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# Distance Matters

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## ABSTRACT

Giant strides in information technology at the turn of the century may have unleashed unreachable goals. With the invention of groupware, people expect to communicate easily with each other and accomplish difficult work even though they are remotely located or rarely overlap in time. Major corporations launch global teams, expecting that technology will make "virtual collocation" possible. Federal research money encourages global science through the establishment of "collaboratories." We review over 10 years of field and laboratory investigations of collocated and noncollocated synchronous group collaborations. In particular, we compare collocated work with remote work as it is possible today and comment on the promise of remote work tomorrow. We focus on the sociotechnical conditions required for effective distance work and bring together the results with four key concepts: common ground, coupling of work, collaboration readiness, and collaboration technology readiness. Groups with high common ground and loosely coupled work, with readiness both for collaboration and collaboration technology, have a chance at succeeding with remote work. Deviations from each of these create strain on the relationships among teammates and require changes in the work or processes of collaboration to succeed. Often they do not succeed because distance still matters.

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## 1. INTRODUCTION

In 1898, Arthur Mee stated,

> If, as it is said to be not unlikely in the near future, the principle of sight is applied to the telephone as well as that of sound, earth will be in truth a paradise, and distance will lose its enchantment by being abolished altogether. (p. 345)

Half a century later, video conferencing became a reality. Mee's predictions are still heard. In 1997, Frances Cairncross, a senior editor at *The Economist,* published a book entitled *The Death of Distance.* The dust jacket blurb stated, "Geography, borders, time zones–all are rapidly becoming irrelevant to the way we conduct our business and personal lives … ." The book trumpeted the marvels of modern communication technologies. As the dust jacket intoned, her book claimed to be "a trendspotter's guide to thriving in the new millenium."

We believe differently. To paraphrase Mark Twain, the reports of distance's death are greatly exaggerated. Even with all our emerging information and communications technologies, distance and its associated attributes of culture, time zones, geography, and language affect how humans interact with each other. There are characteristics of face-to-face human interactions, particularly the space–time contexts in which such interactions take place, that

the emerging technologies are either pragmatically or logically incapable of replicating. Cairncross (1997) was wrong. Distance is not only alive and well, it is in several essential respects immortal.

There are several broad reasons why distance will persist as an important element of human experience. Differences in local physical context, time zones, culture, and language all persist despite the use of distance technologies. Some distance work is possible today, but some aspects of it will remain difficult if not impossible to support even in the future. In this article we explore these issues by examining first how work is conducted when people are maximally collocated, working in project rooms or "warrooms." Second, we examine how work is conducted today when people on the same project or team are not collocated, working on remote teams trying to achieve "virtual collocation." Our findings in these settings fall into two categories: behavior that will change for the better when the technology achieves certain qualities we think are possible in the next 20 years, and behavior that will never change. It is this second category we expand in the third part of the article, exploring why distance will continue to matter even with significant technological advances.

There are many different arrangements in space and time over which people work. In this article, we focus mainly on same-time or synchronous interactions that take place either in the same place or from different places. Asynchronous interactions are also very important to human collaborative activities. Indeed, for the kind of ongoing project work that has been the focus of our field work, it is proper to think of episodes of synchronous interactions embedded in a larger context of asynchronous interactions and parallel activities carried out by the participants. Some important recent work has looked at tools that are used to interleave synchronous and asynchronous work (e.g., Bradner, Kellogg, & Erickson, 1999; Churchill & Bly, 1999a, 1999b; see also Watts & Monk, 1998). We look at some of these issues later. However, our principal focus is on the same-time case because it is especially challenging with respect to the role of distance technologies. Also, the issues of context, time zones, culture, and language play out here most acutely. Our focus is on how people interact with each other as they work on a common goal, either in a formal setting like a scheduled meeting or in informal, impromptu interactions.

However, we want to look at these kinds of synchronous interactions not in isolation, but as they are embedded in a long-term work project. Imagine a small group of five or so people working on a software project that takes several months.[1] Much of the work occurs in individuals' workplaces as they take some portion of the task and attempt to make progress on it. However, they

1. We choose this example because we have studied just such groups extensively (see specific references later).

consult with each other frequently. They may have periodic scheduled meetings. It is not uncommon for a team on a tight schedule to meet every day for 1 or 2 hr. Various subgroups may get together on an impromptu basis. A subgroup may actually work intensely together for extended periods of time, for example, simultaneously debugging a piece of code or arguing about aspects of the system architecture. For other projects, the level of contact may be much lower–formal meetings once a week or less often, few informal meetings, no huddling together of subgroups. Different ways of organizing work and different work objects require various styles and frequency of interaction, a concept highlighted later in this article.

We discuss three kinds of work settings in this article:

1. Collocated interactions.
2. Distant interactions with contemporary technologies.
3. Distant interactions with the kind of improved technology we expect in the next 50 years.

Our assumption is not that it would be ideal if Setting 2 or 3 could replace Setting 1–indeed, our essential point is that they never will. Working together at a distance is another resource for collaboration that gives teams greater flexibility. We want to understand what kinds of options Setting 2 or 3 provide for a work group for whom Setting 1 is an expensive or even unattainable option. What kinds of technologies are needed for effective work in Settings 2 and 3, and more important, because we think distance will never be eradicated, what kinds of work are best suited to this situation?

We present these situations in more detail:

1. Collocated work: This is the case in which the team members are at the same physical location, either temporarily because they have traveled to a common location or permanently because they are at a common site. By "same location" we mean that coworkers can get to each others' workspaces with a short walk.[2] In addition, we assume that the coworkers have access to common spaces for group interactions (meeting rooms, lounges) and have mutual access to significant shared artifacts (displays, files, models–whatever they are using in their work).

2. Distance work today: Today's distance work is interesting because available technology is changing rapidly, and groups vary enormously in what they

2. We use the 30 meters described by Allen (1997) and Kraut, Egido, and Galegher (1990) to specify what we mean by *short*.

have access to. However, to support synchronous work we can assume that today the options include:

a. Telephony in its current incarnation.
b. Meeting room video conferencing.
c. Desktop video and audio conferencing.
d. Chat rooms for text interactions.
e. File transfer.
f. Application sharing.
g. Some very primitive virtual reality options.[3]

There are commercial options emerging for most of these, although lab options have been available for at least 10 to 15 years. All of these vary widely in quality and cost, and even the most expensive have serious limitations.

3. Distance work in the future: Good design and more horsepower in the infrastructure will solve a number of the limitations of current distance technologies.[4] Greater bandwidth will solve the disruptive influence of today's delays in audio and video transmission.[5] Greater bandwidth will allow for larger, smoother, more life-size displays of remote workers, making their interaction more similar to the flow of proximal interaction. Some of the current efforts to create virtual reality meeting rooms that give a sense of a place in space for the participants will provide some level of eye contact and common referent. These advances in technology suggest that with careful human factors in design, there may be technical ways to come closer to some aspects of the face-to-face work. Perhaps even more interesting is the possibility that future tools may provide capabilities that are in some ways superior to face-to-face options (e.g., Hollan & Stornetta, 1992).

Rather than trying to imagine various futures, in our discussion that follows we try to contrast those aspects of distance work that may have technical solutions with those that may not. Ideally, a better understanding of what can be achieved at a distance and what aspects of distance will remain will help us better choose the appropriate technologies and craft an organizational design that creates effective remote work.

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3. For example, Caterpillar used Virtual Reality Cave technology from National Center for Supercomputing Applications to do real-time design sessions between Europe and North America (Lehner & DeFanti, 1997).

4. As Elliot Soloway (personal communication, January 13, 1999) said, "More *zorch* will solve a lot of our problems, but not all."

5. It is well known that any delay greater than 500 msec will severely disrupt conversational flow (Krauss & Bricker, 1967; Riez & Klemmer, 1963).

In explaining the contrast in results we have found, we call on four key concepts:

- Common ground.
- Coupling (dependencies) of group work.
- Collaboration readiness–the motivation for coworkers to collaborate.
- Collaboration technology readiness–the current level of groupware assimilated by the team.

These concepts are defined, examples given, and used in our discussion of the future.

## 2. THE EMPIRICAL CORPUS

We and a number of colleagues have spent much of the past decade trying to understand how groups tackle intellectual tasks when working at the same time, both in collocated and distant situations. There are a wide range of laboratory (G. M. Olson & Olson, 1995; J. S. Olson, Olson, & Meader, 1995, 1997; J. S. Olson, Olson, Storrøsten, & Carter, 1992, 1993; Veinott, Olson, Olson, & Fu, 1999) and field (Covi, Olson, & Rocco, 1998; Finholt & Olson, 1997; J. S. Olson, Covi, Rocco, Miller, & Allie, 1998; J. S. Olson & Teasley, 1996) studies of such work. We have also begun to integrate the literature in the area and extract key concepts (G. M. Olson & Olson, 1997a, 1997b; J. S. Olson & Olson, 1999).

To be more specific, in our laboratory work we have studied synchronous collaboration for both face-to-face (Hymes & Olson, 1992; J. S. Olson et al., 1993) and distributed work (G. M. Olson & Olson, 1997a; J. S. Olson et al., 1995). This work grew out of earlier field studies of software design teams (Herbsleb et al., 1995; G. M. Olson et al., 1995; J. S. Olson et al., 1992) and has been followed up with field studies of teams doing several kinds work (Covi et al., 1998; J. S. Olson et al., 1998; J. S. Olson & Teasley, 1996). Several of these field studies involved global teams with participants from several cultures. These global teams engaged in different kinds of work, in companies with different corporate cultures. We have conducted more focused studies of groups in different national cultures as well (Herbsleb & Kuwana, 1993). We have also been involved in several collaboratory projects in which widely distributed groups of scientists have worked together using the Internet (Finholt & Olson, 1997; G. M. Olson et al., 1998). Therefore, we have an extensive personal experience base from our own research.

We are not the only researchers who have studied these issues, of course. There is a large body of work that spans many of the issues we raise here, but

we do not have the space in this article to review these studies thoroughly. We draw on a number of other studies to help illustrate the points we make. Our goal is not to synthesize the existing literature but to suggest researchable hypotheses that deserve exploration. These are hypotheses that have been suggested to us by our immersion in this problem for more than a decade. Validation of these hypotheses, both through an exhaustive survey of existing research as well as new studies, must await further work.

## 3. COLLOCATED WORK TODAY

We have recently observed the work of people who are maximally collocated (Covi et al., 1998; J. S. Olson et al., 1998). We observed the work of people in nine corporate sites who share office space, typically a large room the size of a conference room, to conduct work like software design, appliance design, organizational redesign, or high-level sales response team.[6] These rooms were often called "project rooms" or "warrooms." In seven of these nine sites, people working in them had no other office and typically were assigned to only the task at hand for the duration of the project. We conducted interviews with both the resident team members and their managers. In two sites, seven groups were tracked over time, with surveys given to all at the end. In three of these groups, we conducted interviews at both the beginning and end of a 6-week period. In addition, we had participants fill out daily diaries indicating the general class of work they were engaged in that day and the location of that work (in the warroom, in a nearby cubicle for concentrated work, in a nearby conference room).

One site collected productivity measures on the six teams that we observed, as they do with all their software engineering teams. The measures allowed a comparison of these groups with the company norm, which showed the company already well above (better than) the national average.[7] The results were remarkable: They produced *double* the function points per unit of staff time[8] compared to the corporate average. None of the groups was even near the previous corporate average. They cut the total time to market (per function point) by two thirds, with none of the groups, again, even near the corporate average.

Remarkable as these are, we must interpret these results with caution. There were many things going on at once. The teams were not only collocated,

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6. A team that was devoted to getting VP approval for closing special deals with large customers.

7. The company allowed us to analyze these numbers, but for reasons of confidentiality, we were not allowed to report actual numbers, only ratios.

8. The software profession metrics count function points instead of lines of code as a way of standardizing different levels of complexity.

they were at a stage in their work where it was deemed appropriate for this intense effort. They were trained in a standard software development method, new to them but not particularly adapted to the fact that they were collocated. Their time was not shared with any other projects. However, the results are striking enough to lend some credence to the claim that being collocated at least assisted in the productivity gain.

What did these teams have that distant teams typically do not? Figure 1 shows one of these six teams at the site where we saw this productivity gain; Figure 2 shows a team from another of the organizations we studied. The team in Figure 1 often worked in subgroups, sometimes with one or two working alone and others having a spontaneous meeting. This fluidity of participation was rated as very important to the timely completion of their work. They could move from one subgroup to another, or to a meeting of the whole, by merely overhearing others' conversations, seeing what someone was working on, and being aware of how long they had worked on it with or without progress.

Figure 2 shows a team from the other site embedded in the artifacts of their work. This team generated 42 flip charts during the course of the 6 weeks we observed them. These flip charts depicted the use cases for their software annotated to show the objects and methods, the object hierarchy, the system architecture, and a to-do list with items ticked off when completed.

Particularly important is the *spatiality* of human interaction. People and objects are located in space, and their role in an ongoing discussion can be indexed by location. If a team member wants to observe his manager's reaction to a point someone made, he can just glance quickly in her direction. A team member can refer to someone's list of ideas on a taped-up flip chart sheet by making a gesture or glance in its direction that everyone can immediately interpret.

These advantages were also noted in the work of Whittaker and Schwarz (1995), who observed developers working with a project planning wall with various paper notations and cards affixed to it. Not only did individuals use it to extract critical information about their work, often meetings were held in front of it to look at interactions and plan in the light of new events.

Similarly, in another of our recent studies, an automotive design group displayed all the parts of a competitor's car on the hall walls to serve as reference points for engineers' current designs. Often there were knots of engineers meeting at the wall to describe and discuss new engineering solutions, either to mimic the competition or to seek to improve on it. The common referent and the layout near the parts it interacted with served to support their discussion.

In videotapes of software design meetings we saw someone describe a complex idea by drawing with his hands in the air (the *air board*; G. M. Olson & Olson, 1991). Later, someone referred to "that idea" by pointing to the spot in the air where the first person had "drawn" his idea. In the warrooms, the location of the flip charts on the walls occasionally signifies such things as the chro-

***Figure 1.*** **The left frame shows a group divided into two subgroups: one working at the whiteboard, the other at a console. The right frame shows the two groups merged to solve a particularly difficult problem together.**

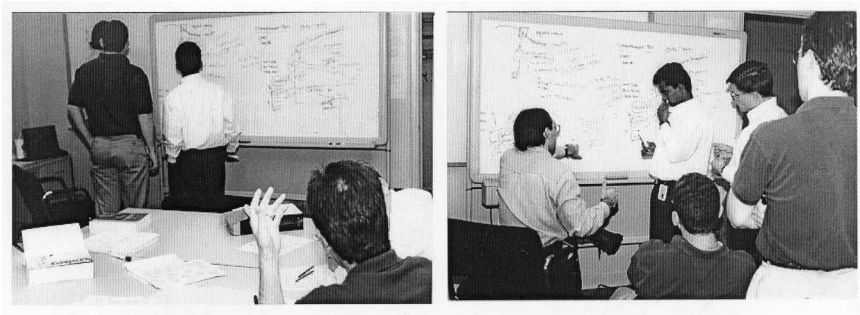
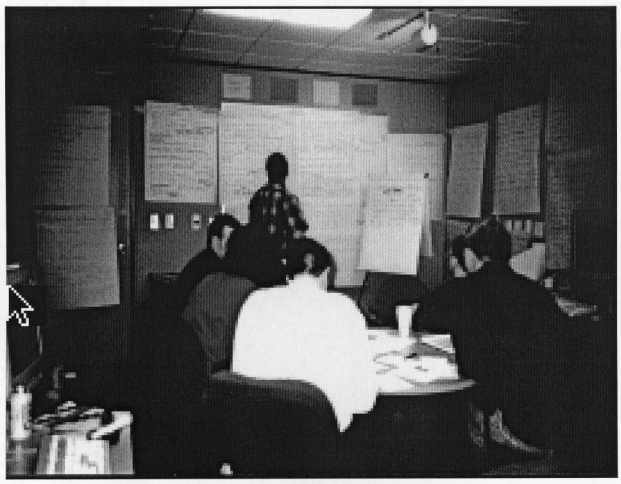


***Figure 2.*** **A team working using an object-oriented development method, creating, editing, and referring to the material on the flip charts throughout the 6 weeks.**



nology of ideas or associatively meaningful clusters. The group wheeled their chairs to a particular place and focused their discussion on the ideas that were spatially clustered at that location.

What is striking about all of this is how effortlessly human perceptual and cognitive capabilities get used to support the easy flow of interactions in such situations. Running effective meetings may take deliberate structuring and facilitation. Confusions and misunderstandings happen all of the time. Lack of

common ground or shared goals can lead to conflict and disruption. However, participants working face to face seldom feel disoriented or without context.

By mere long-term presence, these groups have a lot in common. They are long-term teams who have established their working habits within a corporate culture and reside in the same community. In addition, they had extensive experience working as teams. They were mandated to work collaboratively, and the room and the flip charts and in one case a printing whiteboard were their collaboration technologies. Their adoption of these technologies was smooth; the technologies were small steps from technologies they were familiar with. It is interesting to note that the printing whiteboard was the only new technology offered to them, and they loved it. It provided only one more capability (printing) than their previous technology, but it was a highly valued capability, saving them hours of rewriting the contents of the whiteboard on paper that could be preserved.

The work we observed in these rooms was varied. Sometimes they were all discussing the same issue and coming to an agreement about how they were going to design a portion of the software. At other times, they divided up the work and put effort separately into coding various modules. When they needed to work intensely solo, they moved to nearby unowned cubicles, reducing the amount of disturbance the collocation engendered. However, they were not far away, and when the work had to move back to design, coworkers could find them and bring them back to the fold. All the surveyed teams reported initial fear that working in the rooms would cause too much interruption of their individual work. Their attitudes changed significantly for the better. They found ways to cope with the disadvantages of collocation and highly valued the advantages.

We list in Figure 3 some of the key characteristics of face-to-face interaction. All of these are examples of how the ordinary ebb and flow of situated cognitive and social activities are exploited for ease of interaction and information extraction in collocated settings. This can be used as a list against which one can compare the sets of current technologies to see how difficult it is to do today's work remotely. There are characteristics of being collocated that are unsupported today, making them ripe for design and development.

## 4. REMOTE WORK TODAY

In discussing remote work today, we draw on our lab and field work. We report our observational studies of five corporate sites and two scientific collaboratories, some aspects of which were reported previously (Finholt, personal communication, March 10, 1999; Finholt & Olson, 1997; Herbsleb, personal communication, February 4, 1999; G. M. Olson et al., 1998; J. S. Olson & Teasley, 1996). The five corporate sites included one in a large computer

*Figure 3.* **Key characteristics of collocated synchronous interactions.**

| Characteristic | Description | Implications |
|---|---|---|
| Rapid feedback | As interactions flow, feedback is as rapid as it can be | Quick corrections possible when there are noticed misunderstandings or disagreements |
| Multiple channels | Information among participants flows in many channels–voice, facial expressions, gesture, body posture, and so on | There are many ways to convey a subtle or complex message; also provides redundancy |
| Personal information | The identity of contributors to conversation is usually known | The characteristics of the source can be taken into account |
| Nuanced information | The kind of information that flows is often analog or continuous, with many subtle dimensions (e.g., gestures) | Very small differences in meaning can be conveyed; information can easily be modulated |
| Shared local context | Participants have a similar situation (time of day, local events) | A shared frame on the activities; allows for easy socializing as well as mutual understanding about what is on each others' minds |
| Informal "hall" time before and after | Impromptu interactions take place among subsets of participants on arrival and departure | Opportunistic information exchanges take place, and important social bonding occurs |
| Coreference | Ease of establishing joint reference to objects | Gaze and gesture can easily identify the referent of deictic terms |
| Individual control | Each participant can freely choose what to attend to and change the focus of attention easily | Rich, flexible monitoring of how all of the participants are reacting to whatever is going on |
| Implicit cues | A variety of cues as to what is going on are available in the periphery | Natural operations of human attention provide access to important contextual information |
| Spatiality of reference | People and work objects are located in space | Both people and ideas can be referred to spatially; "air boards" |

company where people from all over the world were reporting their financial figures for aggregation in a monthly report to the senior officers. Three sites were in a large automobile company: one involving the codevelopment of an auto part and software to support future design of this part, and two in transmission design. All the groups in the automobile company involved team members in the United States, Europe, Mexico, or all three. The fifth corporate site involves software enhancement in a large telecommunications company with participants in the United States, England, and Germany. Two scientific collaboratories involve space physicists focusing on the upper atmosphere from around the world, and AIDS researchers, both bench scientists and those running clinical trials—all in the United States.

In addition, we report related findings from comparative laboratory studies we have conducted and reported elsewhere. These studies collected quality, process, and satisfaction measures from over 70 groups of three people each who know each other and have worked together before. These groups of three work on a standard design problem (designing an automatic post office) for 1½ hr. A number of groups work in a standard face-to-face mode using a whiteboard, paper, and pencil; others use a shared editor while working face to face; and others are using the editor while working remotely, connected by either full duplex audio or audio plus high-quality video connections (Hymes & Olson, 1992; G. M. Olson & Olson, 1997b; J. S. Olson et al., 1995; J. S. Olson et al., 1993). We add to this corpus related findings from several other studies.

### 4.1. Successes

There are both successes and failures; we begin on a positive note. The collaboratory of space physicists is an example of success. Their collaboratory focuses on the simultaneous access to real-time data from instruments around the world, allowing senior and junior scientists to talk about phenomena while they are happening. Access to these conversations among scientists has risen dramatically. Many more scientists are able to participate in specific research campaigns. This access is particularly beneficial to students, junior scientists, scientists at nonelite institutions, and scientists in developing countries. Both empirically focused scientists and theoreticians are able to experience phenomena in real time. This access has allowed modelers to predict and alter their models in real time, with models informing empiricists about what phenomena to expect. The online campaigns can be saved and replayed later. This access to stored material has facilitated electronic data analysis workshops in which a wide range of data surrounding upper atmospheric events of particular interest can be discussed over the Internet. These are supplementing or even replacing face-to-face workshops for this purpose.

The design of the collaboratory for the space physicists was highly user centered. Intense analysis of the work they did with the old technology drove the functionality of the new system (McDaniel, Olson, & Olson, 1994). Designs were deployed quickly for testing and iterative design. There have been approximately 10 major redesigns over a 7-year period. The technology has migrated from the early digital embodiment of the original devices, through a more integrated view capturing the relations between the data streams, to today's side-by-side view of the empirical data superimposed on the map and the theoretician's model in the same orientation and scale. The original capabilities included a half dozen data streams, and there were few options for the displays. Today there are scores of data streams with hundreds of display options. The users organize their work into "rooms" with coordinated sets of data and "clubs" of participants. When the scientists began, they were only partially fluent in e-mail. They have been taken through a number of steps to get them to tools they are using today—three-dimensional renderings of data and virtual rooms of objects and remote partners.

In some sense, the use of NetMeeting at Boeing is a similar success (Mark, Grudin, & Poltrock, 1999). Team members rate the meetings in which NetMeeting is used to be high in quality, with good use of time and wide participation. The meetings were most successful when they had a formal structure to them or were facilitated. The facilitators were people who knew both how to debug the technology and ways to overcome the pitfalls of disengagement in remote participants. Furthermore, people who had previously driven for 1 hr to attend a meeting in their area began attending from their offices; when given a choice, they chose to forego the time and stress of travel in favor of the somewhat altered but successful participation remotely.

A third success is the ongoing work at the telecommunications company doing software maintenance and enhancement (Herbsleb & Finholt, personal communication, February 4, 1999). This work involves over 1,000 software engineers in four main sites, working on millions of lines of code. It is supported by a mix of e-mail, video and audio conferencing, transferred files, and fax. Two things seem to contribute to its success. Although the evolving software is somewhat messy, its structure has remained more or less intact for more than a decade. Everyone knows the boundaries, who owns what, who is allowed to change what, and what sorts of things cause problems. There is a detailed process shared across all sites, allowing the teammates to communicate in a common language about the state of the work, what has been done, and what condition it is in when it is handed off. Most team members have been on the project for many years; it takes a novice about 2 years to learn what the long-term members know about the structure and process.

### 4.2. Failures

Many of the attempts to use distance technology either have failed outright or have resulted in Herculean efforts to adjust behavior to the characteristics of the communication media. Our laboratory data show that even for people who know each other and have worked together before, a simple audio connection for conversation and a shared editor for real-time work is insufficient to produce the same quality of work as that done face to face. Those with video connections produced output that was indistinguishable from that produced by people who were face to face. The process of their work changed, however, to require more clarification and more management overhead (discussions about how they will conduct the work, not actually doing the work; J. S. Olson et al., 1995; J. S. Olson et al., 1993; see also Isaacs & Tang, 1994; Tang & Isaacs, 1993). Remote work is hard to conduct, even with the best of today's technologies.

Primary evidence of these efforts in the field has been the repeated observation that, over time, remote work is reorganized to fit the location and technology constraints. We have seen this on three major studies of virtual collocation. In those situations when people attempted to work closely with remote team members on difficult problems (e.g., reconciling reported financial figures, doing software design [not coding], diagnosing mechanical failures to decide whether they are faults of manufacturing or original design), over time, the remote technologies were used less and less. Work was reorganized so that people did not have to rely on tight collaboration with a remote team member. For example, the software design effort was reorganized to partition the design work into loosely coupled modules, assigning all the work of each module to one location, the others to the remote location. In the financial reporting work, the reporting structure was reorganized to be reconciled by region (which happened to be in one location or at least in locations in the same time zone), rather than cutting regional boundaries and reporting up through product lines (which were not collocated). Tight interactions are hard to support; many of the features that collocation affords are totally absent in remote technologies (see Figure 3).

Universally, in all our fieldwork, people complained about the quality of communication over audio and video conferences. Participants in audio conferences had trouble figuring out who is talking or what is being referred to. Video conferencing tools are extremely clumsy and limited. We have seen the first 30 min of a 1 hr meeting devoted to getting all the parties on line. People speaking were not on camera because no one knew how to work the remote camera. People were not only not heard clearly (with no one adjusting the volume or moving toward the microphones), but those who should have heard opt to call the key person later to clarify, rather than interrupt the flow of the

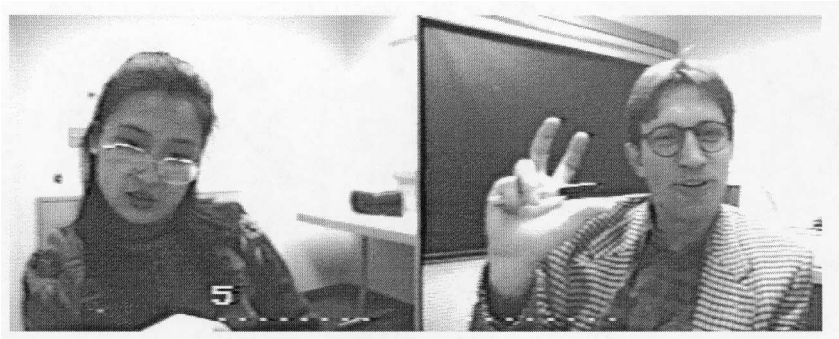
meeting to get them to repeat themselves. Similar results were reported by Tang and Isaacs (1993).

New behaviors emerge to compensate these shortcomings: always identifying oneself before speaking, more formal protocols for turn taking, specialized vocabularies, and discourse rules (e.g., as in air traffic control). Effective communication can take place, but the effort is usually quite large (Heath & Luff, 1991, and Isaacs & Tang, 1994, provided good examples of this). In the Boeing meetings, they evolved to carve out the new role of "virtual meeting facilitator," who also happened to be a process facilitator, making sure that remote sites were polled occasionally, listening for places things might need clarification, and so on. Although people recognize the greater flexibility and access that such new media provide, they still prefer face-to-face interactions for most purposes (Mark et al., 1999).

It is not yet widely recognized where the value of video lies for remote conversation. It is not surprising that if team members are referring to a complex artifact, video of that artifact helps (Farmer & Hyatt, 1994; Nardi, Kuchinsky, Whittaker, Leichner, & Schwarz, 1997). Up until recently, empirical literature showed that although there is a consistent effect on satisfaction (for a review, see Finn, Sellen, & Wilbur, 1997), there is no effect of video on the quality of the work unless it involves negotiation (Short, Williams, & Christie, 1976). Video has been shown to add nothing to the outcome performance of people engaged in a variety of tasks: design, service provision, and instruction, among others (J. S. Olson, Olson, & Meader, 1997); however, video often changes the process (e.g., Daly-Jones, Monk, & Watts, 1998; Isaacs & Tang, 1994; J. S. Olson et al., 1995, 1997; Tang & Isaacs, 1993).

These studies, however, used various teams of people who had a lot in common and who were doing fairly unambiguous tasks. More recently, a study showed that pairs of people from different countries, speaking English as their second language, and performing a task with a moderate amount of ambiguity (reconciling two maps that are slightly different) performed significantly better when they had video compared to audio only (Veinott et al., 1999). Figure 4 shows what the video medium afforded the team members: The person instructing could add gestures to explain the ideas better. Furthermore, the recipient could understand the spoken word better by seeing the speaker (Krauss & Bricker, 1967), and the instructor could see if the recipient had achieved understanding yet. Moreover, the puzzled recipient could assess whether the instructor registered his or her confusion through the gestural as well as the spoken channel. Williams (1997) also reported that native and nonnative speakers behaved differently with respect to audio and video channels. Boyle, Anderson, and Newlands (1994) showed that video can help to disambiguate difficult to understand audio. Therefore, there are clearly situations where even present-day video can play an important role in distance work.

***Figure 4.*** **Two people with little common ground, using a video channel well to achieve understanding on an ambiguous task.**



Our fieldwork has produced numerous examples where participants were unaware of the difficulty they were having with the communication channel. They adapted their behavior rather than fix the technology. On many occasions, the participants shouted because the volume at which they hear the remote people was set too low. Figure 5 shows a remote participant adapting to hear inadequate volume on a speakerphone. He sat this way for 1 hr every week rather than reflect on his difficulty and request an upgrade to a better quality telephone.

Similarly, when using a commercial video conference provider such as Picturetel, people will move the camera back so everyone can be seen. However, because the camera is attached to the monitor, the remote participants appear very small. We know from other work from the laboratory that the size of the image of the remote participants strongly affects the interaction (Grayson & Coventry, 1998). The smaller the image (the more zoomed out), the more stilted the conversation. The closer the image (the more zoomed in), the more natural and interactive the conversation. Apparent distance, called *proxemics* (Hall, 1966), affects behavior. Normally, in a face-to-face situation we would merely move closer to each other, increasing both the volume and the image. The virtual world has decoupled these physical features. Instead, we need to move the microphone, increase the volume of the remote speakers, move the camera or zoom it in or out, and move the monitor closer.

A more glaring example involves the use of a highly impoverished medium, unsuitable for the task at hand. Figure 6 shows several manufacturing engineers in Europe explaining a manufacturing issue to the design engineers in the United States. At this weekly coordination meeting, they connect by audio, not video. It is not clear whether today's video quality could have picked up the details of the defect. But, surely audio description is far worse than having the remote engineers see the problem and be able to converse with ges-

***Figure 5.*** **A participant adjusting to the poor technology rather than requesting better technology.**

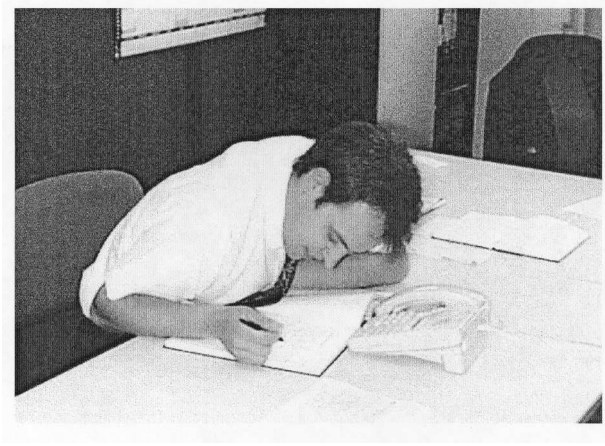
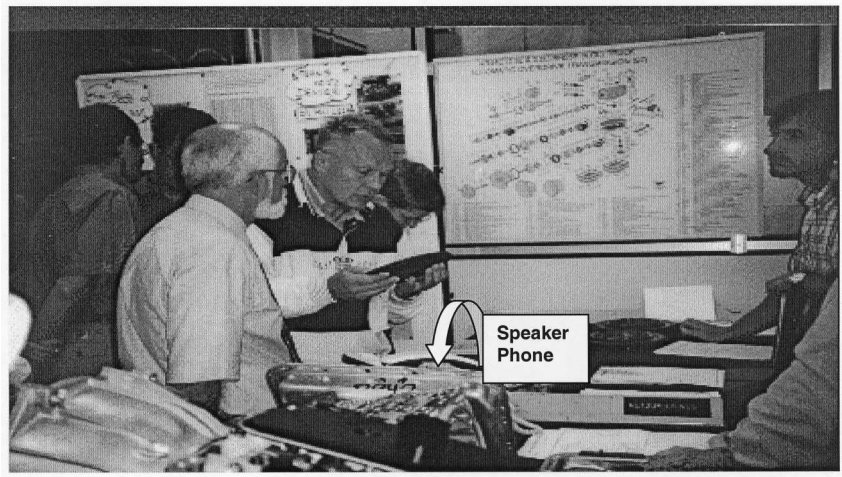


***Figure 6.*** **A remote meeting involving debugging a design issue after discovering defects in manufacturing. The medium supporting this conversation is an audio conference, not video.**




tures. However, media choices are often constrained by social and organizational factors. Many work situations do not easily allow for the selection of appropriate media, although in our experience it is surprising how often this arises because of a tacit acceptance of the current situation, without careful examination of what could be done with different communication tools.

Motivation has been established as one of the major sources of failure in adoption of groupware in general. In Orlikowski's (1992) classic study of the failure to adopt Lotus Notes® in a consultancy, the failure was attributed to the fact that individuals were compensated according to their competitive talents. There was no incentive to share one's best ideas if they were then going to be seen as common, no longer unique. In other organizations where incentives are aligned with how much others use the knowledge you make available to them, Lotus Notes and other jointly-authored groupware systems succeed.

Similarly, in some of our earliest work in attempting to develop a collaboratory for AIDS researchers or brain researchers, there was a definite divide among those who are willing to adopt groupware and those who are not. We spent several years working with various bench scientists, encouraging them to share their ideas and data with others to increase the speed of discovery. Many of the principal researchers remain uninterested, however, because they feared loss of control over the use of their data, perhaps missing a key discovery for which another scientist will get credit. In contrast, some researchers whose work depended on the talents of others (e.g., where one lab is the only place to get a particular analysis done) were eager to collaborate. They have become early adopters of distance technology. Clinicians whose science depends on large sample sizes of patients undergoing experimental treatments have strong incentives to collaborate. They are most interested in both designing experiments collaboratively and sharing the data afterward (Finholt & Teasley, personal communication, March 30, 1999).

A third example highlights how motivation plays out in synchronous remote work as well. At the large automobile company, some of the remote participants used video conferencing, not because they personally believed it would help them communicate but because they wished to be seen using it by the higher level managers who invested in it. The rooms were booked solid, and meetings were cut short due to pressure from the group who had scheduled the room immediately after. In these cases, it was not the performance or satisfaction that made people choose video conferencing; it was the motivation.

One important caveat on our story so far is that interesting behaviors can emerge when tools are used for a very long time, at least when there is clear motivation for doing so. Dourish, Adler, Bellotti, and Henderson (1996) reported the experience of two dyads that used open audio–video connections between their offices for 2 to 3 years. To be sure, these dyads were members of advanced research labs who had intrinsic motivations to use the technology. However, they reported that what at first glance might seem to be serious limitations of the technology (e.g., poor support for eye contact across the video link) are adapted to over time and fade into the background as concerns. If the tools have useful functionality, new practices will emerge to adjust to the characteristics of the tool. The lesson for us is that we should not assume that the

characteristics of present-day tools prevent useful adaptation or incorporation into daily practice. Dourish et al. provided numerous examples of successful adjustments.

## 5. THE FINDINGS INTEGRATED: FOUR CONCEPTS

The results described previously can be synthesized into four key concepts: common ground, coupling of work, collaboration readiness, and collaboration technology readiness. These begin to bring results together so that we can predict some future successes and failures. In each of the following sections, we first define the concept, point to examples in the results mentioned earlier, and then end with a prescription for success.

### 5.1. Common Ground: A Characteristic of the Players

Effective communication between people requires that the communicative exchange take place with respect to some level of common ground (Clark, 1996). *Common ground* refers to that knowledge that the participants have in common, and they are aware that they have it in common. People describe the same event or idea quite differently talking to a spouse, a coworker, a distant relative, a neighbor, a stranger from across the country, and a stranger from overseas. We would make very different assumptions about what they know and therefore how we frame what we say. For example, if asked by a fellow American in London where the London Bridge is, one explains how to get to the more famous Tower Bridge, the real London Bridge having been bought and moved to Arizona. To a German tourist in a café in Arizona asking the same question, one gives explicit directions on how to get to Lake Havasu. In situations where we are interacting with a mixed group, we might even apologize to those with whom we share common ground as we give a fuller account for those with whom we have less common ground.

However, the concept of common ground is subtler than this simple analysis would indicate. We establish common ground not just from some general knowledge about the person's background but also through specific knowledge gleaned from the person's appearance and behavior during the conversational interaction itself. If we say something based on an assumption about what someone knows, but their facial expression or verbal reply indicates that they did not understand us, we will revise our assumptions about what common ground we share and say something to repair the misunderstanding. As Clark and Brennan (1991) showed, this is often a collaborative process in which the participants mutually establish what they know so conversation can proceed.

***Figure 7.*** **Small episodes of negotiating for common ground (based on examples from Clark & Brennan, 1991).**

Alan: Now, um, do you and your husband have a j- car?
Barbara: - have a car?
Alan: Yeah.
Barbara: No.

B: How would you describe the color of this flower?
S: You mean this one [pointing]?
B: Yes.
S: It's off-yellow.

Miss Dimple: Where can I get a hold of you?
Chico: I don't know, lady. You see, I'm very ticklish.
Miss Dimple: I mean, where do you live?
Chico: I live with my brother.

Each of the small conversations in Figure 7 involves episodes of the conversational partners working toward common ground. In the first episode, Barbara attempts to finish Alan's sentence, "have a car," while he utters this slowly. Alan confirms her understanding, "Yeah," and Barbara then answers. In the second episode, there is a momentary confusion about the flower being referred to. A gesture and the query "This one?" solicit the clarification, and the original question is answered. These are all examples of negotiated common ground. They often require rapid back and forth of questions and answers before the original utterance can be answered. In the third episode, taken from a skit by the Marx brothers, there is a misunderstanding of the phrase "Get a hold of … " that produces a humorous reply. This same type of confusion is the core of the famous "Who's on first?" routine by Abbott and Costello.

Participants in a conversation usually establish common ground on the fly. They progressively discover similarities or contrasts between themselves and adapt what they say to these discoveries. Common ground is not necessarily based on preexisting categories; one does not often discover that "you are one of those" and then swap in a whole set of conversational conventions. It is a subtler dance that adapts the steps to each new discovery. This joint construction of common ground can be an especially taxing form of interaction, especially when people appear to be similar but have important, hidden dissimilarities.

More important, we construct common ground from whatever cues we have at the moment. The fewer cues we have, the harder the work in constructing it, and the more likely misinterpretations will occur. These misinterpretations in turn require more work to repair, or if the effort required is too high,

people will abort the effort and move on knowing they do not have perfect correspondence.

Early attempts to characterize some of the ways distance technologies differ from face to face focused on broad properties like *richness* (Daft & Lengel, 1984; Short et al., 1976). Though these descriptions were backed up by more detailed explications of what was meant by these constructs (e.g., rapid feedback, multiple channels, attributes of source, degree of nuancing), in the end the studies that were done focused on the broad construct, not the details. Clark and Brennan (1991) described a number of specific differences among various media, as shown in Figure 8. These descriptions focus on how these media allowed for the expression and joint negotiation of common ground.

Clark and Brennan (1991) outlined the kinds of cues that various media provide, inferring that various media require different kinds and levels of effort for people to obtain common ground. The dimensions by which they describe various media include

- Copresence–same physical environment.
- Visibility–visible to each other.
- Audibility–speech.
- Contemporality–message received immediately.
- Simultaneity–both speakers can send and receive.
- Sequentiality–turns cannot get out of sequence.
- Reviewability–able to review other's messages.
- Revisability–can revise messages before they are sent.

Each of the columns in this figure represent a factor that can contribute to the establishment and maintenance of common ground. Copresence typically implies access to the same artifacts to support the conversation, allowing diectic[9] reference and shared context. Cotemporality leads to understanding of the circadian context. Visibility and audibility provide rich clues to the situation and the state of the person one is conversing with. Simultaneity and sequentiality relieve the person of having to remember the context of the previous utterance when receiving the current one. Reviewability and revisability assist people in both formulating carefully what they mean and having several chances to decode the message received.

Extensions of this figure to new technologies are expected to lead to better understanding of the abilities of the technology to support remote workers' development and maintenance of common ground. Some new technologies like Microsoft NetMeeting®, for example, allow remote access to shared work ob-

9. Diectic are references to objects or ideas made by pointing and gesturing and using the words *this* and *that*.

***Figure 8.*** **The characteristics that contribute to achieving common ground that are inherent in various communication media (based on information in Clark & Brennan, 1991).**

| Medium | Copresence | Visibility | Audibility | Cotemporality | Simultaneity | Sequentiality | Reviewability | Revisability |
|---|---|---|---|---|---|---|---|---|
| Face to face | • | • | • | • | • | • | | |
| Telephone | | | • | • | • | • | | |
| Video conference | | • | • | • | • | • | | |
| Two-way chat | | | | • | • | • | • | • |
| Answering machine | | | • | | | | • | |
| E-mail | | | | | | | • | • |
| Letter | | | | | | | • | • |

ject plus gesturing through the use of a telepointer and markers. Typically, participants talk using audio conferencing. Although it does not provide the complete context of the conversation, it is nonetheless helpful for establishing common ground about the object of the work discussion. Shared file servers such as Lotus Notes allow similar access to shared work objects but without the ability to talk about various new or controversial aspects of it easily. That is, the conversational and object sharing features in copresence are separated, preventing easy reference.

In our studies, we have seen numerous examples of the effect of establishing or not establishing common ground. When teams are fully collocated, it is relatively easy to establish common ground. They share not only cultural and local context, but also more microcontext of who is doing what at the moment and what remains to be done. Both awareness and more general familiarity make communication easier.

Those who are remote complain about the difficulty of establishing common ground. When connected by audio conferencing, it is very difficult to tell who is speaking if you do not know the participants well. Offhand reference to some local event (e.g., the Littleton shooting or the Tour de France) is understood by the locals but makes the remote people feel even more remote. People with video can engage in the subtle negotiation that establishes local common ground–whether what was said was understood or not, whether the conversation can proceed or needs repair. Broad shared knowledge is also important. The people working on the telecommunications project for a long

time had common ground. They knew each other and were schooled in the development process to which they all adhered.

One important feature of collocation that is missing in remote work is awareness of the state of one's coworkers, both their presence–absence and their mental state. This awareness is again an important part of common ground. If you know that someone just returned from a difficult meeting and is stressed, your communication with him or her will be different than if they had just been in the room with you working on the project on which you are focused. There have been a number of attempts to recreate this sense of awareness remotely, including the open video link in the Portland experiment (M. H. Olson & Bly, 1991), desktop glance systems at several Xerox sites (Dourish et al., 1996; Dourish & Bly, 1992; Gaver et al., 1992), Cruiser™ and VideoWindow at Bellcore (Fish, Kraut, Root, & Rice, 1993), Montage® at Sun (Tang, Isaacs, & Rua, 1994), and CAVECAT at Toronto (Mantei, Baecker, Sellen, Buxton, & Mulligan, 1991). All of these installations had some success in getting people to communicate more easily, though a number of human factors, social, and organizational issues interfered with their ready use. In all cases they were abandoned after a demonstration period, in part because their cost could not be justified by appropriate benefit.

On the flip side, people who have established a lot of common ground can communicate well even over impoverished media. In our laboratory studies, we saw that people from different cultures and with different linguistic backgrounds suffered without video, whereas those with cultural and linguistic common ground succeeded with only audio. In the field, we have seen that if there is a fellow countryman at a remote site, they are the contact person of choice. Presumably, the prior established common ground allows them to communicate more easily even without seeing each other. We have witnessed a video conference between the United States and Mexico, all employees of the same company, in which the first part of the meeting did not reveal the presence of an American in the Mexican site. The tone of the meeting was formal and stilted. As soon as the camera panned to reveal the presence of the American in Mexico, the U.S.-based Americans lightened up, joked with him, and proceeded to conduct the meeting in a much more easy-going style.

This leads us to our first set of prescriptions, focusing on the importance of common ground. The more common ground people can establish, the easier the communication, the greater the productivity. If people have established little common ground, allow them to develop it, either by traveling and getting to know each other or by using as high-bandwidth channel as possible. People who have little common ground benefit significantly from having a video channel.

## 5.2. Coupling in Work: A Characteristic of the Work Itself

We use the concept of *coupling* to refer to the extent and kind of communication required by the work, a somewhat different use of the word than in the work of Weick (1976). The concept is also related to the concept of the decomposability of systems in organizational theory (Simon, 1996). Tightly coupled work is work that strongly depends on the talents of collections of workers and is nonroutine, even ambiguous. Components of the work are highly interdependent. The work typically requires frequent, complex communication among the group members, with short feedback loops and multiple streams of information. In contrast, loosely coupled work has fewer dependencies or is more routine. For example, the routing of a travel voucher from originator through approval and finally accounting and payment has a number of dependencies (it cannot be paid until it is approved), but the work is routine enough to not require clarification or reconciliation. In loosely coupled work, there is common ground about the task goal and procedure; it merely needs to be played out. Loosely coupled work requires either less frequent or less complicated interactions.

Coupling is associated with the nature of the task, with some interaction with the common ground of the participants. The greater the number of participants, the more likely all aspects of the task are ambiguous. Tasks that are by nature ambiguous are tightly coupled until clarification is achieved. The more common ground the participants have, the less interaction required to understand the situation and what to do.

Coauthoring an article is an example of a moderately coupled task. After a period of tightly coupled planning, typically one of the authors works on a draft and then sends it around to the other authors for comments. Alternatively, again after the planning stage, different coauthors may write separate sections to be merged later. Control over successive drafts may pass from author to author. The authors may get together occasionally and discuss the current draft, but a lot of the work takes place separately as each author drafts, reads, and revises.

On the other hand, many collaborative design tasks are tightly coupled. Designers may spend a lot of time together in front of a whiteboard or with flip charts as they sketch, discuss, revise, and reflect. They may take a break as one of the members produces an artifact (list, outline, drawing), but then they get back together as a group. When managers discuss a complex decision with multiple competing and ambiguous criteria (e.g., Mintzberg, 1973), they are engaged in an episode of tightly coupled work. Projects, consequently, are not entirely tightly or loosely coupled. Various stages of the work are tightly coupled, and often there are stages where it is loosely coupled, where people who have a shared understanding of what to do, do the work in parallel. Good pre-

sentations are loosely coupled; unclear ones, requiring disambiguation by questions and answers, are tightly coupled.

In our research, we have seen that tightly coupled work is very difficult to do remotely. Technology, at least today, does not support rapid back and forth in conversation or awareness and repair of ambiguity. Consequently, we saw numerous occasions where tightly coupled remote work was judged too difficult. The work was reorganized so that the tightly coupled work was assigned to people who were collocated. In short, the work was reorganized to fit the geography.

The various success cases were all examples of loosely coupled work, or work where the team members had a lot of common ground. The space physicists did their detailed work typically by themselves and their local cohort group. When they are online, they are not dependent on each other. They valued the interchange among people with different backgrounds, jointly assessing whether the current activity was noteworthy or not. The pace of the unfolding science was slow, and though discovery was ambiguous, some of the data gathering and analysis techniques they share were not.

The use of NetMeeting at Boeing was a particularly interesting case of coupling. All teams reported that NetMeeting worked best for formal presentations (loose coupling) or with action items about which only reports of status were allowed (loose coupling). Discussions were described as "round robins," again indicating a formal process, not free-for-all exchange. The meetings were not good for developing a group process or establishing team identity. Face-to-face meetings had a lot of side discussion, story telling, and interjections (all tightly coupled activities), but these activities were rarely noted in the remote meetings.

The large-scale development effort in the telecommunications company might at first glance seem like an exception. As mentioned earlier, design can be a paradigmatic case of tightly coupled work. However, design can become more routine when it involves established product lines, formalized design processes, and highly experienced designers who share lots of knowledge. These developers were schooled in a shared process. They all knew what had to be done and who was responsible. Therefore, although it was design work with some important interactions across distance, it was not ambiguous work, and thus it was moderately to loosely coupled.

The second prescription thus is to design the work organization so that ambiguous, tightly coupled work is collocated. Long-distance dependencies have to be straightforward and unambiguous to succeed. Furthermore, the more formal the procedure to enact the communication (e.g., making it clear who is responsible in an e-mailed request sent to many people, or that all requests are acknowledged, as in airline pilot communication), the more likely the success. Long-distance communication today has nowhere near the richness of awareness and real rapid interchange information as face to face.

## 5.3. Collaboration Readiness

Using shared technology assumes that the coworkers need to share information and are rewarded for it. Different fields and work settings engender a willingness to share. If the strategy for progress or productivity involves "knowledge management" in which people are to give information and seek it from others, a dictate from on high to collaborate will fail unless it aligns with the incentive structure.

The aforementioned results show that success in adopting various collaboration tools was achieved in some communities but not others. For instance, the space physicists had a long tradition of collaboration before they began using the Internet to support their long-distance interactions. On the other hand, our early efforts to engage several biomedical communities ran afoul of their inability to find collaborations with distant players of value. Incentive systems in these various fields made them more or less willing to share and to seek or avoid collaboration technologies.

The failure at the consultancy to adopt Lotus Notes is the classic example of this phenomenon in the realm of asynchronous tools (Orlikowski, 1992). Consultants even reported avoiding learning Lotus Notes because there was no account to which to bill their learning time. In our research, as well, people at the computer company did not learn TeamRoom® (a Lotus Notes application) because they were too busy; they claimed they would learn it if they were paid overtime or could go home for a day and figure it out. It is interesting to note that not only was there no time to learn it, there was no training in how to use it, the mechanics, or how it should be used in their work. One interviewee stated, "I kept feeling that I missed a meeting where this was all explained."

The third prescription is that one should not attempt to introduce groupware and remote technologies in organizations and communities that do not have a culture of sharing and collaboration. If it is decided that the organization needs to collaborate more, that more knowledge needs to be shared, then one has to align the incentive structure with the desired behavior.

## 5.4. Technology Readiness

Some organizations are sufficiently collaborative to be good candidates for successful adoption of the appropriate technologies for distance work. Their habits and infrastructure, however, are not. Those organizations that have not adopted e-mail, for example, will not be ready adopters of NetMeeting. The more advanced technologies, of course, require a technical infrastructure (networking to desktops and meeting rooms, as well as projection equipment in meeting rooms). However, more important, they require the habits, particularly those of preparation (e.g., meeting setup), regular access (e.g., reading Lo-

tus Notes every day), attention given to others' need for information (e.g., thinking whether one's current work could be useful to others then taking the time to make it accessible), and so on. Poor alignment of technology support, existing patterns of everyday usage, and the requirements for a new technology is a major inhibitor of successful adoption (Star & Ruhleder, 1994).

We have made a speculative attempt at ordering technologies, as shown in Figure 9. Clearly, this strict ordering is too simplistic–some kind of more complex partial ordering is required, as well as better articulation of the technologies themselves. However, we have seen repeatedly that failure often results from attempts to introduce technologies in the lower half of the list to organizations or communities that are not yet comfortable with technologies in the upper half of the list.

In our results, the space physicists are good examples of evolving collaboration technology readiness. When they began this effort, some were users of e-mail, telephone, and fax. Indeed, their major collaboration activity was attending conferences where they would discuss with colleagues findings of others they had just heard, as in hallway conversations, and sitting together in a small building in Greenland chatting about a phenomenon that was unfolding. The earliest collaboration technology we offered them allowed similar behavior, but at a distance. Data from the upper atmosphere were displayed in views like the instruments they would read at the site, and they chatted about it. Early behavioral data show that the content and style of the conversations were very similar in face-to-face situations and those now held remotely (McDaniel, Olson, & McGee, 1996).

Later incarnations of the collaboration technology for the space physicists evolved with their general technical sophistication. When the Web became popular, others started putting relevant instruments online. Those who had already participated in the project began to demand access to these sites as well, and the entire project became Web based. As experience grew, they became more and differently collaboration–technology ready. The interface they have now would not likely have been accepted at the outset.

The Boeing teams had experienced video and audio conferencing, even putting shared objects on camera so that they could be viewed (albeit poorly) at both local and remote sites. It was an easy step to adopt NetMeeting; they were appropriately collaboration–technology ready (Mark et al., 1999). However, although they were ready for such technology, frustrations with the audio and the limited usefulness of the video resulted in declining use of NetMeeting. It appears the users were ready for a technology that was unable to deliver on its promise. This, of course, can cause major problems with subsequent attempts to introduce similar tools because such failure experiences are often very memorable. Once burned, twice shy.

***Figure 9.*** **The observed order in which various collaboration technologies were adopted and used in different organizations.**

| |
|---|
| Telephone |
| Fax |
| E-mail |
| Audio conferencing |
| Voicemail |
| E-mail with attachments |
| Video conferencing |
| Repositories built by others (e.g., intranet sites of static information) |
| Shared calendaring |
| Creating repositories |
| Hand-off collaboration (e.g., using the Tracking Changes option in MS Word) |
| Simultaneous collaboration (e.g., NetMeeting, Exceed, or Timbuktu screen sharing) |

At the computer company that attempted to adopt TeamRoom, they were inexperienced with any sharing other than ftp. They did not often think of the fact that information they had would be useful to others; they answered the queries addressed to them personally on the telephone but did not proactively make the answers available to others. With the advent of the Web and the more general habit of people putting up personal Web sites, this group might now be collaboration–technology ready.

It is interesting to note that the automobile company has recently adopted the use of digital still cameras to show various defects or manufacturing problems to remote engineers. This is facilitated by their already exercising e-mail attachments for text-based material. They are ready for digital object sharing and might also be ready now to use the object-camera feature in Picturetel systems.

The fourth prescription is that advanced technologies should be introduced in small steps. It is hard to see far in the future where not only are technologies available, but they fit an entirely new work form. However, as the Boeing example shows, when moving to a new technology it had better deliver on its promised functionality.

## 6. DISTANCE WORK IN THE NEW MILLENNIUM

Could the technology ever get good enough to fully mimic the ease of interaction we see in face-to-face settings? Yes and no. We believe there is room for improvement over today's technologies. However, even with the best design of high bandwidth, display of appropriate proxemics, access to shared objects, and so on, there will always be things about the remote situation that make it qualitatively different than collocation, including aspects of common ground

and context, the effects of differing time zones, cultural differences, and various interactions among these and technology.

Even limited technologies will emerge with extremely useful functionality. The telephone places constraints on the character of the interactions that are possible, but it has been an extremely useful tool, revolutionizing the everyday life of individuals, communities, and organizations (Pool, 1977). As Dourish et al. (1996) pointed out, even today's collaborative technologies can result in productive uses when motivated people use them long enough to evolve social and organizational behaviors that exploit the unique characteristics of the medium. Thus, in short, we envision many useful tools emerging that are going to revolutionize how we collaborate with each other. We will evolve practices that fit these tools into the flow of collaborative activity.

One way to think about what might be possible in the future is to take our earlier list of characteristics of face-to-face interactions and imagine what is the best we could ever hope for. Again, we are mindful of arguments that in thinking about distant interactions we should not fall into the trap of singling out face-to-face interactions as the gold standard. There may be a number of ways in which distant interactions may have properties that are better than "being there" in terms of how a collaborative activity unfolds (Hollan & Stornetta, 1992). However, this exercise will help us think about what the distinctive characteristics of value of face-to-face and remote interactions might be.

Figure 10 presents an initial cut at such an analysis. Today's tools have many useful features, but they have very different characteristics of face-to-face interaction. As technologies evolve, more and more of these characteristics will be amenable to technical solutions. However, we feel that several key elements of interactivity, mostly having to do with the locality and spatiality of an individual participant's situation, will be very resistant to support.

Let us look in a little more detail at some of the characteristics of distance that will continue to be resistant to technological support.

## 6.1. Common Ground, Context, and Trust

We have shown how important common ground and context are to easy communication. One can see that people who are born and live in entirely different countries—with their local political and sports events, holidays, weather, and social interchange with locals—will always have to take extra effort to establish common ground. For example, in a video conference between London and Chicago in March, the entire conference was delayed for 45 min out of the allotted 1 hr because of a huge snowstorm in Chicago, preventing people from coming in on time. Participants in London knew only that the remote partners were absent, not the reason why. It became clear only when the first partici-

***Figure 10.*** **How well today's and future technologies can support the key characteristics of collocated synchronous interactions.**

| Characteristic | Today | Future |
|---|---|---|
| Rapid feedback | | ● |
| Multiple channels | o | ● |
| Personal information | o | ● |
| Nuanced information | o | ● |
| Shared local context | | |
| Informal "hall" time before and after | o | o |
| Coreference | | o |
| Individual control | | o |
| Implicit cues | | o |
| Spatiality of reference | | o |

*Note.* ● = well supported; o = poorly supported.

pant straggled in and was completely drenched from melting snow. It would have taken extra effort on the Chicago end to inform the London participants of the reason for the delay.

Establishing common ground is also an important precursor to trust. Trust is defined as the condition in which one exhibits behavior that makes one vulnerable to someone else, not under one's control (Zand, 1972). People will trust others who make a sincere effort to fulfill commitments, are honest in negotiating commitments, and do not take advantage of another when the opportunity arises (Cummings & Bromiley, 1996). Shared experiences and norms promote the development of trust (Lewis & Weigert, 1985; Mayer, Davis, & Schoorman, 1995). Remote teams have been reported to be less effective and reliable than face-to-face teams, based on the observation simply stated as "trust needs touch" (Handy, 1995). Trust is necessary when teams engage in risky activities, especially when they lack the ability to see each other or to monitor each other's behavior (Jarvenpaa & Leidner, 1999; Nohria & Eccles, 1992; O'Hara-Devereaux & Johansen, 1994).

Trust is very fragile in the world of electronic communication. As Rocco (1998) showed, when people played a variant of the Prisoner's Dilemma, discussion of how to coordinate their investment strategies culminates in cooperation if these discussions are done face to face. They dissipate into defection (looking for a personal benefit instead of the common good) if the communication is done entirely by text-based chat. Surprisingly, and fortunately, this dissipation is diminished if the teammates meet each other face to face before entering into the investment episodes. The question is whether the trust engendered by the face-to-face encounter can be accomplished by video instead of face to face.

Rocco's (1998) result is an important one for today's global teamwork. It suggests that team members should travel to remote sites to engage in a team-building activity to engender lasting trust. However, travel is costly. The question arises whether this same kind of trust and cooperation can be engendered if people engage in the discussion by video. Is the effect of the presession team-building caused by the fact that teammates met each other, saw each other, or engaged in a team-building activity? Subsequent research will need to address such issues.

## 6.2. Different Time Zones

A second difficulty not predicted to be overcome with technology is that remote participants often are working in different time zones. This is even acknowledged by Cairncross (1997) in her book predicting the death of distance. Time zone differences have several effects. First, the more time zones you cross, the less the time when people are at work at the same time. At the automobile site we saw a very different work pace during the hours in the day when "France was still awake" or "when the United States woke up" and the hours of nonoverlap. There was high tension when things could be communicated in real-time long distance, hoping to get things resolved with quick turnaround. When there was nonoverlap, there was a more relaxed pace, a resignation that nothing could be resolved until the next overlap. Background material was prepared in the off times, but no interaction was possible.

The positive side of the time zone difference, of course, is that if properly coordinated, work can proceed 24 hr a day. This requires loosely coupled work and firm communication about the status of pieces of work that needs to be coordinated and any other "color commentary" about the situation to make the next shift of work productive. Such a system was successfully deployed at a paper mill to coordinate observations and maintenance across shifts (Auramaki et al., 1996; Kovalainen, Robinson, & Auramaki, 1998), and in principle could be extended to shift work across time zones.

The second effect of different time zones is that during the overlap, the participants at various sites are at different points in their circadian rhythms. Video conferences between the United States and France saw sleepy morning stragglers at the U.S. site and alert afternoon workers at the French site. Later in the day, the U.S. site had the prelunch agitated workers, and France had tired people ready to close things off and go home.

## 6.3. Culture

Possibly the single biggest factor that global teams need to address is cultural differences. As distances are spanned, cultural differences emerge. We

have observed global teams in engineering disciplines where the participants are from two or three countries, and we have seen frequent misunderstandings resulting from cultural differences. Such simple things as different local conventions about dress can lead to improper attributions about motivation in video conferences. Mexican engineers in khaki shirts and sunglasses looked suspicious to the shirt-and-tie U.S. engineers. Silicon Valley engineers in t-shirts and blue jeans and Big Five consultants in their formal corporate wear made incorrect attributions about each other.

There are also differences in process (Hampden-Turner & Trompenaars, 1993; Hofstede, 1980, 1991; Trompenaars & Hampden-Turner, 1998). It is well known that the American culture is very task oriented, and being part of ad hoc, short-term teams is common. Southern and Eastern Europeans as well as Asians are known to value personal relationships more than the task at hand. They will sacrifice promptness when a previous interaction with a valued colleague is not deemed finished (Hall & Hall, 1990). They will spend whole meetings in social interaction, whereas American business people will at most have a few sentences asking about the family or noting the weather before getting down to business. When remote meetings mix these cultures, there is high likelihood of misunderstandings.

Other process differences attributable to cultural differences have to do with a concept called *power distance* (Hofstede, 1980, 1991). It is relevant to the relationship between a manager and his or her direct reports. In Europe and Asia, workers respect authority. Managers do not need to spend time getting workers to agree to a project or strategy, whereas in the United States, managers need to have people "buy in." In the United States, there is less distance; people at different levels communicate freely. The differences emerge when a U.S. manager has European or Asian direct reports. The manager expects a consideration and discussion about actions he or she proposes. The direct reports will merely take the command and enact their part. The opposite happens with European or Asian managers directing U.S. direct reports; they are surprised when their commands are argued with and when people choose not to enact the commands because they have not been consulted.

Furthermore, even the styles of management differ in startling ways. When giving feedback to a worker, American managers have what is called the "hamburger style of management."

> Managers start with sweet talk–the top of the hamburger bun. Then the criticism is slipped in–the meat. Finally, some encouraging words–the bottom bun. With the Germans, all one gets is the meat. With the Japanese, all one gets is the buns; one has to smell the meat. (Browning, 1994, p. A1)

In the large corporations we work with, Americans are notorious for their dominating turn-taking style, making it difficult for the Europeans or Asians to break into a conversation. Specific procedures must be put in place to counteract this. The American participants were told to allow pauses at the end of turns. They are told to make them extra long during video conferences in which transmission delays add further difficulty.

Increasing numbers of participants in global teams have some degree of sophistication about linguistic and cultural differences. Global companies are being populated by sophisticated internationalists who have taken classes on cultural differences and are more sensitive to differences. However, even for such sophisticates, their own cultural habits and viewpoints are the natural and automatic ones. It takes effort to maintain culturally neutral behaviors in the midst of intense interactions. Such sophisticates lose track of their culture-spanning, turn-taking rules in the heat of discussion. Local conventions about work schedules or the importance of nonwork time dominate as deadlines approach. Sensitivity to cultural differences will always take more effort, no matter how good the technology. There is no compelling evidence that cultural differences are receding in our tightly knit global community. Indeed, it is possible some of the differentiation allowed by modern information technology may work to preserve such differences (e.g., van Alstyne & Brynjolfsson, 1996).

## 6.4. Interactions Among These Factors and With Technology

We have seen instances when culture, time zones, and technology interact. In one memorable case, a talk was given to a group of U.S. executives by a U.S. professor during the period that the professor was in the Netherlands. The talk was to be given by Intel ProShare® desktop video, projected to the U.S. site. This was scheduled with consideration of the number of time zones crossed (six) but without consideration of the Dutch calendar. The talk was given at 7 p.m. local Dutch time on Friday, May 5. This talk was projected in the United States at 1 p.m., as the first session after a lunch. When arranging for technical support in the Netherlands, it was discovered that May 5 was not only a holiday, a celebration of the liberation of Holland after the second World War, but it was the 50th anniversary of that liberation. As the question and answer period went on after the talk (moving on to 10 p.m. Dutch time) the speaker and the technical support person noted wistfully the fireworks and revelers outside the window. The audience in the United States was oblivious to the situation; they continued a slow-paced question and answer and local discussion of the topics. The motivation of each of the remote people to continuing in the discussion was markedly different at the two locations–irritating to one and pleasantly relaxed to the other.

At the automobile company, we witnessed two other such interactions of culture. At one, routine video conference meetings were scheduled for Friday morning, U.S. time. To accommodate the French local time, these were scheduled first thing, 7:30 a.m. in the United States. Unfortunately, for the French who traditionally work a 35-hr week, Friday afternoon is outside of normal work time. The French, respecting the authority of the manager, did not complain. Their behavior during the meeting, however, was irritated and short, intolerant of expansion, clarification, or discussion episodes. The French had one-word responses to almost all agenda items. This, of course, could be corrected by better knowledge of the local situations in scheduling such conferences. However, it is difficult to anticipate all dimensions of such differences, particularly for three or more sites participating.

The most egregious misunderstanding we witnessed occurred as an interaction of culture and the distance technology. Video conferencing is expensive. Americans, being task focused and cost conscious, begin a video conference when everyone is in the room. As soon as the video is on, the first agenda item is discussed, and at the end of the last item, the video is terminated. At one particular meeting we witnessed a typically abrupt beginning and end by the Americans to a three-way conference between the United States, France, and Germany. Unfortunately, one of the French engineers was experiencing his last day on the job having been forced into retirement after a misunderstanding about a rule for certain workers. The Americans said nothing to him about this unhappy situation and did not say a personal goodbye. They cut the video connection as usual, right after the last agenda item. The Germans stayed on the video conference a full 15 min after the Americans left, wishing him well and kidding him affectionately about what he was going to do in retirement. The French and Germans were embarrassed for the Americans' apparent affront.

Perhaps these remote technologies are so new that we just have not yet had time to adapt to them. We established rules of behavior to accommodate these cultural differences to fit fast travel. "When in Rome, do as the Romans do." We adapt to the manners of the site to which we travel. However, in a video conference, where is "Rome?" There is no default location to which the parties accommodate. No one even thinks that they are experiencing a foreign culture and that misunderstandings might abound.

The automobile company is using one interesting solution to help alleviate this issue. They have rotational engineers at each remote location, putting a French and German engineer in the United States for 3 years, a U.S. and French engineer in Germany, and so on. We have not seen an English engineer in the United States; perhaps they are fooled by not realizing that, as George Bernard Shaw said, "We are divided by a common language." These remote ambassadors play several important roles. When there are questions about who in the United States fulfills a particular role, the French call up their

countryman. Not only does the liaison know the local people and their roles, they can translate various behaviors so that they will be less likely to be misinterpreted. Second, in their work in the remote location, they are the eyes and ears of their countrymen, noting and reporting on activities that the U.S. people do not realize that the French might need to know.

Therefore, many aspects of the local context, time zone, and culture sum to make it unlikely that even with the best technologies, we will easily achieve remote common ground. Mee (1898) stated in the last century, "Distance will lose its enchantment by being abolished altogether" (p. 345). We think not. Clearly, although we will be able to bridge some of the distance and make communication richer for remote work than it is today, distance still matters.

## 7. CONCLUSION

Collaborative work at a distance will be difficult to do for a long time, if not forever. There will likely always be certain kinds of advantages to being together. However, as a wide range of collaborative tools emerges, we will find useful ways to use them to accomplish our goals. If at some point in the past we had written a similar article about telegraphy, the telephone, radio, television, or fax machines, we would have had figures that catalog their shortcomings. However, in their own ways, all of them have turned out to have been useful for a variety of purposes, and they worked their ways into social and organizational life in enduring fashion. Indeed, some of the most profound changes in social and organizational behavior in this century can be traced to these tools. The rich repertoire of present and future collaborative technologies will have a similar fate. We will find uses for them, and descriptions of collaborative work in the future will enumerate the emergent social practices that have put these technologies to useful ends. However, it is our belief that in these future descriptions, distance will continue to matter.

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## NOTES

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