

A FRAMEWORK FOR UNDERSTANDING EFFECTS OF PROXIMITY ON COLLABORATION : IMPLICATIONS FOR TECHNOLOGIES TO SUPPORT REMOTE COLLABORATIVE WORK¹

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Introduction

Increasingly, collaborating with other people is as likely to take place over distance or time as it is face-to-face. Over recent years, an abundance of new communication technologies have been developed to mediate remote collaboration -- electronic mail, bulletin boards, document sharing, video conferencing, and the like. Yet, to date collaboration over distance remains substantially harder to accomplish than collaboration when members of a work group are co-located. For example, in collaboration at a distance, communication is typically less frequent, characterized by longer lags between messages, and more effortful to produce.

In this paper we focus on the ways in which proximity might facilitate cooperative work. We concentrate on types of teamwork in which multiple individuals with particular areas of expertise coordinate their efforts to conduct joint projects and to produce joint artifacts. This type of coordination and division of labor characterizes many common forms of intellectual teamwork, including software development, product design, managerial decision-making, and research and development. Our goals are to identify the mechanisms by which proximity makes collaboration easier, to consider how current computer-mediated communications technologies provide or fail to provide key benefits of proximity, and to suggest directions for future research on the impact of proximity on collaboration.

An example of the effects of proximity

Even in the age of telecommunication and the Internet, physical proximity increases the likelihood of collaboration. Hagstrom (1965) demonstrated this phenomenon for scientific collaboration in the 1960s, and it is still true among scientists who have access to the Internet and are heavy users of telecommunications and computer-mediated communications. Consider, for example, a re-analysis of data originally reported in Kraut, Egido & Galegher (1989), predicting the probability of successful collaboration among scientists and engineers in a large telecommunications company. This company had been using Internet-based electronic mail since its founding and at the time of data collection, every member of the research division had an email account and a personal workstation or computer, and most used electronic mail heavily.

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Kraut, Egidio & Galegher examined which of the 164 scientists and engineers in the sample actually collaborated, as a function of the pairs' *organizational proximity* (closeness in terms of group, department, and laboratory structure), *research similarity* (based on an index of the semantic similarity of a pair's publications), and *physical proximity* (an ordinal measure of how close the office of potential collaborators were -- same corridor, same floor, same building, different buildings).

Results showed that even in this environment, pairs of researchers were unlikely to complete a technical report together unless their offices were physically near each other, even if they had previously published on similar topics or worked in the same department in the company. As Figure 1 shows, virtually all joint publications occurred among researchers with compatible expertise. But researchers with the most compatible expertise were more than four times as likely to publish together if their offices were on the same corridor as they are if their offices were on different floors of the same building, and researchers whose offices were in different buildings almost never collaborated with each other even if they had highly similar interests.

Similar results occurred concerning the association of organizational proximity with collaboration: Both between pairs of researchers in the same department and between those in different departments, researchers who had offices that were physically close to each other were more likely to collaborate than those located farther apart. The statistical interactions between physical proximity and both research similarity and organizational proximity suggest that physical proximity induces collaboration among people who might otherwise not collaborate. For example, if two were in the same department, they were two-thirds more likely to collaborate if their offices were on then same corridor than if the offices were only on the same floor. However, if they were not in the same department, then being on the same corridor boosted their likelihood of collaborating over eight times.

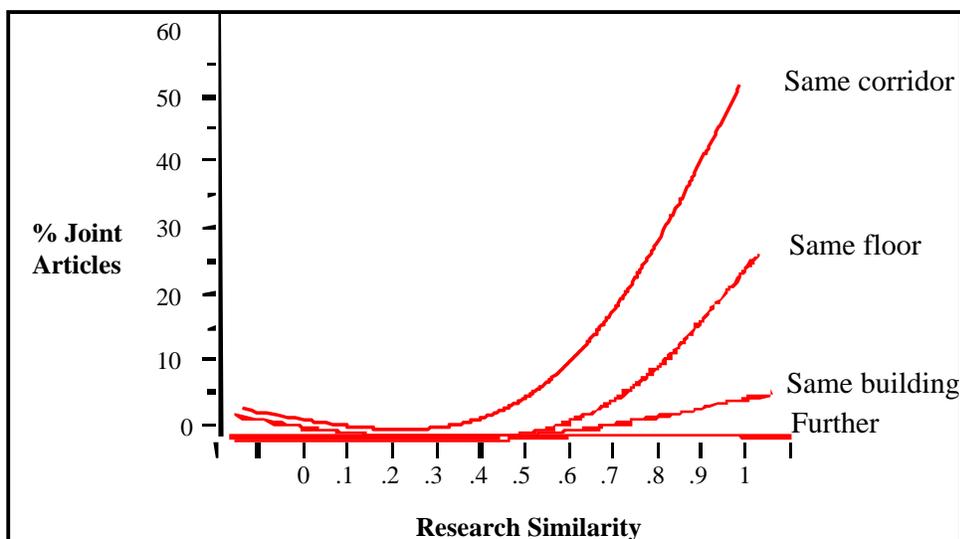


Figure 1: Association of research similarity and probability of collaboration at different levels of physical proximity

Understanding how proximity facilitates collaboration

The preceding analyses demonstrate that something about physical proximity encourages or enables collaboration among researchers with the right "fit"— common research interests or organizational membership and may even compensate for poor fit. However, this demonstration tells us little about the mechanisms through which proximity works its magic. Collaborative projects are complex endeavors, often taking between a year and 18 months to move from an initial idea for a first paper submission (Garvey, Lin, & Nelson, 1970), and involve overcoming many social and work-oriented hurdles (Kraut, Galegher & Egidio, 1990). During this process, there are many places where proximity might facilitate collaboration.

In the remainder of this paper we look more closely at how proximity facilitates interpersonal interaction and awareness in collaborative work. The approach we will use focuses on providing a conceptual analysis of how relevant attributes or "affordances" of proximity facilitate specific types of interaction and awareness. This approach builds upon earlier more holistic research (e.g., Chapanis, Ochsman, Parrish, & Weeks, 1972; Daft & Lengel, 1984; Short, Williams & Christy, 1976; Sproull & Kiesler, 1991), which examined at a descriptive level how types of media influence the success of collaboration. It also builds upon other recent decompositional analyses of media effects, including Daly-Jones, Monk & Watt's (1998) thoughtful analysis of the different functions of audio and visual information and Olson, Teasley, Covi, and Olson's (in press) analysis of the benefits of co-location for collaborative task work.

In the first section of the paper we describe in more detail some of the ways proximity can facilitate collaborative work. In particular, we consider how proximity influences informal awareness and communication, both of which play important roles in team coordination and performance. Then, we present a framework for analyzing the affordances or properties of proximity that facilitate awareness and communication. This framework considers both attributes of media (audio, video, and the like) and attributes of social interaction (e.g., dyadic vs. multiparty interactions). We describe how the presence or absence of these affordances in specific communications technologies might impact how well those technologies meet the needs of distributed workers. Finally, we end with some general conclusions and directions for future research.

Effects of Proximity on Awareness and Informal Communication

Observational and survey studies of work teams have suggested that two important mechanisms by which proximity promotes collaborative work are through support for passive awareness of others' activities and by the facilitation of informal communication. When people are co-located, they can view others' activities and overhear others' discussions, thereby learning about the existence of new potential collaborators and monitoring the progress of their current collaborators (e.g., Hutchins, 1991; Kraut, Fish, Root and Chalfonte, 1990). Proximity also facilitates informal conversations (Allen, 1977; Festinger, Schachter & Back, 1950; Kraut, Egidio, & Galegher, 1990; Kraut & Streeter, 1995), which can serve to enhance social relationships and work coordination (see, e.g., Kiesler & Cummings, in press, for a review). In the remainder of this section we consider how proximity might facilitate awareness and informal communication in more detail.

Awareness

Research suggests that teams are more successful at coordinating their activities if they can keep aware of the state of their team, its tasks and its environment (e.g., Cannon-Bowers, Salas, & Converse, 1993; Orasanu, 1990; Orasanu & Salas, 1993). When people share a physical work environment, there are informal mechanisms by which this awareness may arise. For example, one might overhear other people discussing an interesting project while waiting in line in the cafeteria, pass by an ongoing activity on the way to the water fountain, see someone else's output in the printer room, or view a project presentation diagram on a hallway whiteboard. As these examples suggest, awareness cues are of a number of different varieties. Some cues to others' activities are made available asynchronously, through traces of their endeavors (e.g., computer printouts).

Other cues, on which we focus here, are made available by being in the same place at the same time as other people. First, when people are co-located, there may be perceptual cues to others' presence and overall business. For example, one might become aware that a collaborator was back in the office by hearing his/her door being unlocked, realize an office mate was busy by hearing fingers on the keyboard, know that a colleague was in the office by seeing his back from the doorway, or know that a certain colleague was nearby by smelling perfume. These perceptual cues provide high-level information about others (e.g., presence vs. absence, busy vs. idle) but very little information about what activities they are currently engaged in.

Second, when people are co-located they can be observed in interactions with others in the environment. Simply seeing, for instance, that a person is engaged in a conversation with the head of the department, or that three colleagues are meeting together in an office, can provide cues for inferring social, business, and political alignments among one's colleagues.

Third, when people are co-located there are opportunities to learn more specifically about the activities others are engaged in through overhearing others' discussions. For example, a person might overhear other people discussing an interesting project while waiting in line in the cafeteria. Several studies have suggested that overhearing others' conversations is important to maintaining awareness in collaborative projects (Health & Luff, 1992; Hutchins, 1994).

Many systems to support awareness in distributed groups have focused on providing perceptual cues to others' presence and business (e.g., Ackerman & Starr, 1995; Root, 1988), perhaps under the assumption that knowing if and when others are present and busy is more important than knowing exactly what activity they are engaged in. To our knowledge, however, the relative importance of various types of awareness cues has never been systematically examined.

Informal communication

A second way in which proximity can facilitate collaboration is through facilitating informal communication. By "informal communication" we mean communication that is relatively unplanned, in contrast to scheduled project meetings and other planned interactions. Proximity clearly increases the frequency of these informal contacts. Kraut, Egido and Galegher (1990), for example, found that the psychologists they surveyed reported talking multiple times per day

with collaborators who had adjacent offices, approximately daily with collaborators who had offices on the same floor, and approximately once a week with collaborators in different buildings on the same campus. Topics of informal communication range considerably, and include discussions of people's whereabouts and activities, exchanging documents and other task-related materials, reporting project status, obtaining or giving assistance, and the like (Isaacs, Whittaker, Frohlich, & O'Connell, 1997).

Informal communication has been posited to have three types of effects on collaboration: First, casual conversations can enable people to identify common interests and goals, leading to new collaborations (e.g., Allen, 1977; Festinger et al., 1950). Second, informal communication can help current collaborators maintain awareness of project status and coordinate their activities (e.g., Kraut, Egidio & Galegher, 1990). Finally, informal communication can help develop and maintain social bonds between coworkers (Nardi & Whittaker, in press). As Kraut et al. (1990) found, it is not uncommon that a single conversation, through shifts of topic, might have benefits on all three aspects of collaboration.

Formal Communication	Informal Communication
Scheduled in Advance	Unscheduled
Arranged participants	Random participants
Participants in role	Participants out of role
Preset agenda	Unarranged agenda
One-way	Interactive
Impoverished content	Rich content
Formal language and speech register	Informal language and speech register

Table 1. Some characteristics of informal communication (from Kraut, Fish, Root, & Chalfonte, 1990).

Kraut et al. (1990) suggest seven dimensions along which the informality-formality of communication may be characterized (see Table 1). One set of dimensions pertains to the spontaneity of the interaction in terms of timing, participants, roles, and agenda. As Kraut et al. point out, informal communication tends to be *opportunistic* -- based on the social situations in which one finds oneself. Seeing another person in the hallway, for instance, can serve as a trigger, reminding one that one has a question for that person. Encountering a problem while working can likewise serve as an impetus to seek help from a work partner (Belloti & Bly, 1996).

A second set of dimensions pertain to the discourse style of informal versus formal communication. Informal communications tend to have a conversational style, in which participants exchange speaking and listening roles frequently, and provide one another with verbal and nonverbal backchannel responses (e.g., head nods or "mhm"s) as they speak (Duncan & Fiske, 1977). As Clark and his colleagues have shown (e.g., Clark, 1996; Clark & Wilkes-Gibbs, 1986; Clark & Brennan, 1991) this style of conversation enables communicators to quickly and easily *ground* their utterances -- that is, to establish to the satisfaction of all parties that a message has been understood as intended.

A Framework for Understanding Effects of Proximity on Collaboration

There are at least two aspects of informal communication which might mediate its effects on work and social relationships: its richness in terms of visual, audible, and other sensory cues, and its frequent, opportunistic nature. Of these two aspects, the latter has received more attention through theories such as media richness (Daft & Lengel, 1984), described in the next section. After we describe media richness and related theories, we will turn to an alternative explanation of the effects of proximity: its impact on the frequency and nature of interpersonal encounters among co-located workers. We end this section by considering how properties of specific media might shape the types of interpersonal encounters possible using those media.

Media richness as an explanation for proximity effects

One explanation for the failure of technologies to support interpersonal interaction among remotely distributed workers is based on the concept of "media richness" (Daft & Lengel, 1984). In face-to-face environments, participants have a full range of cues available to them during interactions, including other's facial expressions, gestures, verbal speech (with its associated intonation cues), and behaviors as well as a shared view of the physical environment. Collaborative technologies can be evaluated in terms of their richness by considering how many of these cues they provide. Thus, standard head-oriented video conferencing (facial expressions plus speech) is richer than telephony (speech only) which is in turn richer than email (text with no intonation).

Clark and Brennan (1991) have offered an influential framework for examining the impact of communications media on interpersonal communication that is based in part on the "richness" concept. Their framework examines the "affordances" of media with respect to providing key characteristics of face-to-face conversation. Table 2 lists a subset of the affordances they describe that are pertinent to our current discussion of synchronous encounters.

Affordances of Face-to-Face Communication	Telephone	Desktop Video Conferencing	Electronic Chat
Auditory co-presence	Yes	Yes	No
Visual co-presence	No	Yes	No
Physical co-presence	No	No	No

Table 2. Examples of relationships between media and selected affordances of face-to-face communication (adapted from Clark & Brennan, 1991). No = not present; Yes = present, at least to some degree.

Auditory co-presence refers to participants' mutual sharing of a common auditory environment, including both speech and environmental sounds. Auditory co-presence makes it easy to communicate through spoken communication, which is typically less effortful to produce than written or typed messages (cf. Levelt, 1989; Clark & Brennan, 1991). Auditory co-presence may also make it easier to convey emotions and attitudes (though intonation patterns and speaking volume, e.g., Scherer, 1986) and to monitor others' comprehension through their vocal backchannel responses (Duncan & Fiske, 1977; Rutter, 1984, Yngve, 1970).

Visual co-presence refers to participants' ability for people to see one another. Visual co-presence enables people to use facial expressions to convey attitudes and emotions, gaze direction to indicate attention and comprehension, and head nods and other visual backchannel responses as others are speaking (Duncan & Fiske, 1977; Ekman & Friesen, 1969).

Lastly, proximity can provide full *physical copresence* in which people mutually share an auditory, visual, and tactile environment. Physical-copresence permits multimodal interactions involving speech, visual cues, and actual physical actions. Speakers can use deictic gestures to refer quickly and easily to objects or other people in the shared environment (McNeill & Levy, 1982) and can observe other's actions and changes in objects to monitor task status (Rutter, 1984).

Creating virtual co-presence through communications technologies

Clark and Brennan's (1991) theory of affordances provides a useful framework for assessing the ways in which technologies for distributed work provide the benefits of face-to-face communication. In this section we briefly discuss the affordances of three communications technologies -- telephony, desktop video conferencing, and electronic chat -- for providing the types of co-presence found in face-to-face conversation. We focus on these three technologies because they are all synchronous technologies which can be used to support groups of more than two people.²

As shown in Table 2, media vary considerable in the extent to which they provide auditory, visual, and physical copresence. Telephony provides a degree of auditory co-presence, in that interactions are real time, and when the connection is full-duplex, users can use others' vocal feedback to help shape their utterances. Telephony does not provide full auditory co-presence however -- telephone users can typically hear one another, but not the full range of sounds in each person's surrounding environment. In addition, there is no physical or visual copresence.

Traditional desktop video conferencing systems link participants by video feeds that show one another's faces and, optionally, upper body (e.g., Sellen, Fish et al., 1990). These systems typically provide the same type of auditory co-presence as telephony (others' voices but not necessarily background sounds). Desktop video conferencing also provides partial visual co-presence, in that participants can typically view one another's facial expressions, and can sometimes view each others' gestures and gaze direction. These systems do not, however, provide physical co-presence.

² For the purposes of this discussion we assume symmetry in participants' modes of access to an interaction -- that is, that all parties are using the same technology. Performing collaborative actions and maintaining awareness when there is variety among media (e.g., a meeting in which some participants are co-located, others are connected by audio, and yet others connected by telephone) can be very complex

Alternative forms of video conferencing may provide different affordances of face-to-face communication. For example, task-oriented video systems, which provide visual displays of task objects and the environment rather than other participants (e.g., Fussell, Kraut, & Siegel, 2000, Nardi et al., 1993; Kraut, Miller, & Siegel, 1996, Kuzuoka, Kosuge, & Tanaka, 1994) provide partial physical co-presence at the expense of views of participants faces. Large display video systems such as ClearBoard (Ishii & Kobayashi, 1992) and VideoWindow (Fish et al., 1990) provide both partial physical co-presence and a view of others' faces and bodies; however, the cost and the specialized equipment required for such systems makes their widespread implementation for distributed work unlikely.

Finally, synchronous text messaging or "chat" provides virtually none of the affordances of face-to-face communication outlined by Clark and Brennan (1991). Synchronous text services such as Internet Relay Chat directly copy text typed at one terminal to another person's terminal, in close to real time. Figure 2 shows a typical generic chat interface, in which participants' names are listed on the right side of the screen and the text appears on the left side. As can be seen, electronic chat provides no auditory, visual, or physical co-presence.

Today's Topic	Participants
Sue: Hi everyone	@chanserv
Sam: Hi Sue	@John-away
Peter: How's the project going?	@Sue
Sally: How are you?	Sam
Sue: Fine, we're almost done.	Peter
	Sally
	Linda

Figure 2. An example of a generic "chat" interface.

Limitations to affordance theory

Although Clark and Brennan's framework has proven useful for a theoretical understanding of how different media may vary in their impact on conversation, there are a number of problems with using this framework to predict how well technologies might support the sorts of informal encounters thought to mediate the effects of proximity on collaborative success. First, while shared auditory and visual cues are clearly important for certain types of work activities, such as collaborative physical tasks (e.g., Fussell et al., 2000; Kraut et al., 1996; Kuzuoka et al., 1994; Nardi et al., 1993) it is not at all clear that such cues are important for the sorts of informal conversations proximity enhances. Second, although auditory and visual cues might indeed improve the efficiency of conversational grounding, it has never been demonstrated that the efficiency of individual conversations has an impact on longer term social and work awareness and relationships. Finally, as Nardi & Whittaker (in press) point out, Clark and Brennan's framework pertains to interactions which are already underway. It does not provide a means for

anticipating when people might encounter others and engage in conversation. In the next section we turn to an alternative framework for understanding the benefits of proximity, one which focuses on the impact of being co-located on the frequency and nature of interpersonal contacts.

Interpersonal encounters

An alternative way of conceptualizing the benefits of proximity is in terms of the types of interpersonal encounters it facilitates. By encounters we mean occasions in which two people come into contact with one another. These encounters may be passive (e.g., when two people simply look at one another) or they may involve active engagement in conversations or other activities with a joint focus of attention (Goffman, 1961). As shown in Table 3, proximity both provides preconditions for encounters (e.g., by the presence of other individuals and activities) and influences the form of these encounters.

Property	Definition
Multi-person	Multiple people are present at the same time
Multi-activity	Multiple activities take place in close proximity at the same time
Chance encounters	People encounter others during the course of their normal work activities
Extended encounters	People may remain in one another's presence for extended periods of time
Repeated encounters	People may encounter the same individuals multiple times
Open encounters	Individuals may come and go during ongoing interactions
Private encounters	People can position themselves to create private conversations

Table 3. Some properties of interpersonal encounters among co-located individuals.

Multi-person. One characteristic of the types of shared work spaces studied by Kraut and his colleagues (Kraut, Egido & Galegher, 1990; Kraut et al., 1990) is that multiple individuals are present at the same time. These individuals are, at any one moment, of three types: those working alone, those engaged in conversations with others, and those with whom one is directly engaged (if one is engaged in conversation). Although this may seem a trivial point, we will discuss further below how the presence of these other individuals with whom one is *not* currently interacting is one characteristic of proximity not realized in many popular communications technologies and not included in most experimental studies of media effects.

Multi-activity. The presence of others with whom one is not engaged suggests another feature of proximity: multiple activities can take place simultaneously in more-or-less the same spot. For example, one person might go to a common area to pick up a computer printout while a colleague is there checking the mailbox and yet two more colleagues are chatting by the coffee pot, all of which happen to be in the same location. Such overlapping of activities in the same spot makes possible both visual cues to others' activities and overhearing of others' conversations, the two main mechanisms proposed for maintaining awareness above. This feature is also not currently implemented in most communications technologies, nor included in most experimental studies of media effects.

Chance encounters refers to the ability of people to come across others with whom they might interact during the course of their normal work activities. Proximity facilitates chance encounters in the workplace through two related mechanisms: First, people can navigate through the environment, thereby coming across other individuals and activities. Bellotti & Bly (1996) and Whittaker et al. (1994) have described the importance of mobility for work teams. Second, other people can move through the environment and arrive at one's own location. Whittaker et al. found that a sizable proportion of the informal conversations they studied occurred when others arrived at a worker's office door.

Extended encounters. Although many informal encounters are fleeting (e.g., when one says "hi" to a colleague at a water fountain) proximity can also lead to longer periods of time during which people are in each other's presence. When people are co-present for periods of time, there appear to be what Goffman (1967) terms "involvement obligations" in that some degree of interpersonal communication is felt necessary, and its lack perceived as social discomfort. These longer interactions, such as lunchroom conversations, cover more topics. McDaniel et al. (1996) for example found that scientists using synchronous chat to observe data turned their topics of conversation to other things (including the chat technology, jokes, sports, etc.) when data collection was quiet. Fussell (in preparation) likewise found that volunteer staff in an online support chatroom shifted their conversation from work to social topics when those in need of assistance were not present.

Repeated encounters. In large part, the spaces in a physical environment such as an office building or laboratory are relatively permanent. Thus, a person one encounters at the coffee station or printer table on one day is likely to be encountered again in the future through repetition of actions. Festinger, Schachter and Back (1950) demonstrated how through repeated encounters relationships among unacquainted individuals can move to passing acquaintance, informal conversation, and sometimes the development of deeper friendships. Although informal conversations tend to be of short duration (Kraut et al., 1990; Whittaker et al., 1994) they typically take place within a broader context of a more enduring work or social relationship. The common ground established in prior interactions may serve as the foundation for shorter informal conversations. Whittaker et al. (1994), for example, found that greater frequency of interaction between two colleagues was correlated with shorter duration of each particular conversation.

Open encounters refers to whether an ongoing interaction can be joined by new individuals. Informal conversations in face-to-face settings often take place in hallways, lunchrooms, and other at least partially public locations. Ongoing conversations can be joined by new parties, which can shape their time course and agenda. The presence of new individuals can provide an impetus for formal introductions as well as a way to identify other potential collaborators with similar interests. New individuals may also interrupt ongoing discussions to start their own conversations. For example, Whittaker et al. (1994) found that the majority of informal dyadic conversations they observed were terminated by a third party joining in.

Private encounters. Although many people may be present at the same time in a public place such as a hallway or lunchroom, private conversations are possible by moving closer together

and lower one's voice. This may permit smooth switches from work-related to more personal topics.

Virtual encounters

The properties of encounters described above are in principle independent of specific media. Rather, they are aspects of the ways in which specific implementations of technologies incorporate principles of social interaction. Table 4 shows how the same four types of communications technologies we considered earlier in terms of affordances might be characterized with respect to the properties of encounters shown in Table 3.

Properties of Interpersonal Encounters	Telephone	Desktop Video Conferencing	Electronic Chat
Multi-person	No	No	Yes
Multi-activity	No	No	Yes
Chance encounters	No	No	Yes
Extended encounters	No	No	Yes
Repeated encounters	Yes	Yes	Yes
Open encounters	No	No	Yes
Private encounters	No	No	Yes

Table 4. Examples of properties of interpersonal encounters made possible by selected media.

Interestingly, the encounters framework provides opposite predictions than does media richness theory for the success of technologies for supporting remote collaboration. For example, while telephony provides auditory copresence and many of Clark & Brennan's (1991) other affordances of face-to-face communication, it is quite limited in its ability to allow spontaneous contacts among people. In its standard usage, the telephone typically does not provide for new parties to enter an existing conversation midway through (open encounters), does not provide for multiple activities to take place at the same time (multi-activity), and cannot create fully spontaneous encounters because the calling party must have a formalized intention to reach the other person prior to dialing. Similarly, it would be unusual for two parties to stay connected via telephone after a conversation was completed, thereby giving rise to pressures to communicate (extended encounters).

Desktop video systems also are typically closed membership and single activity, and provide few of the properties of proximity for social encounters described above. As Monk and Watts (in press) describe, most video systems provide no mechanisms for what they call "peripheral participation". One exception is the VideoWindow system developed at Bellcore (Fish et al., 1990). VideoWindow linked two coffee areas in two separate buildings of the same corporation, using a large screen that rendered images of remote participants at more or less life size. Unlike most systems for remote collaboration, VideoWindow permitted open membership and multiple activities at the same time, as well as extended interaction.

Electronic chat systems perhaps illustrate best the differences in predictions regarding media suitability for remote collaboration based on richness theories versus social encounters. Chat has

virtually none of the affordances of face-to-face communication outlined by Clark and Brennan (1991) -- no auditory copresence, no visual co-presence, and no physical co-presence. Yet, chat provides, to at least some extent, most all of the properties of encounters supplied by proximity. Chatrooms are characterized by multiplicity of conversational threads (e.g., Cherny, 1999; Fussell, in preparation, Murphy & Collins, 1997; Suler, 1997). These multiplicity of threads reflect the fact that a single chatroom may be used for multiple purposes at the same time, leading to opportunities for familiarity and awareness of others and their activities. Chat can provide chance encounters, when two people independently find themselves in the chatroom at the same time, and repeated encounters, when they meet by chance on multiple occasions. Furthermore, unlike users of the telephone and many video conferencing systems, people tend to remain connected to chatrooms after they have finished a task-related conversation, and these idle times may give rise to informal communication (McDaniel et al., 1996; Fussell, in preparation).

Interactions between media richness and social encounters

Although we are arguing that any medium for synchronous group communication (e.g., telephony, video conferencing, electronic chat) might be configured to allow the types of passive and active encounters described above, the affordances of particular media may impact the initiation and outcome of these encounters. Some examples of the way media affordances might shape interpersonal encounters are described briefly below.

Presence or absence of visual cues. Visual cues might make it easier for participants to transform passive encounters into active conversations. Fish et al. (1990), for example, suggest that one reason fewer encounters were converted to conversations with their VideoWindow system is that in some cases it was difficult to establish the eye contact that indicates to another person an interest in engaging with them. However, since there were other differences (e.g., prior acquaintance) between co-located and video connected participants in that study that were not controlled for, it remains an empirical issue whether gaze plays a necessary role in the initiation of active encounters. Similarly, visual cues have been argued to facilitate conversational grounding. However, as noted above the extent to which visual cues mediate the longer term benefits of proximity have yet to be systematically examined.

Typing versus speaking. As we noted earlier, for most people speaking is easier than typing (Levelt, 1989; Clark & Brennan, 1991), and typed discourse appears to differ in a number of ways from spoken conversation (cf. Cherny, 1999; Suler, 1997). For example, typed messages tend to be shorter, and may omit hedges and other politeness markers (Brennan & Ohaeri, 1999; Kraut et al., 1992). It is not yet clear what the impact of these differences in conversational style might be on either short term inferences about others or longer term aspects of collaboration.

Ease of information processing. More generally, properties of the medium through which one encounters others can make information processing more or less difficult. Some evidence suggests that when technologies make information processing more difficult, people will use stereotypes and schemas to draw inferences about their partners, rather than more thoughtful impression formation processes (e.g., Hinds, 1999). The longer-term impact of such differences in impression formation on collaborative work remains unclear.

Contextual information. Whittaker et al. (1994) suggest that the frequent short contacts characteristic of informal communication are made possible by the common ground or shared knowledge and beliefs established among a set of communicators in their previous interactions. The processes by which previous interactions set the stage for current ones is not well understood. Electronic chat systems provide a degree of *reviewability* (Clark & Brennan, 1991) in that a record of the ongoing conversation is kept on the screen. In some cases, this record can persist across different conversations with the same person. Nardi et al. (2000) have suggested these conversational logs might help provide interactants with shared knowledge and history that would facilitate the grounding of brief informal messages.

Synchronicity. Although all the media we are considering here are cotemporal, in that people are "present" at the same time (cf. Clark & Brennan, 1991), certain media such as electronic chat can introduce slight delays between message production and reception that have the potential to disrupt smooth conversational grounding (e.g., Krauss & Bricker, 1966). Such delays could conceivably affect people's willingness to engage in conversations with others or the outcomes of these engagements, but this has yet to be empirically tested. Perhaps more interestingly, synchronous text programs, because of their logging capabilities, can also be used asynchronously. A person can type a message to any colleague with the software running, regardless of whether that person is actually seated at the terminal. The person can then read the log and retrieve the message upon his/her return (Nardi et al., 2000).

Visibility of others' interactions. In face-to-face settings, private conversations can be accomplished by people moving closer together and lowering their voices. This behavior both provides a context for certain types of informal communication and serves as an indication to others that the people involved are actively engaged and not open to other encounters. Privacy in electronic text systems, in contrast, is established through the opening of a private dialogue box in which only the interested parties are present. While this does provide the desired effect of limiting overhearers, it fails to indicate to others that the participants are engaged. In observational studies of chatroom interaction (Fussell, in preparation) this invisibility of private interactions appears to lead to confusions about others' availability for encounters.

Future Directions

We have argued that the benefits of proximity on distributed work might be understood within a framework which considers both the affordances of media for communication and the types of interpersonal encounters made possible by particular instantiations of those media. This framework, however, needs further refinement and empirical test before it can be usefully applied to the design or selection of systems to support distributed work.

Refining the model

Each of the components of our framework -- media affordances, interpersonal encounters, and the interactions between them -- is in need of further conceptual development. With respect to media affordances, our distinctions may be both incomplete and at the wrong level of analysis. There are other sense-based affordances (e.g., smell) that might play a role in awareness of

others that we have not considered. In addition, concepts such as auditory, visual, and physical co-presence might be best broken down further. For example, there may be important differences between the type of auditory co-presence that occurs when people are co-located and that which occurs in audio or video conferencing. In the former but not the latter, people can hear sounds in their environment in addition to one another's voices, and these sounds may be useful in determining others' presence and availability. Similarly, visual co-presence may be broken down into a number of different sources of visual information (e.g., others' faces, eye gaze, etc.) which may have differential effects on collaborative work.

There is also a need for a better understanding of the types of passive awareness and informal communication that occur among co-located workers and the effects of this awareness and communication on task coordination and performance. We have suggested several aspects of social encounters that might be important (e.g., openness, duration, and the like). To date, however, there is little research on the role of these factors in promoting awareness and communication. For example, although research has considered the causes and consequences of active encounters among co-located individuals, we have little data on how frequently people passively encounter others, or on the factors that influence whether passive encounters will turn into active conversations. With respect to informal communication, we have some information on the types of topics people discuss (e.g., work status, others' availability and whereabouts, social pleasantries) but no clear data on the consequences of each of these types of conversation or on how frequency and topics of informal communication might be shaped by the nature of the work people are doing.

Finally, we need clarification of the ways in which affordances of media might interact with the dimensions of social encounters we have discussed. For example, we suggested earlier that temporal delays might hinder conversational grounding in certain media such as chatrooms. The long term impact of such effects has yet to be examined systematically. It may well be that the benefits that electronic chat provides in terms of interpersonal encounters outweigh the costs it creates with respect to conversational grounding. We consider the types of research that would be necessary to assess the relative benefits and costs of particular technologies for longer term collaborative work in the next section.

Towards new research paradigms

We have argued that most observational and survey studies examining the effects of proximity on distributed work confound affordances of currently available technologies with the types of social encounters made possible by specific implementations of those technologies. To understand the relative contributions of these two dimensions of physical proximity, we need to develop research paradigms that will allow us to disentangle their effects.

Studying informal awareness and communication is problematic, however, in that they cannot be imposed upon experimental participants by the investigator. Whereas we can study task-related communication by instructing participants to perform a task, we cannot study informal communication by instructing participants to talk "informally" because the very instruction to engage in social interaction transforms the nature of the conversation from informal to formal. Perhaps as a result, virtually all laboratory studies of media effects have used research paradigms

that fall on the "formal" side of all the dimensions of communications formality suggested by Kraut et al. (1990; see Table 1 above). Participants come to the laboratory at preset times, to perform a specified task, often in a specified role. Studies typically last only for a single session, and task efficiency is stressed. The need for awareness or informal contact with those outside of the team is virtually nonexistent. Although this type of research paradigm is useful for analyzing the effects of media on task performance, the design is such that it provides little insight into the relative contributions of media affordances and properties of interpersonal encounters on collaborative work.

We are currently exploring new research paradigms that will enable us to systematically manipulate dimensions of social encounters to examine their effects on collaborative work. Rather than running one team at a time in a task-oriented scenario, we ask multiple teams to participate simultaneously and manipulate the ways in which these teams can become aware of one another and engage in informal communications. Our goal is to better understand the factors that shape interpersonal encounters and of the ways encounters influence team collaboration and performance.

Conclusion

Proximity clearly benefits collaborative work, but the mechanisms by which it does so remain unclear. We have presented a framework that considers two aspects of physical proximity that might benefit collaboration -- its affordances for shared auditory, visual, and physical experiences, and its effects on the dynamics of interpersonal encounters. We have tried to outline how these two aspects of proximity, alone and in combination, might influence informal awareness and communication processes among colleagues. It is clear, however, that additional conceptual development and systematic experimental research are required if we are to truly understand how media might be developed and implemented to create virtual proximity among distributed workers.

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