to signal something about the nature of the intonation contour.

A **period** indicates a fall to a low pitch at the end of an intonation unit, as if to indicate that no more is to come. These do not necessarily come at the end of sentences, and frequently do appear at other places. Not that sometimes people keep speaking after finial intonation contours, but there is usually a pause.

A **comma** indicates that the intonation unit is intended to continue into another one. It is often signaled by a slight rise in pitch at the end of an intonation unit, sometimes by staying the same (when you would expect to go down) or even by going down slightly, but not enough to signal finality.

A **question mark** indicates an appeal, signaled by a marked high rise in pitch at the end if the intonation unit. "'Appeal' here refers to when a speaker, in producing an utterance, seeks a validating response from a listener." (duBois et al., p.55) It is not used simply for the grammatical form of a question. Imagine this example:

J: …Should we waste him?
Or should we stop him,
And …then waste him.
(duBois et al., p.55)

The first is an appeal to others. The second is a proposal or possibly a plan.

An **exclamation poin**t indicates a higher than expected pitch on a word. It appears BEFORE the word.

A **sequence of three dots** indicates a medium or long pauses within or between intonation units.

A **sequence of two dots** indicates a short pause. Normally the dots appear before the word that follows them UNTIL it is unclear who the next speaker will be, in which case they appear on a line of their own:

B: …I remember,
…I used to help Billy,
and I'd get twenty-five cents a week,
…
R: [A week].
B: [Twenty]---
(duBois et al., p.62)

Appendix D: Transcription Coding Rule (cont.)

Other Conventions

A **(PAUSE)** indicates a **vey long pause**. A long pause indicates a situation in which a speaker seems to stop short without completing what he/she was saying, take a long pause, then resume to complete what he/she was saying before.

The angle-bracket pair **<Q Q>** surround speech that has quotation quality. As in:

Female: You always say,
<Q I'm going out Q>
just like that

Transcriber annotations or explanations are indicated by **double parentheses** surrounding the comment. Those include descriptions of the board movement and descriptions of the facial movement and gestures of the participants.

When syllables are extended beyond the normal lengths for such syllables. The **lengthening** is shown with the symbol "=":

A: …and the=n the ma=n
… uh=her boyfriend whatever was gonna move in= with them
…
(Edwards & Lampert, Talking Data, 1993)

<X X> indicates doubtful portion of the transcription.

Appendix E: IRB Approval Letter

VirginiaTech

Office of Research Compliance
Institutional Review Board
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, Virginia 24061
540/231-4991 Fax 540/231-0959
e-mail moored@vt.edu
www.irb.vt.edu
FWA00000572(expires 1/20/2010)
IRB # is IRB00000667

DATE: November 8, 2007

MEMORANDUM

TO: Deborah Tatar
Priyadharsini Duraisamy
Joon Suk Lee

FROM: David M. Moore

Approval date: 11/8/2007
Continuing Review Due Date:10/24/2008
Expiration Date: 11/7/2008

SUBJECT: **IRB Expedited Approval:** "Evaluation of the Efficiency of Content Specific Pointing in a Collaborative Software Game" , IRB # 07-568

This memo is regarding the above-mentioned protocol. The proposed research is eligible for expedited review according to the specifications authorized by 45 CFR 46.110 and 21 CFR 56.110. As Chair of the Virginia Tech Institutional Review Board, I have granted approval to the study for a period of 12 months, effective November 8, 2007.

As an investigator of human subjects, your responsibilities include the following:

1. Report promptly proposed changes in previously approved human subject research activities to the IRB, including changes to your study forms, procedures and investigators, regardless of how minor. The proposed changes must not be initiated without IRB review and approval, except where necessary to eliminate apparent immediate hazards to the subjects.
2. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.
3. Report promptly to the IRB of the study's closing (i.e., data collecting and data analysis complete at Virginia Tech). If the study is to continue past the expiration date (listed above), investigators must submit a request for continuing review prior to the continuing review due date (listed above). It is the researcher's responsibility to obtained re-approval from the IRB before the study's expiration date.
4. If re-approval is not obtained (unless the study has been reported to the IRB as closed) prior to the expiration date, all activities involving human subjects and data analysis must cease immediately, except where necessary to eliminate apparent immediate hazards to the subjects.

Important:
If you are conducting **federally funded non-exempt research**, this approval letter must state that the IRB has compared the OSP grant application and IRB application and found the documents to be consistent. Otherwise, this approval letter is invalid for OSP to release funds. Visit our website at http://www.irb.vt.edu/pages/newstudy.htm#OSP for further information.

cc: File

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VIRGINIA POLYTECHNIC INSTITUTE UNIVERSITY AND STATE UNIVERSITY

An equal opportunity, affirmative action institution

Appendix E: IRB Approval Letter (cont.)

VirginiaTech

Office of Research Compliance
Institutional Review Board
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, Virginia 24060
540/231-4606 Fax 540/231-0959
e-mail irb@vt.edu
Website: www.irb.vt.edu

MEMORANDUM

DATE: February 27, 2012

TO: Deborah Tatar, Joon Suk Lee, Jose Alvarado, Stacy Branham, Kristen Marohn, Claire Clausen

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires May 31, 2014)

PROTOCOL TITLE: Micro-Coordination Research: Study 1

IRB NUMBER: 11-076

Effective March 23, 2012, the Virginia Tech IRB Chair, Dr. David M. Moore, approved the continuation request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at http://www.irb.vt.edu/pages/responsibilities.htm (please review before the commencement of your research).

PROTOCOL INFORMATION:
Approved as: **Expedited, under 45 CFR 46.110 category(ies) 6, 7**
Protocol Approval Date: **3/23/2012 (protocol's initial approval date: 3/23/2011)**
Protocol Expiration Date: **3/22/2013**
Continuing Review Due Date*: **3/8/2013**
*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:
Per federally regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals / work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Invent the Future

V I R G I N I A P O L Y T E C H N I C I N S T I T U T E A N D S T A T E U N I V E R S I T Y

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