The Mutual Knowledge Problem and Its Consequences for Dispersed Collaboration

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Abstract

This paper proposes that maintaining "mutual knowledge" is a central problem of geographically dispersed collaboration and traces the consequences of failure to do so. It presents a model of these processes which is grounded in study of thirteen geographically dispersed teams. Five types of problems constituting failures of mutual knowledge are identified: failure to communicate and retain contextual information, unevenly distributed information, difficulty communicating and understanding the salience of information, differences in speed of access to information, and difficulty interpreting the meaning of silence. The frequency of occurrence and severity of each problem in the teams are analyzed. Attribution theory, the concept of cognitive load, and feedback dynamics are harnessed to explain how dispersed partners are likely to interpret failures of mutual knowledge and the consequences of these interpretations for the integrity of the effort. In particular, it is suggested that unrecognized differences in the situations, contexts, and constraints of dispersed collaborators constitute "hidden profiles" that can increase the likelihood of dispositional rather than situational attribution, with consequences for cohesion and learning. Moderators and accelerators of these dynamics are identified, and implications for both dispersed and collocated collaboration are discussed.

(Dispersed Collaboration; Dispersed Teams; Distributed Work; Virtual Teams; Mutual Knowledge; Information Exchange; Information Sharing; Shared Understanding; Attribution; Proximity; Computer-Mediated Communication; Systems Dynamics; Cognitive Load)

The organization of group work and the means of communication to support it are changing. Developments in communication and collaborative technologies have made it feasible for groups to work together despite physical dispersion of members. Organizations have been quick to experiment with geographically dispersed work teams to take advantage of interorganizational and international opportunities and maximize the use of scarce resources. This is likely to be an increasingly prevalent and important form of work in the years ahead (Arthur and Rousseau 1996, Boudreau et al. 1998, DeSanctis and Poole 1997, Handy 1995, Kemske 1998, O'Hara-Devereaux and Johansen 1994, Townsend et al. 1998).

Geographically dispersed teams are groups of people with a common purpose who carry out interdependent tasks across locations and time, using technology to communicate much more than they use face-to-face meetings (adapted from Lipnack and Stamps 1997, and Maznevski and Chudoba 2000). The use of such teams has outpaced our understanding of their dynamics, and inexplicable problems have been noted. In a field description of dispersed collaboration, Armstrong and Cole (1995, p. 187) observe these puzzles: "A decision made in one country elicits an unexpected reaction from team members in another country . . . Conflicts escalate strangely between distributed groups, resisting reason. Group members at sites separated by even a few kilometers begin to talk in the language of 'us and them'."

This paper utilizes the communications literature on "mutual knowledge" to explore challenges of communication and collaboration under dispersed and technology-mediated conditions. Mutual knowledge is knowledge that the communicating parties share in common and know they share (Krauss and Fussell 1990). In the work of communication theorist Herbert Clark and his associates, mutual knowledge is referred to more broadly as "common ground," and considered integral to the coordination of actions (Clark 1996, Clark and Carlson 1982, Clark and Marshall 1981). But members of dispersed teams do not stand on common ground. Indeed, the usage "common ground" suggests how deeply engrained physical copresence and shared physical setting may be to establishing shared understanding and affiliation. In 1990, Krauss and Fussell raised the question of how the use of new communications technologies to support cooperative work would interact with the problem of establishing mutual knowledge. This paper takes up that question and adds to it two additional ones: "How does geographic

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dispersion of team members affect the mutual knowledge problem?" and "To the extent that geographic dispersion and use of new communications technologies affect the mutual knowledge problem, what are the consequences for collaboration?"

The Mutual Knowledge Problem

Establishing mutual knowledge is important because it increases the likelihood that communication will be understood (Clark 1996, Clark and Carlson 1982, Clark and Marshall 1981, Fussell and Krauss 1992, Krauss and Fussell 1990). People may start with the same information, have a shared experience, or share information through communication. In each case, mutual knowledge consists not only of the information itself but also the awareness that the other knows it. For example, Clark (1996) describes standing on a beach on a beautiful day, examining a rare conch shell. If his son joins him, their mutual knowledge now includes the characteristics of the beautiful day, the beach and the sea, the presence of Clark, the presence of the son, the conch shell between them, and their awareness that they share this knowledge in common. When they talk with each other then and later, they can refer to aspects of this experience with considerable confidence that what they say will be understood by the other. They also can coordinate future actions with the help of this mutual knowledge. For example, they could agree to meet back at the same place in an hour.

Mutual knowledge increases the likelihood of comprehension because it allows speakers "to formulate their contributions with an awareness of what their addressee does and does not know" (Krauss and Fussell 1990, p. 112). Proceeding without mutual knowledge, people may speak and understand what is said on the basis of their own information and interpretation of the situation, falsely assuming that the other speaks and understands on the basis of that same information and interpretation (Blakar 1985). Krauss and Fussell (1990) describe three mechanisms by which mutual knowledge is established: direct knowledge, interactional dynamics, and category membership. The next sections draw on several research literatures to consider how dispersed collaboration and use of new communication technologies impact these three mechanisms.

Direct Knowledge

Direct knowledge is created in the course of firsthand experience with individuals (Krauss and Fussell 1990). One can make informed guesses about what they know and do not know on the basis of experiences shared with them and knowledge of their habits and environment gleaned from firsthand observation. The mutual knowledge that Clark and his son have concerning their day at the beach is direct knowledge because it is based on shared experience in a particular setting. For members of dispersed collaborations, opportunities to achieve unmediated knowledge of their partners and their partners' situations are likely to be limited. Rather than absorbing direct knowledge by visiting each other's offices, walking through the same building, attending the same meetings, and driving the same streets, dispersed collaborators must find other means to establish what their remote partners do and do not know: interaction and category membership.

Interactional Dynamics

In lieu of direct knowledge, mutual knowledge can be established through interaction. However, research concerning information sharing and media effects in groups raises questions about the likelihood of success under dispersed and technology-mediated conditions. It is well established that groups that meet face-to-face tend to dwell on commonly held information in their discussions and overlook uniquely held information (Stasser and Stewart 1992; Stasser et al. 1995; Stasser and Titus 1985, 1987). According to Stasser and his colleagues, group members engage in discussion by sampling from their pool of information. As the number of people who have a particular piece of information increases, so does the mathematical probability that it will be mentioned in the group's discussion. Moreover, when it is mentioned, it probably will be salient to a larger proportion of the group because they have encountered it previously. By contrast, pieces of information known to only one or a few people must compete in the information pool with more commonly held information. If mentioned, uniquely held information may not be as salient to group members as commonly held information, and fail to draw attention.

When a group's discussion is mediated by technology, the problem seems to be worse. Three experimental studies compared information exchange in groups using synchronous text-based computer conferencing and face-to-face groups. They found information exchange to be less complete and discussion more biased in the groups using technology to communicate (Hightower and Sayeed 1995, 1996; Hollingshead 1996). The computer-mediated groups exchanged less information overall and took more time doing it. One of the most robust findings concerning the effect of computer mediation on communication is that it proceeds at a slower rate than does face-to-face (Lebie et al. 1996, Straus 1997, Straus and McGrath 1994, Walther and Burgoon 1992). There is considerable evidence that groups using this medium take longer to complete tasks

than groups working face-to-face (Kiesler et al. 1985, McGuire et al. 1987, Weisband 1992). The slower rate has been attributed to the time required to type words rather than say them (Siegel et al. 1986) and the effort required to convey nuances in text without paraverbal and nonverbal cues such as tone of voice, facial expression, and gesture (Hightower and Sayeed 1995, 1996; McGrath and Hollingshead 1994). For these reasons, it appears that groups communicating through such means are not able to sample as much information from their information pool during a given period of time as can groups working face-to-face. As a consequence, less uniquely held information is aired, and their discussion is more biased by commonly held information.

Warkentin et al. (1997) got somewhat different results in a follow-up study under different conditions. They compared information exchange in student groups meeting face-to-face without computer support with information exchange in groups whose members were located at three different universities across the United States and who used asynchronous computer conferencing to communicate. The dispersed groups still exchanged less unique information than the collocated groups; however, the relationship did not reach significance in this study. It is possible that the technology used (an asynchronous rather than synchronous mode) and the longer time frame given the dispersed groups (three weeks versus 25 minutes) allowed for improved information exchange by giving group members offline time to assess information and frame their contributions.

It is important to note how the study conditions differ from geographically dispersed collaboration in practice in organizations. Tasks were relatively straightforward. People did not have to gather information themselves; they were given a packet of clues. By contrast, dispersed collaborators in organizations typically work on complex tasks for which the relevant information must be distinguished from millions of other details. Hightower and Sayeed (1995) note that when groups using computer-mediated communication were given a higher information load, their discussion became even more biased. They express concern about how groups communicating through such media will handle ambiguous and complex information problems.

Dispersed collaboration is distinguished both by heavy use of mediated communication and distribution of partners across more than one location. Thus far, we have examined media effects on information sharing. It is also important to consider the effects on information sharing of differences among locations and distribution of information across locations. The locations of dispersed collaborators may differ in their physical layout and travel requirements, holidays and customs, access to information, available equipment and support, strength of competing demands, and so forth. For dispersed team members to understand each other and coordinate their work, they must achieve mutual knowledge concerning such differences. However, information about one's own location and context may be uniquely held information. According to the principle of group discussion based on sampling from the information pool, such information is less likely to be mentioned and heeded in group discussions than is commonly held information.

When people attempt to achieve mutual knowledge through interaction, they must both share information and confirm that the information has been received and understood. Electronic mediation poses hurdles not only to information sharing but also confirmation. Give and take is hampered by the slower pace and greater effort required by most forms of mediated communication. In particular, conversations conducted through computers do not typically provide efficient back-channel feedback (Brennan 1998). Back-channel feedback includes head nods, brief verbalizations such as "yeah" and "m-hmmm," smiles, and the like (Kraut et al. 1982, Yngve 1970). These nonverbal and brief verbal cues efficiently signal the state of mutual knowledge without taking over the speaking turn. In addition, feedback lags associated with mediated communication and dispersed collaboration are likely to have a devastating impact on the establishment of mutual knowledge. "A delay of 1.6 seconds is sufficient to disrupt the ability of the sender to refer efficiently to the . . . stimuli, despite the fact that the back-channel response is eventually transmitted," observe Krauss and Fussell (1990, p. 132).

Thus, the communication literature raises the following questions: Will uniquely held information be shared and recognized in geographically dispersed, computer-mediated teams? Will feedback in such teams confirm receipt and understanding of information exchanged? In other words, can interaction effectively establish mutual knowledge in dispersed computer-mediated teams?

Category Membership

Finally, people make assumptions about others' knowledge on the basis of the social categorizations they apply to them (Clark and Marshall 1981, Krauss and Fussell 1990). For example, they assume that a cabdriver knows the route to the airport and that a fellow American knows the words to the national anthem. In dispersed collaborations, people may assume mutual knowledge on the basis of shared professional status or organizational membership. However, achieving mutual knowledge will be

more difficult if a dispersed team spans functional, cultural and organizational boundaries. Many dispersed collaborations do span such boundaries.

In addition to influencing assumptions about shared knowledge, social categorization affects the development of relationships among people communicating via computer mediation. Lea and Spears (1991, 1992, 1993) have observed that the medium reduces the number of cues available to communicators about each other relative to face-to-face communication. According to their social identity/deindividuation (SIDE) theory, when people communicate with others they do not know well through such media, they experience feelings of isolation, anonymity, and deindividuation. As a consequence, they "overattribute" on the basis of the few social cues they glean. They use relatively meager information to assign remote others to social categories and treat them accordingly. If they conclude that they share an identity with a remote partner, they are more likely to view the relationship and the remote other positively than if they find no shared social identity. Thus, SIDE theory asserts that social categorizations exert considerable influence over conclusions drawn about remote others, positive and negative feelings about them, and affiliation with them in lieu of the individuating information available in relationships carried out face-to-face.

The salience of social categorization for dispersed collaborators raises the following questions: Does social categorization help dispersed collaborators establish mutual knowledge of important matters? If people assign remote others to social categories on the basis of meager information, will they form inappropriate expectations about what they know? If they form inappropriate expectations, what are the consequences for the relationship?

Consequences of Failure to Establish Mutual Knowledge

The preceding discussion suggests that it may be difficult for geographically dispersed, technology-mediated teams to achieve mutual knowledge. This section considers the consequences of failure to establish mutual knowledge. In the communications literature, mutual knowledge is considered to be a precondition for effective communication and the performance of cooperative work. However, according to Krauss and Fussell (1990), this does not mean that communication must be error free. It depends on whether the consequences of misunderstandings are major or minor, and whether the dynamics of conversation provide mechanisms for detecting and correcting errors. Beyond this, there is little discussion in this literature of specific consequences of failure to establish mutual knowledge. "What is important for us," writes Clark (1996, p. 121) is "how common ground gets staked out and exploited." Therefore, I turn to other literatures to explore the consequences of failure to establish mutual knowledge on decision quality, productivity, and relationships in dispersed teams, taking into account the moderating factors noted by Krauss and Fussell (1990).

Decision Quality and Productivity. As discussed above, when task-relevant information is distributed among members of a group, there is a risk that they will fail to share and heed uniquely held relevant information. Research shows that the consequence is poorer decision quality (Dennis 1996, Stasser and Titus 1985). The risk may be greater for dispersed teams relative to collocated teams for two reasons. First, there is a significant probability that task-relevant information will be distributed across locations and that critical pieces of information will surface at isolated locations. Second, a dispersed group's means of communication will likely restrict interaction, such that sampling from the information pool is less than it would be for a collocated team, with the consequence of poor decision quality.

Groups may attempt to protect decision quality by monitoring and correcting failures of mutual knowledge. In this case, a critical consideration is the ease and speed of detecting and correcting errors (Krauss and Fussell 1990). The more arduous and time-consuming this process is, the greater the probable loss in productivity. This could be a problem for dispersed groups using computer-mediated communication because the interaction required to detect and correct communication errors seems to be less efficient in conversations involving computers than in face-to-face conversations (Brennan 1998; Hightower and Sayeed 1995, 1996; McGrath and Hollingshead 1994; Siegel et al. 1986). Hightower and Sayeed (1995, p. 43) point out that "creating mutual understanding . . . require(s) group members (using computer-mediated communication) to transmit much more information than those working face to face." It is reasonable to expect that dispersed groups using such media will have to sacrifice speed if they must protect decision quality, and decision quality hinges on mutual knowledge of distributed information.

This discussion raises the following questions: When task-relevant information is distributed, do dispersed teams make poorer quality decisions because of failure to establish mutual knowledge? Do dispersed teams develop strategies to limit information-processing burdens and preserve decision quality? Must they accept reduced productivity or are there other options?

Relationships. The work of communication theorist Rolv Blakar and his colleagues provides a critical link

between the concept of mutual knowledge and the consequences for working relationships of failure to establish mutual knowledge. This stream of research investigates how family members react to communication difficulties caused by lack of mutual knowledge. Blakar calls the problem an absence of "shared social reality," however, its operationalization is consistent with lack of mutual knowledge (i.e., people who are engaged in communication have different information but do not realize this is the case). In the studies, pairs of family members are given maps of a city. One subject's map contains arrows that mark a route through the city. This subject is told to describe the route to his or her partner so that the partner can follow the route on his or her own map. Unbeknownst to the subjects, their maps differ in key respects, making it impossible for them to carry out the task successfully. Blakar and his associates were interested in when and how such problems are solved, allowing communication to be reestablished (Blakar 1973, 1984; Hultberg et al. 1980).

They concluded that it is essential that communication difficulties are "adequately attributed" by the participants. When an error or conflict in information exchange is detected, people make attributions concerning its cause. The research focuses on whether attributions concerning communication difficulties are personal or situational (Heider 1958) and constructive or nonconstructive for continued communication. Personal attributions associate the cause of the communication conflict with some characteristic or behavior of an individual. For example, participants in the study conducted by Hultberg et al. (1980) made personal attributions when they made statements such as "My explanation was not adequate" or "You give damned bad explanations!" They made situational attributions when they investigated the credibility of the maps they were using. Attributions were judged to be constructive if they facilitated inquiry and change to reduce the incidence of communication conflicts in the future. Attributions were nonconstructive if they were task irrelevant or destructive to cooperation, inquiry, and adaptation. The researchers suggested that situational as opposed to personal attributions tend to produce better resolution of conflicts because they focus participants on modifying the "contracts" that guide the communication process (Blakar 1984). If attributions are destructive, contracts concerning the communication process break down and people withdraw from cooperation.

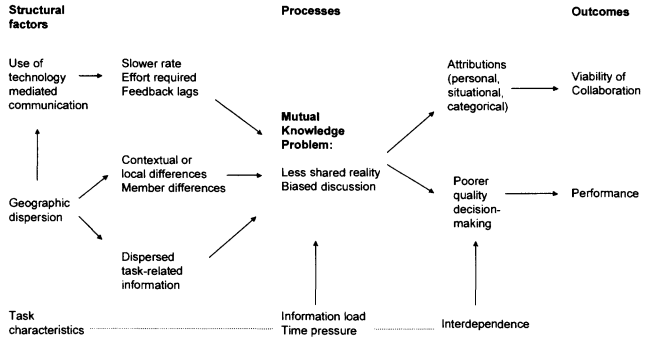
This work has significant implications for the study of mutual knowledge in dispersed collaboration. It recognizes that communication failures are interpreted and that interpretations can vary. These interpretations can change people's perceptions of each other, their willingness to cooperate, and the ways in which they communicate and cooperate. The first part of this section suggests that dispersed collaborations are vulnerable to failures of mutual knowledge. Therefore, the way such failures are interpreted—i.e., attributed—could be critical for the long-term viability of dispersed collaboration.

Blakar and his collaborators focus on the distinction between personal and situational attributions. Applying these ideas to dispersed collaboration, we should consider how the dynamics of social categorization influence attributions and outcomes. As noted previously, Lea and Spears (1991, 1992, 1993) have observed that people using computer-mediated communication with remote others they do not know well rely heavily on social categorizations to guide their relationships. The social categorizations provide a basis for affiliation if participants share a significant social identity. However, they also can provide fodder for in-group/out-group dynamics if remote others are seen as belonging to social categories different and less attractive than oneself. This raises the question of whether or under what circumstances the attributions remote collaborators make concerning failures of mutual knowledge will be personal, categorical, or situational. It is not clear how these different types of attributions affect the viability of dispersed collaboration. Lea and Spears (1992) observe that people tend to overlook errors made by others with whom they share a significant social identity. On the other hand, collaborators might recategorize less generously remote others with whom they experience a communication failure. In addition, we can think of Blakar's "contracts" as norms: understandings within a group about what behaviors are and are not appropriate (Jackson 1965). Ideally, groups that experience communication failures will modify their norms to prevent future occurrences. However, if communication failures are blamed on individuals or subgroups, cooperative norms may break down.

This discussion presents the following questions: How are failures of mutual knowledge attributed in dispersed collaborations? Under what circumstances are attributions individual, categorical, or situational in nature, and with what consequences for future communication and collaboration?

Figure 1 summarizes the relationships discussed in this section. The discussion raises important questions about how mutual knowledge is established and its significance in dispersed collaboration. The existing literature provides a basis for expecting a number of problems with serious consequences. There is a need for close examination of the dynamics of actual dispersed collaborations to see if such problems do occur and how they manifest

Figure 1 **Likely Impact of Dispersion and Mediated Communication on Mutual Knowledge and on Collaborative Outcomes**



themselves. This suggests a fine-grained qualitative analysis of the communication and experiences of groups involved in such collaborations. This approach should illuminate the dynamics suggested by these theories and how they affect participants in ways other types of investigations would not.

Method

The data were contained in an archival dataset that was created in the course of a collaborative project involving graduate business faculty and students located at nine universities on three continents. The project was intended to improve students' technical skills, give them experience in using technology to collaborate with remote partners, and expose them to the possibilities of electronic commerce. I gave my graduate students the option of participating in this project in lieu of the group project I usually assign in my Organizational Behavior course at George Mason University (GMU). Half my students decided to participate in the dispersed teams project. Each of them chose a partner within my class and these pairs were assigned randomly to a team with pairs from two other universities.

The six-member teams included pairs from two U.S. universities and one university located elsewhere. Non-U.S. partners were located in Canada (Université Laval, Memorial University of Newfoundland), Australia (Southern Cross University), and Portugal (Universidade do Minho). There were 45 teams in all, including 13 teams with GMU students. Only the data generated by the 13 teams that had GMU members are used in the analysis, yielding 13 cases. The students ranged in age from 23 to 48 years old, and all were graduate students taking business or management information systems courses. Because a number of foreign exchange students participated, countries of origin included the United States, Canada, Colombia, Portugal, Germany, Ukraine, India, Thailand, Hong Kong, and Indonesia. All of the participants based in Australia were Asian exchange students.

The teams were given the assignment of (1) coming up with an idea for a business that would use the Internet in some way, (2) writing a business plan, and (3) creating a presentation for investors or an online storefront. The project spanned a seven-week period. Communication tools used by the teams included electronic mail, Internet-based "chat" tools, an Internet-based voting tool (Dennis et al. 1996), telephone, and fax. The project home page was a common point of reference for the teams. Home page material included detailed team assignments for each week, sample business plans, project evaluation criteria, and links to resources such as the voting tool, chat rooms, and information about electronic commerce. The teams were permitted to use whatever communication tools they found useful, including those that they found independently on the World Wide Web.

The nine faculty members whose students participated in the project communicated with each other through electronic mail, a faculty listserv, and occasional telephone calls. None of the faculty had met any of the others face-to-face. Thus, the faculty also was a dispersed team that collaborated for three months to manage a complex global social system. Despite efforts to make project requirements consistent across all nine universities, differences were discovered as the project unfolded. When any such difference was discovered, affected students were informed immediately and every effort was made to bring requirements into alignment.

Data Sources

Data constituting the cases include 1,649 pieces of e-mail exchanged by members of the 13 teams, printouts of their online chats, team logs of their use of communication tools, 26 analysis papers written by project participants, and grades awarded independently to each team by two instructors. George Mason University students who participated in the project turned in copies of their e-mail on disk and on paper. On every team on which GMU students worked, there were two Texas Christian University (TCU) students, as well as two students from a university abroad. The TCU students turned in copies of their e-mail, and their professor sent copies to me. I compared the two sets of records and added to the master record newly discovered e-mails. This strategy was intended to identify all cross-site e-mails. As a result of the cross-check, there were only a handful of points in the team histories at which it was clear from the content of the

messages that an e-mail was missing, and I earmarked these points. The count of e-mail records by team ranged from 61 messages (Team 30) to 217 messages (Team 6).

Each team's communication log listed the team's online chats and use of other Web-based tools such as the voting tool. The number of chats held by teams or subsets of teams ranged from none (Teams 11, 18, and 26) to five (Teams 5, 21, and 39). The teams turned in copies of the texts of most of their chats. However, on some occasions they failed to make a printout so the text was not available for analysis. Descriptive information about each of the cases appears on the left side of Table 1.

GMU students wrote individual six-page analysis papers after the project ended. They were instructed to analyze one or two events in the life of their team that they considered to be significant, using e-mail and chat records as a resource. They were required to do their best to examine these events from the perspectives of the other team members as well as from their personal perspective.

To understand the experiences of the teams, I also drew on my experiences as a member of the geographically dispersed faculty team and my work with the students engaged in the project. In addition, several members of the faculty team wrote about their experiences and circulated these narratives. Finally, my colleague at TCU sent me copies of the grades she awarded to each of the 13 teams that included GMU students so that I would have two perspectives, hers and my own, on team performance.

Cursory review of the cases suggested that there had been a great deal of conflict in the teams. In seven of the 13 teams, conflict escalated to the point that hostile coalitions formed. In five of these teams, members at two sites began to complain about partners at the third site, refusing in some cases to send them pieces of the team's work or put their names on finished work. Two teams evidenced shifting coalitions among subgroups at the three sites. Close examination of episodes of conflict, frustration, or confusion in the teams seemed to be merited.

Data Analysis

Data management and analysis procedures are summarized in Table 2. My objectives were to analyze episodes of conflict, frustration, or confusion in the teams, examine the significance and consequences of these episodes in the context of each case as a whole, and look for patterns across cases. I followed Eisenhardt's (1989) specifications for analysis of multiple case studies, with the addition of an embedded information-processing analysis of episodes of conflict, frustration, or confusion within cases (Yin 1994, Coulam and Smith 1985). Steps included (1) putting the 13 cases into an accessible form without compromising their richness, (2) understanding each case on its own terms before attempting to generalize across cases (Eisenhardt 1989, Miles and Huberman 1994), (3) conducting an embedded information-processing analysis of episodes of conflict, frustration, or confusion, (4) creating and refining constructs that cut across cases, (5) identifying other variables of interest, (6) reviewing all cases to refine the definition of constructs and build evidence to measure or refute them, (7) integrating the constructs into a tentative model, and (8) reviewing all cases to refute or refine the model.

Data Management. I followed the process used by Gersick (1988) in her study of eight collocated project teams to gradually condense the voluminous case histories so they could be reviewed telescopically as well as microscopically. I wanted to make it possible to follow the flow of each case while preserving tight links to the original pieces of data. Each of the 13 teams' e-mail was read into AskSam, a text-management software program. Missing e-mail identified through the crosscheck with TCU was added to the files. Each piece of e-mail was assigned an identification number.

AskSam was used to create fields within which to annotate each piece of e-mail. In one such field, my research assistant summarized the literal content of the e-mail. This paralleled Gersick's literal summaries of the team meetings she studied. In another field, my research assistant recorded her interpretations of the activity in the team and the questions that came to her mind. She had been a member of one of the teams and recognized nuances of situations that a newcomer to the complex project probably would have failed to grasp. Her attention was directed primarily to the microscopic level—recording the literal content of each piece of e-mail—with secondary attention to the flow of events.

Case Analysis. I studied each case and recorded my observations in a field created for this purpose. Creation of the summaries made it possible for me to review entire cases quickly when I wished to, tracking the overall flow of events. In addition, counts of the number of e-mails each team exchanged during each day of the project were generated through the software and transformed into graphs of the team's communication activity—another perspective on the flow of the whole. I also examined the e-mail microscopically, comparing my impressions with the summaries and comments of my research assistant. I wanted to be sure that the summaries she prepared were sufficiently descriptive, so that I could rely on them when I wished to move quickly through the material. Using AskSam, one can double-click on the summary of a piece

Table 1 Information by Case

Team	Non U.S. location	Grades	Number of emails	Chats*	Lack of contextual information	Unevenly distributed information	Differences in salience of information	Relative speed of access	Meaning of silence uncertain	Technical problems	Use of external information	Coalition activity
15	Australia	100; 95	156	4	*c*	*u*		*r*	*q*	*T*	*E*	some
26	Canada (Newfoundland)	86; 95**	65	0	*C*	*U*	*s*		*q*		*E*	none
11	Portugal	96; 86	159	0	*C*	*U*	*S*	*R*	*Q*	*T*	*E*	much
30	Canada (Newfoundland)	93; 93	61	3		*U*	*S*		*Q*	*t*	*e*	none
17	Canada (Newfoundland)	90; 90	125	1	*C*	*U*	*s*		*q*	*t*	*E*	some
21	Portugal	90; 90	95	5	*C*	*u*		*r*	*Q*	*T*	*E*	none
1	Portugal	90; 81	85	1	*c*	*U*			*q*	*T*	*e*	some
5	Australia	90; 74	156	5		*U*		*R*	*Q*	*T*	*E*	much
6	Portugal	86; 86	217	1			*S*		*Q*	*T*	*E*	none
3	Canada (Quebec)	86; 86**	153	3	*C*	*u*	*s*	*R*	*Q*	*T*	*e*	much
18	Canada (Quebec)	83; 83	105	0	*C*	*U*	*s*	*r*	*q*	*t*	*E*	none
37	Canada (Newfoundland)	83; 83	130	2	*C*	*U*	*s*	*r*	*q*	*T*	*e*	none
39	Canada (Quebec)	83; 83	142	5	*c*	*U*	*s*	*r*	*q*	*T*	*E*	much

C, U, R, S, Q, and *T* = serious problems of this type in the team. *c, u, r, s, q,* and *t* = some problems of this type in the team.
E = frequent use of information from external sources in the team. *e* = some use of information from external sources in the team.
* represents the number of chats involving at least two locations during which project work was conducted
** number adjusted to reflect differences in grading criteria

of e-mail and be shown the full text. Thus, it was easy to move as I did between microscopic and telescopic views of the team's work. Like Gersick, I eventually condensed the summaries two more times: first into a timeline of key events and then into stages of team activity. I also tracked team behaviors and activities that are generally considered to be predictors of performance and viability: performance strategies, planning activities, leadership activities, roles, coalitions and conflicts, communication with or about outside stakeholders and authorities, and milestones in project development.

After studying a team's e-mail and recording my observations, I reviewed the analysis papers written by the two GMU members of the team. The papers gave me insight into their interpretations of the team's interaction, which I could compare with the e-mail and chat records, my own analysis, and the commentary of my research assistant.

Information-Processing Analysis. Information-processing analyses of collectives such as organizations and teams investigate two central questions: (1) how interactions among members of a collective are influenced by individual information-processing characteristics and limitations, and (2) how structures and systems shape the interactions among individuals and the decisions and actions of the collective. Considerable attention is devoted to examining how individuals "perceive and interpret stimuli and how they remember, use and communicate information about a complex world" (Coulam and Smith 1985, p. 1). Accordingly, information-processing analysis is an appropriate method for investigating the establishment of mutual knowledge and failures of mutual knowledge. The typical medium for information-processing analyses is the case study because of the fine-grained evidence that is required (Coulam and Smith 1985).

I analyzed the exchange and processing of information leading up to, during, and after episodes of conflict, frustration, or confusion in the teams. From e-mail and chat records, I determined what information each team member did and did not have at the time a problem arose. This included activities such as establishing to whom e-mails

Table 2 Data Analysis Procedures

Stages of Work and Key Observations	Activities	Purpose
Data Manipulation		
	Check completeness of e-mail records by comparing e-mail turned in by team members at ECU and SWU.	
	Add to the master file any newly discovered e-mails.	
	Import all e-mail into text management software program.	
	Adjust time stamps to Eastern Standard Time so e-mail can be sequenced correctly and resequence.	
	Assemble records and reports of team "chat" sessions.	
	Research assistant writes a literal summary of each of the 1,649 pieces of e-mail and of each chat session. Focus on content of individual pieces rather than overall flow of events. Observations and questions noted in separate field.	Gersick 1988: Begin process of gradually condensing voluminous transcripts of team activity into summaries of event sequences.
Data analysis		
	Researcher studies each case, moving between summaries and actual text of e-mails. Observations and questions noted in separate field.	Eisenhardt 1989:540; Miles and Huberman 1994: "Allow the unique patterns of each case to emerge" before attempting to generalize across cases."
	Review and write summaries of analysis papers written by members of each team. Papers focused on one or two critical events in the life of the team.	Get perspective on the meaning that participants made of the team's interactions.
	Triangulate researcher impressions with those recorded by participants and research assistant, and with e-mail records.	Develop a deep understanding of each individual case from multiple perspectives.
Observation of high degree of conflict in teams and decision to examine episodes of frustration, conflict or confusion in depth.	Review all team cases and analysis papers to select episodes of frustration, conflict or confusion.	See whether there seem to be some generalizations across cases that could be explored.
	Trace development of each episode, attempting to determine what happened and how each team member saw it.	
Observation that in these episodes, people frequently seemed to be working from different information.	Carefully identify exactly what e-mails and chat experiences the parties to an incident did and did not have at the time it occurred.	
Observation that there seemed to be recurrent types of problems.	Create five constructs representing types of problems observed.	
	Study all 13 cases again in depth to 1) challenge and refine the descriptions of types of problems, 2) document their frequency, 3) document the frequency of other variables of interest, and 4) look for other important types of problems not represented by the constructs.	Eisenhardt 1989: Refine definition of constructs and build evidence that measures the construct in each case.
Observation that there seem to be causal relationships between information exchange activities and failures, attributions about team members, and team coalition activity.	Integrate constructs into a tentative model, drawing on the cases and the relevant literature.	
	Study the 13 cases in their entirety a third time to challenge and refine this model.	Eisenhardt 1989: Verify that the emergent relationships between constructs fit with the evidence in each case.

were and were not addressed, and whether the addresses were correct. I also compared accounts in the student analysis papers with the e-mail and chat records, noting points of divergence in content or tone. In a systematic way, I sought to understand the perspective of each member of a team as an episode unfolded on the basis of the information he or she had at the time and what he or she wrote in e-mail or chats.

Cross-Case Analysis. Across cases, I noticed recurring patterns in the development of problems. I studied these patterns inductively. I characterized individual incidents, grouped them, and adjusted the descriptions and groupings iteratively. Eventually, I characterized five types of problems: (1) failure to communicate and retain contextual information, (2) unevenly distributed information, (3) differences in the salience of information to individuals, (4) relative differences in speed of access to information, and (5) interpretation of the meaning of silence. I reviewed all the cases to refine or refute my descriptions of these problems and assess their frequency across cases and their seriousness within cases. I recorded the identification numbers of e-mails or chats in which I observed each type of problem. Then I reviewed the accumulated evidence in light of my knowledge of each team's case and judged whether each problem was (1) present and serious, (2) present but not serious, or (3) absent. The charting technique is an adaptation of techniques suggested by Miles and Huberman (1994) and used by Elsbach and Sutton (1992). I found I could integrate the five problems into a model that described how episodes typically unfolded and their consequences for teams. In another review of the cases, I sought to refine or refute this model.

Findings

This section reports findings at the episode, case, and cross-case levels of analysis. I describe the five types of problems observed, their frequency and severity across cases, and their association with team strategies and outcomes. I also present a model that summarizes the relationship of problems to each other and the processes observed across cases.

Types of Problems

Failure to Communicate and Retain Contextual Information. Team members had difficulty gathering and remembering information about the contexts within which their distant partners worked. They also failed to communicate important information about their own context and constraints to their remote partners. The teams involved in the project, including the dispersed faculty team, sometimes failed to recognize differences across sites in deadlines for deliverables, evaluation criteria, and the timing of spring break. Only belatedly did many teams come to understand competing time commitments that were affecting members' participation. Team members also sometimes assumed that the collocated partners were in closer touch with each other than they were.

For example, Team 26 experienced conflict over whether or not to schedule online "chat" sessions among team members. The GMU pair refused to schedule a session. According to a GMU partner, we "felt strongly that a phone call would be much more efficient." In his analysis paper, he interpreted the TCU partners' insistence on using the medium as follows: "Perhaps they did not realize how difficult it is to implement the necessary scheduling." What was not communicated in the team was the fact that using chat tools was part of the evaluation criteria at TCU but not at GMU. The TCU students were taking a management information systems course, while the GMU students were taking an organizational behavior course. Despite efforts to make requirements consistent, differences such as this one surfaced. The conflict stemmed from a difference in the *organizational contexts* of the GMU and TCU members, but to the end, the GMU partners saw it only as a *preference* on the part of the TCU partners. Important information about the organizational context and constraints was not communicated among dispersed team members.

In Teams 3, 6, 17, and 18, some team members disappeared during what turned out to be their spring break. One of Team 18's GMU partners believes that she sent her remote partners an e-mail that described GMU's upcoming spring break and stated that she and her collocated partner would be away for three days. When I studied the e-mail records, I could not find her message. At this point, the team had turned in its business plan, but faced an impending deadline for its presentation. After several days passed without e-mail from GMU, exasperated team members at TCU wrote to their partners at Université Laval in Canada: "I can't believe what I just heard. Is it true that Anna and George have spring break now???" Replied the Canadians, "Maybe they are out of town!" Team 3 had a similar experience when partners at Memorial University of Newfoundland who were responsible for assembling all parts of the business plan vanished without warning from the e-mail traffic for three days. Panicked team members at other schools eventually took over the task of their silent partners. The Canadian partners had not mentioned their upcoming break to their distant team members.

In Team 6, e-mail records show that a team member *did* warn the others about a trip during spring break; however, the information did not seem to register in the minds

of the remote partners. Requests from teammates for immediate action continued to arrive in her e-mail while she was away. It appears to be difficult for teammates to create a mental map of their distant partners' situation and to update that map when new information arrives.

At the outset, some students failed to send an initial e-mail message to their teammates for up to three weeks. Often, persons reported later that they were taking midterm examinations or completing some other project. However, they failed to perceive the need to describe their situation to remote partners whose situations might be quite different. Relationships fared better when preoccupied teammates laid out immediately the constraints under which they were operating.

Participants also seemed to exaggerate the completeness of communication in the collocated condition. This is yet another way of misjudging the context of remote partners. A GMU partner in Team 11 assumed that concerns she had expressed on the telephone to one partner at TCU would be conveyed to the other partner at TCU. Later the GMU partner wrote that she had *repeatedly* asked TCU to make a particular change in the team's home page, while one of the TCU teammates insisted that he had *never* heard this concern. One factor in this difference was the GMU partner's assumption about the ease and completeness of communication between the collocated TCU partners.

Unevenly Distributed Information. Unevenly distributed information also interfered with team-level collaboration and caused problems in relationships. Two causes were errors in e-mail addresses and failure to send copies of e-mail to all team members. Team members also may have thought they sent e-mail that in fact never went out or was undelivered. The bucket of information being passed among team members proved to be far leakier than they realized. Wildly different perspectives among team members were created because of differences in the information they received.

In two teams (Teams 37 and 11), partners located outside the United States were quick to initiate communication, yet this failed to become common knowledge in the team. On the contrary, the impression grew that these partners were absent or unwilling to communicate. Meanwhile, they wondered why their initial messages were ignored. In Team 37, a Canadian partner was the second person to check in. After introducing herself, she explained that her collocated teammate was away for a few days but would write shortly. She mistyped the address of one GMU partner, but typed the second GMU address correctly. However, neither GMU partner ever indicated having received her e-mail. E-mail records confirm that at least one of the TCU partners received the e-mail, however this person did not correct the GMU partners when they complained that the Canadians had not been heard from. The dynamic created in the team concerning the Canadians teammates' tardiness persisted to the end, even though it was based on inaccurate information.

In Team 11, the Portuguese partners were the first to write to the group. Their message contained two incorrect e-mail addresses and two correct addresses. It was five days before one GMU team member discovered the message from Portugal in her e-mail. By that time, both GMU and TCU members had begun to worry and complain about what they thought had been silence from Portugal. The Portuguese probably were receiving mail from the United States but wondering why their greeting was being ignored. Moreover, there is no evidence that the GMU partner who found the e-mail from Portugal ever forwarded it to the rest of the team. The Portuguese operated on the assumption that the entire team had the information contained in the initial note, but in fact, only one or two United States members had it.

Impressions formed as a result of unevenly distributed information persisted in the face of correcting information. This is not surprising when one considers how difficult it is to trace all the ways in which a particular piece of information (in this case, erroneous information) has shaped one's feelings about another person. The history of Team 30 offers a striking illustration. The mailing list used by one of the GMU partners, Paul, had an error in it: It included one person who was a member of a different team and omitted one person (Don) who was a member of Paul's team. By the time the situation came to a head, Paul thought he had sent six e-mails to the entire team. He was receiving e-mail from his team member, Don, but did not realize that he was not sending mail to Don. The person who was receiving the e-mail in error never notified Paul. Eventually, Paul spent several hours investigating chat room sites and proposed one to the team. He was astonished when Don wrote within hours proposing a different chat room, assuming that the team would meet there, and ignoring Paul's message. In his analysis paper, Paul wrote that this indicated "resentment toward me for taking the initiative and making decisions."

Paul gave Don the benefit of the doubt by writing to check the e-mail address, but Don did not respond to this note, which offended Paul even more. But let us look at this from Don's point of view: Even though Paul has written six detailed e-mails to the team, Don has not received *any* of them. To Don, Paul is a deadbeat team member who now has finally sent a short note asking if he has Don's address right! Eventually, Paul removed the incorrect name from his mailing list and added Don's name,

but Paul did not change his understanding of the team or see how differently this exchange must have appeared to Don. Even though Paul figured out that he had Don's name and address wrong and offered to send Don all the early messages he had written, Paul still presented the exchange as a power struggle in his analysis paper. Paul still thought that Don deliberately ignored the work he had done.

In relationships conducted face-to-face, it is a challenging cognitive exercise to interpret a set of facts from the perspective of another person. It is far more difficult to determine how the information before the other party differs from one's own, and then see things from the other's perspective. Geographic dispersion makes these two activities more difficult because of undetected "leaks in the bucket," because partners seem to have difficulty retaining information about remote locations, and because feedback processes are laborious. In addition, the data suggest that team members with complete or correct information may not speak up when erroneous conclusions are voiced in the team.

Problems stemming from unevenly distributed information were not limited to cases involving errors in addresses and undelivered mail. Sometimes people knew they were exchanging mail with only part of the team, but failed to understand how this affected the perspectives of team members who did not receive the mail, or how it affected the dynamics of the team as a whole. In Team 11, Lisa in Portugal suggested a focus for the team's project. Team members at GMU and TCU exchanged e-mail about Lisa's idea without copying her. They agreed that her idea was creative and interesting but too complex for the team's time frame. When the team voted electronically, Lisa's idea was not selected. From Lisa's perspective, her idea was met by silence. There was no discussion, praise, or criticism—just a vote. When team members began volunteering via e-mail to develop particular parts of the business plan, the Portuguese part of the team was silent. I suspect that the GMU and TCU members were more conscious of the silence from Portugal than their own silence in response to Lisa's idea. E-mail concerning Lisa's idea was exchanged. It just wasn't sent to Lisa.

It is not news that private conversations can create problems in a team. However, the dynamics and consequences of this behavior in dispersed teams are worth noting. Private exchanges of e-mail distort perceptions of the volume of activity in a team. This can confuse members' sense of pace and timing. Members who are receiving all the e-mail will perceive some members as active and others as relatively inactive. Those who are not receiving all the mail will perceive the energy level of the team to be low and the pace to be slow. Accordingly, they may further reduce their pace, or berate members for inactivity because they do not know of their efforts. Analysis of the team histories suggests that these kinds of perceptions can be excruciatingly difficult to identify and change when a team is dispersed. Private "conversations" may create much more confusion for dispersed teams than face-to-face teams.

Differences in the Salience of Information. Teams also encountered problems that hinged on differences in the salience of information among team members. Writers tended to assume that what was salient to them would be salient to their readers. Scholars have observed that mediated communication often lacks cues to *meaning* such as facial expressions, body language, and tone of voice (Kiesler and Sproull 1992, Sproull and Kiesler 1986). However, these types of cues also signal the *salience* to the communicator of one piece of information relative to another. Dispersed team members were not successful in communicating to their partners what parts of their messages, or which messages, they considered most important. When an e-mail message addressed several topics, partners sometimes differed on which topics they found salient. For example, as described previously, a GMU partner who wanted a change made in the team home page raised the issue on the telephone with TCU Partner 1 and in a postscript to a four-paragraph e-mail to TCU Partner 2. The proposed change was the last of three issues addressed in the e-mail. TCU Partner 2 later insisted indignantly that he had never heard of the request. Clearly, the postscript had greater salience to the sender than to the receiver.

Differences in information salience were exacerbated by unwieldy feedback processes in the dispersed teams and the making of indirect requests. Analyzing a tense exchange in Team 6, a GMU member observed:

> With so much information going back and forth, it was difficult for my teammates to absorb every detail . . . Because I couldn't "see" if the receiver was paying attention, I didn't know if my message had to be repeated. Yet it is time-consuming to let the sender know my perception of their message.

In other cases, writers did not use in their e-mail key words that they thought they had used. In Team 18, Anna wanted to clear up irritation that had resulted when she and George disappeared for three days during GMU's spring break. In her analysis paper, she wrote, "When everything was done, I thought it was time to clear our misunderstandings. I didn't want to brush things away. I sent an e-mail saying that we need to have a chat as there were some misunderstandings to be cleared." The chat never took place. One reason may be that Anna did not

actually use the words "clear our misunderstandings" in her e-mail. Instead, she wrote, "There seems to be a communications lapse between us. George and I thought that we probably need to discuss certain aspects from the home page. Is it possible to chat today? . . . This is important, so please let us know soon." It is unlikely that Anna's wish to resolve the issue of why she and George disappeared was clear to her dispersed teammates because she said that she wanted to "discuss certain aspects from the home page." Confusion due to indirect wording is not confined to computer-mediated communication, as Tannen (1994) has shown. But the characteristics of some of the communication technologies used by dispersed groups probably make it difficult for members to recognize the meaning and importance of indirect requests like this one.

In addition, there was a tendency to request feedback from the team indirectly, yet to expect quick responses from everyone. (Kiesler et al. 1984 predicted the latter.) "Every time I sent an e-mail requesting "any thoughts" from everyone, I expected to receive one from everyone. And when I didn't, I felt that those who didn't respond were not holding up their end of the bargain," reported a member of Team 5. A member of Team 17 observed, "People always said, 'Hope to hear from you soon.' Who then has responsibility for initiating communication?" A member of Team 11 recalled sending e-mail "into the abyss," and GMU-based members of Team 6 discussed the feedback problem among themselves, but never with other members of their team. In an analysis paper, one wrote:

> We wanted acknowledgment of the time we spent on the deliverable as well as a feeling that we were on target. No one responded. We sent another e-mail saying that we hadn't heard from anyone. Finally, we heard from one group member, but even that message contained minimal information.

Clearly, the salience of the request for feedback was higher for senders than receivers. Thus, when electronic communication is voluminous, senders and receivers unwittingly may differ in what they find most salient and fail to fulfill their distant partners' expectations. This problem may be complicated by a tendency to state requests indirectly, yet expect quick responses from all members. In general, the level of feedback among members of a dispersed group is not likely to be as high as members would wish, and may not be sufficient to ensure shared understanding.

Relative Differences in Speed of Access to Information. Research has shown that teams using computer-mediated communication operate at a slower rate than teams meeting face-to-face (Lebie et al. 1996, Straus 1997, Straus and McGrath 1994, Walther and Burgoon 1992). However, this study surfaced a second type of problem involving speed: relative differences among team members in speed of access to information. One manifestation of this problem stemmed from differences among team members in access to communications technology. Some members had 24-hour e-mail access while their partners had access only when at their university. If some members see e-mail only once a day or once every few days, this limits the interaction that is possible and slows the pace of the team. Observed a member of Team 3, "Some problems dragged on for days while the suspicions of group members intensified. In reality, the problem could have been as simple as someone not being able to get to the computer lab to check their messages."

A second manifestation seemed to stem from differences in the speed of electronic transmissions among parts of a team. This was exemplified by the relationship among members of Team 5, which included two members in Australia and four members in the United States, two of them in Virginia and two in Texas. The team held five online chats during which tensions between the members in the United States and Australia were evident. Near the end of the team's fifth chat, an American team member observed that the Australian members always seemed to be "25 minutes behind the discussion" and suggested that this could be an artifact of the speed of transmission between the continents. The team members at the two United States locations could carry on a relatively rapid exchange until being "interrupted" by team members in Australia who referred to subjects from which the others had moved on.

I was not able to verify this hypothesis through chat room transcripts or other means. However, the explanation proposed by the team member is credible. Telephone lines carried most of the Internet traffic between the United States and Australia and they frequently became overloaded, resulting in breakdowns and time lags. This would mean that parts of the team were communicating at different rates—one rate between the two sites in the United States and another rate between the United States and Australia. This is a recipe for frustration and irritation for all. If the members in Australia responded to messages the instant they received them, their responses still would appear in the chat room traffic well after the conversation between the United States partners had moved on because of time lags coming and going. Moreover, from the perspective of the Australian partners, a stream of unrelated comments by the United States partners would always follow their messages. It would appear that their comments were ignored.

Both types of problems concerning relative speed

tended to be invisible to team members. Instead, they were attributed to remote partners' lack of conscientiousness. In addition, recognizing the constraints on access to information was only of limited help to the teams. The fact remained that it was difficult for team members to work "in sync" with one another. Although the source of problems sometimes was identified, suspicions and impressions that had formed tended to persist.

Interpreting the Meaning of Silence. One of the biggest challenges team members faced was interpreting the meaning of their partners' silence. Over the course of the project, it became clear that silence had meant all of the following at one time or another: I agree. I strongly disagree. I am indifferent. I am out of town. I am having technical problems. I don't know how to address this sensitive issue. I am busy with other things. I did not notice your question. I did not realize that you wanted a response.

Partners often misinterpreted silence. One common problem was interpreting silence as consent when it stemmed from disagreement or inattention. For example, United States members of Team 11 misjudged the silence of their Portuguese partners after an electronic vote. The Americans interpreted the silence as consent, and then began to wonder. When they inquired, their Portuguese partners replied, "Yes we are still (here), but you had decided everything. Now you should tell us what you want . . . We don't know (anything) about (the business idea that was chosen)." Similarly, a GMU member of Team 6 informed her teammates that she would be away during spring break. "I asked if I needed to submit anything for the home page before I departed . . . When I didn't receive a response, I assumed everything was in order." After she had left, her teammates began to write terse e-mails, asking for the address of her personal home page, which they wished to link to the team home page.

Silence due to technical problems or faulty information sometimes was interpreted as intentional nonparticipation. A member of Team 21 became concerned when various team members "did not respond to most of the e-mails and kept missing chat room meetings." He interpreted this as his partners' "unwillingness to work." It eventually was discovered that the U.S. partners thought the time difference between themselves and their Portuguese partners was six hours, when it was five hours. Times for the synchronous "chats" among the partners were communicated in error, which meant that the Portuguese partners would arrive at the appointed hour and find no one there. This confusion persisted over the course of four chats and two weeks before it was ironed out.

In meetings conducted face-to-face, it can be difficult to interpret the meaning of team members' silence. However, geographic dispersion and reliance on communications technology add new dimensions of uncertainty and complicate efforts to resolve the uncertainty. A partner could be out of town or silenced by technical problems. There may be a tendency to fall silent rather than address sensitive issues because of the difficulty of communicating nuances when using less rich communications media. In particular, uncertainty about silence can make it difficult to know when a decision has been made in a geographically dispersed group.

Clearly, the 13 dispersed teams struggled with problems involving the distribution and interpretation of information. The problems were serious. They affected individual working relationships and the viability of teams as wholes. Relationship problems were created and magnified by flaws in information management. These problems were difficult to correct. Corrective feedback was scarce and slow, and it was laborious to modify impressions in the face of new information. Impressions persisted in the face of corrected information. Table 3 summarizes the five types of problems identified.

Frequency of Problems

Table 1 displays the occurrence by team of each type of problem described above. The display includes indicators of team activity (the total number of e-mails logged, the number of online chats held, and communication with external sources of information), in-group/out-group dynamics (whether hostile coalitions formed), and performance (grades received). Also noted for each team is the occurrence and severity of technical problems such as the inability to access groupware, chat line, or e-mail servers when planned, the inability to transmit compatible files among team members, and the use of incorrect passwords or procedures. Table 4 summarizes the frequencies of occurrence and severity of each problem across all the teams. It shows that the most severe disruptions to teams' work were caused by uneven exchange of information and technical problems. These problems were serious in nine of the 13 teams. The most common problems across teams were difficulty interpreting the meaning of silence, uneven exchange of information, and technical problems. Difficulty interpreting the meaning of silence was "some problem" or "a serious problem" in all 13 teams. Uneven exchange of information and technical problems were "some problem" or "a serious problem" in 12 of the 13 teams.

Association with Strategies and Outcomes

I looked for relationships between the incidence and severity of particular problems in teams and a measure of

Table 3 Types of Information Problems

Failure to communicate and retain contextual information
Propositions: It is difficult for dispersed collaborators to gather, retain, and update information about the contexts in which their distant partners work, particularly as the number of locations increases. Reciprocally, dispersed collaborators often fail to communicate important information about their own context, situation, and constraints to their remote partners.
Examples of such information include the length of the trip to the office, the quality, accessibility, and features of equipment, measurement processes and standards; local holidays and customary practices, pressure from local supervisors and coworkers, local history and interpretive schemas, competing responsibilities, and local emergencies.
Unevenly distributed information
Propositions: Dispersed collaborators fail more often than they realize to distribute the same information to all members. Causes include human and technological error, and selective distribution without awareness of all its consequences.
Uneven distribution of information results in team members having different perspectives because of the different information they have. Partners with complete or correct information may not speak up when erroneous conclusions are voiced in the team. Impressions created on the basis of unevenly distributed information often persist in the face of correcting information. Uneven distribution of information distorts perceptions of the volume of activity in a team, and confuses the team's pacing and timing.
Differences in the salience of information among members of a dispersed collaboration
Propositions: Dispersed collaborators tend to be less successful than collocated collaborators in communicating to their partners what parts of their messages, or which messages, they consider most important. They may assume that what is salient to them will be salient to remote partners. In particular, requests that are stated indirectly may be salient to the person making the request but not salient to the object of the request. While this problem is not unique to dispersed teams, it may be problematic for them because of restricted back-channel feedback and often slow feedback cycles.
Relative differences in speed of access to information
Propositions: Dispersed collaborations are susceptible to problems that stem from parts of a team communicating at different rates. Some members may be in frequent contact with one another while others are heard from less often. Causes include differences among parts of a team in the speed of electronic transmissions or in access to communications technology. This means that partners are not synchronized in terms of their access to information and their ability to detect and correct misunderstandings. The structural causes of these types of problems tend to be invisible to team members. Even when recognized, differences in communication rate pose problems for collaboration.
Interpretation of the meaning of silence
Propositions: Dispersed collaborators often are uncertain about or misinterpret the meaning of their remote partners' silence. Geographic dispersion and reliance on communications technology add new dimensions of uncertainty to the meaning of silence and complicate efforts to resolve the uncertainty. There may be a tendency to fall silent rather than address sensitive issues because of the difficulty of communicating nuances using the available media. Uncertainty about silence can make it difficult to know when a decision has been made in a geographically dispersed group.

Table 4 Frequency of Problems Across Teams (in percentages)

	Type of problem					
Extent of problem	Lack of contextual information	Unevenly distributed information	Differences in salience of information	Differences in speed of access	Meaning of silence uncertain	Technical problems
Serious problem	54	69	23	23	46	69
Some problem	23	23	46	38	54	23
Not a problem	23	8	31	38	0	8

performance (i.e., grades received), the incidence of hostile coalitions, and the number of e-mails and chats logged. I also looked to see whether teams could be grouped by their task and relationship management strategies. The data suggest four constellations: (1) good performance, task focus, moderate relationship demands, relatively low volume of communication, and low coalition activity; (2) good performance, high task and relationship demands, relatively high volume of communication, and high coalition activity; (3) weaker performance, relatively high volume of communication, many and diverse information problems, and high coalition activity; and (4) weaker performance, relationship focus, task secondary, relatively high volume of communication, and low coalition activity. There were no obvious direct relationships in this small sample between the incidence and severity of particular information problems and performance. Information problems seemed to be more damaging to relationships than to task performance. It also seemed to matter how members dealt with the information problems that occurred: the extent to which they extended the benefit of the doubt when remote partners did not behave as expected, and the extent to which they were able to identify aspects of the situation that helped explain behavior that was contrary to expectations.

Thus, teams with an average grade of 90% and above seem to constitute two types: those that exchanged relatively little e-mail and did not develop coalition activity, and those that exchanged more e-mail and developed coalition activity. Teams 26, 30, and 21 fit the first category and Teams 15, 11, and 17 fit the second. The three teams that earned a grade of 90 or above and avoided the development of hostile coalitions emphasized minimalism and closure in their work processes and tended to give remote partners the benefit of the doubt. In other words, they kept task and social demands relatively low. They exchanged some personal information at the outset, but otherwise tended to focus on the task at hand. The tone was businesslike but gracious. Through skill or luck, they agreed quickly on a viable idea for a business and then focused on implementing the idea. Giving remote partners the benefit of the doubt was important, as each of these teams did encounter significant information exchange problems early in their lives that easily could have escalated. However, members' interpretations of these events, attributions made about remote partners, and consequent behaviors did not accelerate the development of hostile relationships in the team. They struggled to maintain a gracious tone despite unanswered questions, seeming slights, and frustration.

For example, Team 26 exchanged only 65 messages, less than half the number that many other teams exchanged. The average grade it received on its project was second highest among the thirteen teams studied. Individual introductions were brief and businesslike, but the tone of communication was gracious overall. One team member repeatedly modeled this behavior, while still taking a strong stand on a few issues. The team's communication is peppered with comments such as "Good ideas!," "Thanks for the vote of confidence," "Great pic," and "What a talented group!" The group encountered a serious challenge early on because of errors in e-mail addresses involving both the GMU and TCU partners. The upshot was that four of the six team members voted to accept a project idea that the two GMU members had never even received, while a project proposal from GMU bounced back undelivered from TCU. Both GMU members noted in their analysis papers that they were irritated by this event; however, one of them added, "I do understand why this occurred. An initial phase of confusion is to be expected in virtual teams that rely primarily on e-mail for communication." In other words, he made a situational rather than personal or categorical attribution. When new challenges involving differences in context, constraints, and ideas arose for the team, they were handled in sophisticated ways. Confronting disagreements over elements of the business plan, a team member in Canada wrote, "Greetings, friends. We seem to be at odds over what our company should be doing . . ."

In the other three teams that earned a grade of 90 or above (Teams 15, 11, and 17) some members were determined to turn in a quality product and managed to do so. However, life inside the team was turbulent. Attempts were made to extend the benefit of the doubt to remote partners; however, attributions grew harsh. For example, a member of Team 11 eventually wrote, "We got a cheap excuse (from the Portuguese partners) that I did not buy." Ultimately, partners at two of the three locations began planning to do the project as a group of four and discussed whether to withhold the names of the out-group members from the finished product. It may be that the approach to the task these teams took was relatively demanding, and it overwhelmed the team's social capacity and available communication media. For example, these teams debated longer on the kind of business they would design than did Teams 26, 30, and 17. When information problems occurred, they were difficult to resolve and did considerable damage.

The same problems and processes appeared in a more virulent form in Teams 5, 3, and 39, whose grades averaged below 90 percent and who had a relatively high volume of communication, frequent and diverse information problems, and fierce coalition activity. Almost all

of the teams with much coalition activity included students who were high achievers, judging from the quality of their work in my course overall. They may have demanded more from the dispersed mode of work and their remote partners than could be delivered. For example, Team 5 subjected ideas to intense scrutiny but struggled in the aftermath to maintain working relationships. Reflected a member of Team 3, "Our group lacked any real talent for offering compromises and moving on." Another member of Team 3 described the behavior of partners as "belligerent, lackadaisical, and indifferent." These groups seem to have become caught in destructive and self-reinforcing patterns of interaction to which dispersed teams are susceptible.

On the other hand, Teams 6 and 37 privileged harmony over quality. Team 6 is an outlier in that its e-mail volume was the highest of all the teams and its internal relationships appear to have been the most positive. Members of this team realized early on that uneven distribution of information among team members could be a problem and invested considerable effort in avoiding this situation. However, the team's work product was not graded as highly as that of some of the other teams. In analysis papers, members of both Teams 6 and 37 suggested that desire for harmony in the team had interfered with scrutiny of business ideas. Wrote a member of Team 37, "(We) felt we should go along with the other members' ideas . . . even though we did not agree with them . . . The whole team was never in conflict. Everyone was very polite."

Integrative Model

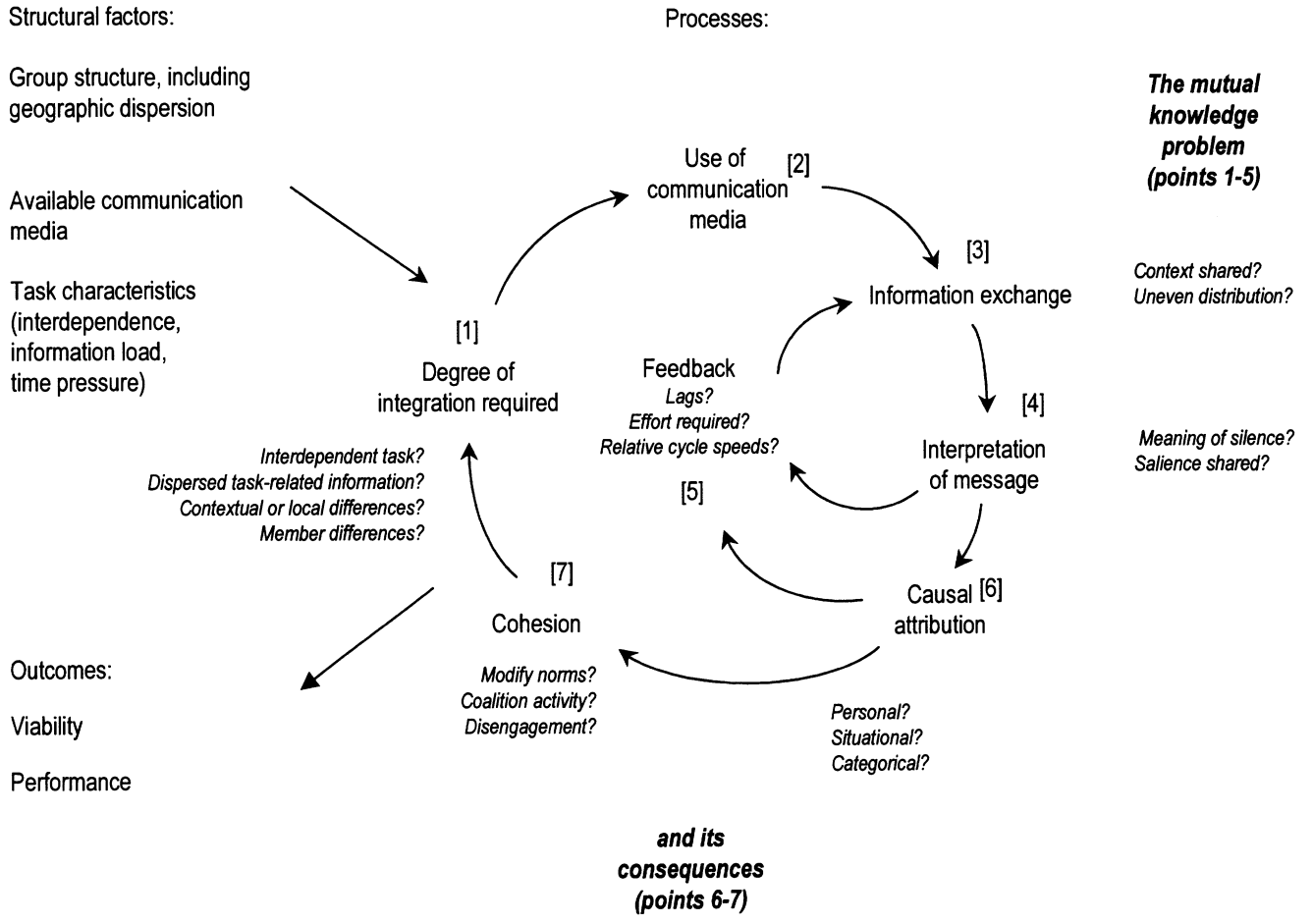
Figure 2 summarizes the processes I observed. It focuses on the challenges dispersed teams face in integrating individual member contributions and maintaining social integration in light of the mutual knowledge problem and its consequences. The task requirements, context, and composition of the group establish the degree of integration required for effective performance and how difficult to achieve this is likely to be (see Point [1] in Figure 2). For example, a complex task may require a high level of integration of individual expertise for success. However, achieving this integration will be more challenging if group members start from different social and practical realities—e.g., come from or live in different cultures, have different functional backgrounds, are working across organizational boundaries, or are widely dispersed geographically from one another. In addition, the characteristics of the available communication technologies, their appropriateness for the task at hand, and how the group uses these technologies (Point [2]) represent another set of enabling and constraining conditions (DeSanctis and Poole 1994, Maznevski and Chudoba 2000, McLeod 1996).

Failure to exchange adequate information about context and failure to distribute the same information to all members of the team constitute two major pitfalls in information exchange (Point [3]) to which dispersed teams may be subject. It may also be difficult for team members to retain and update information about remote contexts provided by their distant teammates. As a consequence of these failures, group members are more likely to work from different definitions of the situation, which handicaps communication and collaboration. In addition, failure to share and retain up-to-date information about context contributes to communication breakdowns by limiting the ability of senders to frame communication in a decentered rather than self-centered way. Messages framed in a decentered or receiver-centered way have a better chance of being interpreted accurately (Point [4]) (Blakar 1985). The likelihood of tension is probably greater if group members' social and practical realities are quite different from the outset (Point [1]); however, subsequent aspects of interaction may add to the confusion. Human error in using technology and technical failures can create information distribution problems in an otherwise untroubled situation. However, once tensions have begun to develop, negative attributions have been made (Point [6]) and coalitions have formed (Point [7]), members may be more inclined to distribute information selectively among team members, and problems escalate.

Exchange of information is just one part of the communication process. Receivers must "decode" the symbols that constitute a message and interpret the meaning of the sender (Redding 1972, Rommetveit 1968). The contexts within which senders and receivers encode and interpret information are likely to differ when their geographic locations are distant, increasing the likelihood of misinterpretation. This problem is exacerbated by failure to exchange sufficient information about context. Two other possible pitfalls at this stage (Point [4]) of the process are the drawing of erroneous conclusions about remote partners' silence, and differences in the salience to sender and receiver of different parts of a message, leading to differing interpretations of the message.

The available information and how it is processed affects attributions (Point [6]). I propose that personal attributions are made about remote partners more often than collocated partners because more information is available about the local than the remote situation. The complexity of dispersed structures and processes also makes situational attribution difficult. Interpretations and attributions can be checked through feedback, however geographically dispersed groups face three challenges: time lags,

Figure 2 The Mutual Knowledge Problem and Its Consequences for Dispersed Collaboration



the effort required to seek and give feedback when dispersed, and relative differences that may exist in feedback speeds among parts of the group (Point [5]). Slow feedback cycles (Point [5]) reduce corrective feedback and increase the likelihood of erroneous interpretations (Point [4]) and exaggerated attributions (Point [6]).

Finally, there may be a tendency to generalize such social perceptions, particularly negative ones, to the locational subgroup of which a person is a member, which sets in motion in-group/out-group dynamics (Point [7]) that are destructive to group cohesion. In some cases that I studied, collocated partners relied increasingly on each other, criticizing their remote partners among themselves and sometimes disengaging from the group's work. In other cases, subgroups in two locations exchanged critical e-mail about the third subgroup and refused to send them work products. Typically, an important piece of information was not sent, sent to the wrong place, or lost in transit (Point [3]), which affected the conclusions drawn by all parties (Point [4]) and led to negative attributions to individuals and subgroups (Point [6]) and the disintegration of relationships (Point [7]). Sometimes, problems were mitigated when errors were caught in the course of a feedback cycle (Point [5]). However, there were instances in which this correction was so slow in coming that those involved were unable to trace and modify all the faulty conclusions they had drawn. The cycle depicted in Figure 2 can be self-reinforcing: The problems of information exchange, interpretation, and attribution described here, and their disintegrative effect on team relationships, add to the already substantial integration challenge confronted by a geographically dispersed group (Point [1]).

Discussion

This paper proposes that a central problem of geographically dispersed collaboration is maintaining mutual

knowledge. Both physical dispersion of collaborators and frequent use of communications technology tend to negatively affect the means by which people establish mutual knowledge. I also suggest that failure to establish and maintain mutual knowledge can have serious consequences for the viability of dispersed collaboration. My empirical findings support and develop this theory. The five specific problems I identified inductively are manifestations of the mutual-knowledge problem that are especially likely under conditions of physical dispersion. I describe ways in which these problems interact, exacerbating factors, and typical consequences. While failure to establish and maintain mutual knowledge may be more likely and serious when collaborators are physically dispersed, the problems, processes, and consequences are probably not limited to dispersed collaboration. I offer grounded suggestions about how and when these dynamics might appear in collocated collaborations.

Failures of Information Exchange

Two specific problems that came to light in this study concern failures of information exchange which result in dispersed partners having different information, but not knowing this is the case. Members of the teams I studied often failed to guess which of the many features of their context and situation differed from the contexts and situations of remote partners. They did not communicate critical local information. Second, team members failed far more often than they realized to distribute the same information to all members. Causes included human and technological error, and selective distribution without apparent awareness of all its consequences.

Identification of these failures of information exchange extends our understanding of both mutual knowledge and dispersed collaboration. One reason that geographic dispersion poses challenges to collaboration is that locations are likely to differ. Differences can include the length of the trip to the office; the quality, accessibility, and features of equipment; measurement processes and standards; local holidays and customary practices; pressure from local supervisors and coworkers; local history and interpretive schemas; competing responsibilities; and local emergencies. In addition, dispersed teams may be more likely than collocated teams to include members with different cultural backgrounds and organizational affiliations, which introduce still more contextual differences. People who wish to collaborate must discover and work across these differences.

However, my research suggests that dispersed collaborators are not skilled at discovering and communicating about such differences. In addition, when the information *was* mentioned in the teams I studied, remote partners sometimes failed to note or remember it. This makes sense when we think of local information as a "hidden profile" (Stasser and Stewart 1992; Stasser et al. 1995; Stasser and Titus 1985, 1987). According to the principle of information sampling, uniquely held information is less likely than commonly held information to be mentioned in group discussions. If mentioned, it is less likely than commonly held information to be salient to group members. These problems are exacerbated by high information load (Stasser and Titus 1987) and use of text-based communication technologies (Hightower and Sayeed 1995, 1996; Hollingshead 1996). Thus, members of dispersed teams may have difficulty achieving mutual knowledge of important aspects of the situations and contexts in which partners function. In addition, the problem of unrecognized differences in context exacerbates other problems described below.

Unrecognized differences in context should be less of a problem for collocated teams than dispersed teams to the extent that collocated team members share context in common. Collocated teams also have more powerful ways of discovering differences, such as visual inspection and face-to-face communication. Future research should compare the mechanisms by which members of collocated and dispersed teams identify differences in situations, constraints, and assumptions. In addition, research should continue to examine how dispersed collaborators handle contextual information. It would be useful to identify conditions under which they are able to form mental maps of the situations of remote partners and update them as situations change. We may also wish to compare the ability of dispersed collaborators to detect differences in task-related information across locations relative to differences in context, including cultural context.

Communication across distance and via technology was shown in my study to be a particularly leaky process. Messages were addressed incorrectly, undelivered, or deliberately not sent to team members. People worked from different information far more often than they realized, and this caused serious problems in communication and relationships. Confusion and conflict was promulgated not just by different interpretations of the same information, but also by different interpretations of different information. I have shown that members often blamed each other for their frustrations.

This problem has implications for the development of trust in dispersed collaboration. Jarvenpaa and Leidner (1999) and Jarvenpaa et al. (1998) found that trust in dispersed teams was predicted most strongly during the early phases of team activity by perceptions of other members' "integrity," by which they mean "adherence to principles thought to make the trustee dependable and reliable" such

as demonstrated work ethic, fair dealings, and consistency" (Jarvenpaa et al. 1998, p. 31). The authors propose that trusting action and demonstrated reliability increase trust in dispersed teams. However, my work suggests that human and technical errors in information distribution may be common in dispersed collaboration, particularly during the early phases of activity. If these are interpreted as failures of personal reliability, they are likely to inhibit the development and maintenance of trust.

Failures of Interpretation

This study also identified three problems that disrupted shared interpretation of information in the dispersed teams: difficulty communicating and understanding the salience of information, differences in speed of access to information, and difficulty interpreting the meaning of silence. When problems of salience occurred, partners had the same information but attended to different parts of it and misunderstood each other as a result. While this problem is not unique to dispersed teams, it probably is exacerbated by the use of computer-mediated communication. The medium does not provide the paraverbal and verbal cues that people use in conversation to signal the importance of one piece of information relative to another. Furthermore, failure to communicate salience may be more costly in dispersed than collocated collaborations because of slow feedback channels and restricted backchannel feedback. Slow and effortful feedback limits detection and correction of misunderstandings. Kiesler and Sproull (1992, Sproull and Kiesler 1986) described how computer mediation restricts cues to the meaning of communication. I focus on the problem of signaling the importance of one piece of information relative to another and how this problem is manifested in dispersed collaboration and exacerbated by the other problems identified in this study.

The members of the dispersed teams I studied also had difficulty working together when the speed of feedback cycles differed among parts of the group. Some members were in frequent contact with rapid feedback cycles, while contact with others was limited and slower paced. These differences were caused by differences in access to communication technology and the distribution of members across distance and time. The teams were not synchronized in their access to information and ability to detect and correct misunderstandings, and so had a difficult time maintaining mutual knowledge.

This observation reveals a new side of the issue of rate in computer-mediated communication. Researchers have shown that the rate at which computer-mediated communication proceeds affects group productivity and the development of relationships (Straus 1997, Straus and McGrath 1994, Walther 1992, Walther and Burgoon 1992). My finding calls attention to the consequences of parts of a group communicating at different rates. Future research should explore whether uneven feedback cycles within a group have a different impact than uniform feedback cycles. Uneven feedback cycles across parts of a group could be more destructive than a uniformly slow pace because subgroups grow out of sync with, and isolated from, the group. This could result in their becoming scapegoats. Ironically, feedback cycles may be slower and more uneven among parts of a group under just those conditions for which rapid cycles are most needed: when the contexts of senders and receivers differ substantially. For example, feedback cycles may be unpredictable when part of a team is traveling constantly or located in an area with a weak communications infrastructure.

Finally, I observed that team members often misinterpreted the meaning of their remote partners' silence. Physical dispersion and dependence on communications technology add sources of uncertainty about the meaning of silence beyond those experienced by groups that meet face-to-face. Partners may fall silent because they find it difficult and time-consuming to convey sensitive issues in text, or because of technical failures. They may be silent because they agree, because they disagree, or because they are physically absent. In the mutual knowledge literature, Brennan (1998) describes how lack of feedback (i.e., silence) leads to failures of grounding in conversations with and through computers. Without feedback, one does not know whether a computer is working, has completed the task, has malfunctioned, or is waiting for additional inputs. I broaden her point by showing how physical dispersion presents additional sources of uncertainty as to the meaning of partners' silence.

Consequences for Attribution

The failures of information exchange and interpretation identified in this study have consequences for attribution processes. They illuminate two reasons why people are likely to make personal rather than situational attributions concerning remote partners. First, failure to share and remember information about remote situations and contexts, and uneven distribution of information, mean that remote partners often lack information to make situational attributions. According to the attribution literature, when people do not have situational information, they tend to make personal attributions, i.e., their explanations focus on the dispositions of individuals (Jones and Nisbett 1972, Nisbett et al. 1973).

The study also demonstrates the complexity of communicating and collaborating across distance and via

technology. Information about multiple locations must be gathered, integrated, and updated. Multiple possible explanations for unexpected behavior and silences must be weighed and investigated. Exchanges between subgroups must be reported to the whole. Feedback lags, which may be different for each location, must be taken into account. There is considerable evidence that when people work under heavy cognitive load, they become more likely to make personal rather than situational attributions (Gilbert and Hixon 1991, Gilbert and Osborne 1989, Gilbert et al. 1988).

Falling back on personal attributions because of a lack of information or information-processing limitations amounts to blaming individuals for problems that may have broader causes. This distracts partners from full diagnosis of problems and modification of practices to prevent reoccurrences. It also damages partners' opinions of each other. These points are consistent with the observations of Blakar (1984) and Hultberg et al. (1980) concerning the effects of personal versus situational and constructive versus nonconstructive attributions among the family members they studied.

Attribution processes among people who collaborate across distance and through the use of computer mediation merit additional attention. One of the contributions of this study is harnessing the power of the well developed literature concerning attribution to help understand the development of such relationships. Two information-based antecedents of attribution, situational information and cognitive load, are explored in this study. However, the attribution literature describes additional information-based antecedents of attribution, as well as a number of motivation-based antecedents. (See Kelley and Michaela 1980 for a summary.) This literature could help us understand how dispersed collaborators make sense of their complicated world.

Future research might also explore whether cognitive load is indeed higher in dispersed than collocated teams, and trace all its consequences. Two consequences are discussed in this paper: bias toward dispositional attribution and difficulty identifying uniquely held information. However, there could be other consequences over time, such as stress or burnout. In addition, the concept of cognitive load facilitates application of these findings to collocated teams: Members of collocated teams may be most likely to encounter the problems of mutual knowledge, and their consequences discussed here, when members are experiencing heavy cognitive load.

The data suggest that processes that began with failures of mutual knowledge and produced personal rather than situational attribution eventually led to the fracturing of some teams into in-groups and out-groups. There was a tendency to generalize attributions, particularly negative ones, to others at the same location. Team members' analysis papers describe remote *subgroups* as "lackadaisical," "aggressive," and having an "inferiority complex." This is consistent with the work of Lea and Spears (1991, 1992, 1993) who suggest that people using computer-mediated communication tend to categorize remote others on the basis of meager cues. In a dispersed team, one salient basis for social categorization is location, e.g., the California group or the Portuguese group or the client-site group. According to the literatures concerning group identity and in-group/out-group conflict, such tendencies are exacerbated by weak team integration (Karakowsky and Siegel 1995, McDonald 1995) and the need for a target for displaced hostility (Brewer 1986). Frustration in search of an outlet may build up in dispersed collaborations because of the elusive problems of information exchange and interpretation described in this study, and other structural and technical challenges. Once in-group/out-group dynamics had arisen in the teams I studied, subgroups tended to withhold information from each other. This erodes mutual knowledge to a greater degree, and worsens problems. It also creates differing impressions among parts of a group of the group's timing and pace, impacting motivation and coordination.

Future research should explore the role of social categorization processes in dispersed work groups, including generalization on the basis of location. Dynamics involving subgroups should be investigated because dispersed teams in practice typically include collocated subgroups (Goodman and Wilson 1998, Leonard et al. 1998, Maznevski and Chudoba 2000, Mazchrzak et al. 2000, Snow et al. 1996).

Association with Performance

There were no clear relationships between team performance and particular problems of information exchange and interpretation, or the general incidence of such problems. Failures of mutual knowledge were ubiquitous across the teams. Although it was possible to distinguish different team performance strategies, no one strategy was associated with high performance. However, performance strategies did seem to be associated with different *relational* outcomes in the teams. Future research should return to this issue with more sensitive task designs. In particular, designs should vary the distribution of task-related information across locations and the amount of interdependence required of team members. Using such tasks, relationships among team performance, performance strategies, and the failures of mutual knowledge identified in this study should be examined.

Amplifying and Moderating Forces

Feedback lags seem to amplify the problems of information exchange and interpretation identified by this study. Krauss and Bricker (1966) demonstrate that feedback lags disrupt the ability of senders and receivers to establish common referents, a building block of mutual knowledge. In addition, this study suggests that feedback lags contribute to the exaggeration of negative attributions concerning remote partners and make it more difficult for dispersed collaborators to diagnose their situation.

Without feedback, deprived collaborators are left to speculate why their expectations have not been fulfilled and when feedback will come. In the absence of situational information, they are likely to make negative attributions concerning the dispositions of their remote partners. These attributions can grow more negative as waiting continues. Deprived collaborators also sometimes amplify their demands, triggering an exaggerated response from their remote partners. The situation is like that of the person who ultimately turns the hot water up too high in the shower because of time lags between turns of the faucet and response. One participant said as much: "Some problems dragged on for days *while the suspicions of group members intensified.* In reality, the problem could have been as simple as someone not being able to get to the computer lab to check their messages." The speed of feedback cycles may constitute a critical constraint for geographically dispersed groups.

In addition, feedback lags and dispersed information make it extremely difficult for people to get an overview of the structure and functioning of a dispersed system of relationships. Actions and reactions are difficult to interpret when disrupted by lags in feedback. Blaming is a common response when individuals do not grasp the structure and dynamics of complex systems of which they are a part (Bowen 1985, Senge 1990). In future research, systems dynamics theory (Sterman 1989) might contribute to our understanding of the impacts of distributed information and feedback lags on dispersed collaboration and computer-mediated communication.

In both dispersed and collocated collaboration, problems establishing and maintaining mutual knowledge are most likely to occur when there is a great deal of uniquely held task-related and contextual information and limited communication channels. Exacerbating factors can be expected to include heavy cognitive load, a complex interdependent task, tight time limits, and a complex team design—particularly one involving strong subgroup identities, which may reinforce local perspectives.

For situations in which these factors are operating, practices that should moderate problems include methodically seeking out situational and uniquely held information, giving prompt feedback whenever possible, focusing on the overall structure and processes of the system of relationships rather than on individuals, reexamining group operating practices and norms, and extending the benefit of the doubt rather than engaging in the creation of out-groups. The overall effect of these practices is to direct attention to group-level diagnosis and learning.

Limitations

The mode of generalization appropriate to case study research is analytic generalization—generalization to theory rather than statistical generalization (Yin 1994). Therefore, it is important to articulate how the teams studied here may be typical and atypical of geographically dispersed work groups. Geographically dispersed work groups take many different forms in practice (Goodman and Wilson 1998, Leonard et al. 1998, Maznevski and Chudoba 2000, Mazchrzak et al. 2000, Snow et al. 1996). The teams I studied probably are atypical in the limitations they faced around means of communication. Travel, videoconferencing, and telephone conferencing were not an option for them, and they were limited by personal expense in their use of the telephone. Occasional face-to-face meetings and more telephone contact might moderate the processes observed; however, there is reason to think that basic tendencies might be the same. Additional modes of contact could contribute to uneven exchange of information among parts of a team if used extensively by dyads or subgroups.

Several team design factors should also be noted: group identity and time frame (discussed in Walther 1997), interdependence, and composition. The local university-based subgroups of the teams studied probably had a considerably stronger basis for identity than the teams as wholes. While dispersed teams in practice are often composed of people from multiple organizations and subgroups with strong identities, the weak basis for team identity should be taken into account. Likewise, the teams' seven-week time frame is not unusual in business practice; however, its relative shortness and the teams' low expectation of future interaction should also be noted. As discussed previously, the team's level of interdependence could be characterized as moderate. They carried out a project that required research, creativity, and a range of skills with outcomes of significance for the members. The teams were composed of adult professionals representing a range of ages with moderate international and technical experience. We must continue to examine the forms that dispersed collaboration takes in practice and

take these structural factors into account in our research designs and theories.

Another limitation of the study is the use of one primary judge of the meaning of the data. Case study and multiple case study methodologists struggle with the issue of reliability, given the unwieldy form of the data and the time required to review it, and this study faces the same challenge. This work followed the recommended practice of preserving a case study database and case study protocol (Yin 1994) so that another researcher could review the process. Following Eisenhardt (1989), the protocol included two reviews of all the cases that were aimed at testing reliability, one after initial formulation of constructs and the second after formulation of the model to refine or refute emerging conclusions.

There are also some safeguards peculiar to this study. There was a clear standard as to what constituted the foundation of the data because every effort was made to develop complete e-mail histories of each team. Communication and the flow of events were preserved in a record that did not reflect the choices of a researcher. While I was the final judge of the meaning of this communication and these events, I did compare my impressions with those recorded separately by a research assistant and by 26 participants in the teams. When these impressions diverged, I could and did minutely examine the e-mail records to try to understand the divergence.

In addition, I provided numerous detailed examples in this report so that some assessment of the evidence can be made in lieu of a full review of the records. Gersick (1988) observes that the advantage of a single patient judge of meaning is that analysis is done consistently, yielding understanding of a whole event. However, this will always be one side of a trade-off in a study such as this one.

A third limitation is that this study did not compare the dispersed teams with collocated teams, so we cannot determine the extent to which the problems and processes described also occur in collocated collaborations. This issue must be explored empirically. However, I have taken care to describe when we might see these dynamics in collocated collaborations, and to provide grounded reasons why failure to establish and maintain mutual knowledge should be more likely and more serious in dispersed collaborations.

Implications for Practice

While the conclusions offered here are tentative, designers and members of geographically dispersed teams may still be interested in the implications for practice. This work suggests that designers of dispersed teams should aggressively explore in advance potential differences in situations and incentives that will affect team members. Goals, incentives, and situations should be aligned whenever possible. When they cannot be, these differences should be brought to all team members' attention.

Ideally, all members of a dispersed collaboration should be sent the same information. Beyond the content of the information, this provides each member with an accurate picture of the *pace* of activity in the collaboration, including any differences in pace among subgroups. In practice, however, the information load could be overwhelming. If there is a risk of overload, leaders and members of dispersed teams should communicate information that establishes or makes adjustments to the parameters of collaboration such as (1) the availability of members (including identification of holidays), and constraints on availability such as competing responsibilities; (2) the objectives of the collaboration and solution contexts; (3) local requirements, customs, processes, and constraints that bear on member availability, objectives, or solutions; (4) means of communication and norms, including backup procedures; and (5) reports on the pace of activity overall and the pace in any subgroups.

Members of dispersed teams and people communicating via computer mediation should resist making assumptions about the situation and constraints of remote others. Instead, they should actively seek out such information. It is also important for individuals to monitor the tendency to leap to dispositional attributions about remote partners. Situational causes should be considered, even if information to support them is not immediately available. In addition, prompt feedback when possible helps everyone in a complex distributed system to correct inaccurate interpretations and attributions. Training in systems thinking may be useful for members of distributed work groups by helping them appreciate the structure, processes, and time lags of the system of which they are a part.

We have entered a new era of collaborative activity, one in which it is feasible for work groups to span time zones rather than yards or miles. There are many advantages to be gained through the use of such groups. However, their usefulness will be maximized if we understand characteristic dynamics sufficiently well, so that effective team designs can be developed and effective training can be offered. The literature on computer-mediated communication has led the way by exploring the nature of communication in such groups. However, it is argued here that not only the mode of communication but also the fact that these groups are complex distributed dynamic systems will affect processes, and outcomes. We know that people tend not to be sensitive to the structure, processes, and time lags of the systems of which they are

a part. However, successful collaboration in geographically dispersed work groups may hinge on members mastering these skills: grasping local realities and the big picture, establishing mutual knowledge, taking into account the dynamics of feedback processes, and understanding the processes linking distant but interdependent parts.

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