Computer-Mediated Communication for Intellectual Teamwork: A Field Experiment in Group Writing

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To work together on complex projects, people must agree on a set of shared goals, coordinate the actions of contributors, and weave the components they have created independently into a unified whole. These activities are the basic components of intellectual teamwork---people working together over substantial periods of time to create information-intensive products. Intellectual teamwork demands extensive information sharing and coordination, but these communication needs vary over time and over tasks. These projects typically involve an initial phase during which group members settle on an interpretation of the problem, define their goals and plan their work, an execution phase during which group members may work independently to carry out the various tasks associated with the project, and an integration phase during which group members must bring their individual inputs together to create a final product [Biks90; Finh90; Krau88; McGr90).

These variations suggest that different communication modalities may be useful at successive stages in the life of a long-term project. A relatively static medium such as writing may be sufficient for exchanging information, but tasks that involve ambiguous goals, multiple perspectives, and information that is susceptible to multiple interpretations---characteristics of the planning and integrative phases of intellectual teamwork---are typically associated with high levels of direct, informal, face-to-face communication [Daft81; Daft87; Tush78, Tush79; Vand76]. Face-to-face interaction can support the rich communication required for integrative work, but creating the conditions to support face-to-face communication can be expensive, and sometimes, logistically impossible.

Of course, other forms of communication---telephones, for instance---are available to counter these disadvantages. Telephones permit easy communication across both short and long distances, and they support naturalistic interaction embodying many of the features of Face-to-Face conversation. Nevertheless, as anyone who has ever played an extended game of "telephone tag" knows, they require the sender and the receiver to be simultaneously available. This limitation is inconsistent with current communication needs in business and science, both of which are becoming, on the one hand, more geographically and temporally distributed, and, on the other, more interconnected.

These considerations have prompted people to turn to electronic mail and computer conferencing to counter the costs and restrictions associated with face-to-face communication and the demand for synchronous availability associated with telephones. Some studies have shown that computer-mediated communication can help bring people into contact with each other, and that it is both popular and easy to use [Feld87; Huff88; Joha88; Krau90]. Nonetheless, there are reasons to suspect that it may be problematic for some aspects of complex collaborative work.

First, the lack of interactivity associated with e-mail and computer conferencing creates problems because communicators are unable to modify messages as they create them in response to signals from their communication partners. Second, although computer-mediated communication allows individuals to address all group members simultaneously, responses are likely to be directed to the original sender, resulting in pairwise interactions that undermine the level of mutual knowledge within the group as a whole. Third, computer-mediated communication can lead to uncertainties about the activities of others that do not arise when more direct contact is possible. Finally, during project planning and the integration of interim products, it is often helpful for all members of a workgroup to be able to view, refer to, and manipulate a shared document or other artifact.

These demands may depend on the divisibility of the project [Katz78; Tush78; Tush79] A restricted communication medium should have a smaller impact on the execution of a project that can be easily divided between group members than on the execution of a project that requires more intricate coordination. Thus, computer-mediated communication may have different value during different phases and for different types of team projects. Indeed, some recent research on the uses of electronic mail tends to support the model we have sketched here. For example, Finholt, Sproull & Kiesler's [Finh90] study of ad hoc task groups indicates that electronic mail is typically used for coordinating work rather than for substantive discussion [See also Sumn88.].

To assess the utility of computer-mediated communication for various types and phases of intellectual teamwork, we constructed an experiment in which the participants carried out a complex collaborative writing project. In this experiment, defining the contents of the required document and the strategy for constructing it were treated as the planning phase, original writing as the execution stage, and revision and assembly of the final document as the integration phase. The experiment assesses the effects of task divisibility and communication modality on work processes, on group performance, on individual experiences in the group and on the extent to which group members feel that the group is a viable, cohesive social entity.

METHOD

Design

One hundred and seventeen first-year MBA students enrolled in a managerial communication course were randomly assigned to three-person groups, which were, in turn, randomly assigned to experimental conditions. Each student participated in two different groups, one for each of two two-week-long projects. The two projects differed on the basis of divisibility, and, for each project, there were three different communication conditions. Project Divisibility had two levels (Divisible vs. Integrative). Communication Modality had three levels (Face-to-Face, Computer Only and Computer+Phone). For the first project, one half of the groups were assigned to the Face-to-Face group and the other half was evenly divided between the Computer Only and Computer+Phone conditions. For the second project, students who had previously

been in Face-to-Face groups were assigned to one of the two Computer-Mediated groups, and students who had previously been in Computer-Mediated groups were assigned to Face-to-Face groups.

Independent Variables

Project Divisibility. Students were required to carry out a divisible project and an integrative project, each of which involved responding to the dilemmas presented in a business case. In the divisible case, the students were required to write several documents to announce and justify news of a lay-off to different audiences. We believed that the demands for integration were reduced in this project, because different students could write different documents with only moderate coordination. In the integrative case, students were to analyze a company's personnel problems and recommend solutions in a single report to management. Compared to the divisible project, the proposal required in the integrative project imposed a greater demand for joint planning and integration of individual contributions.

Communication Modality. In the Computer Only condition, students were required to conduct all project-related interactions through a computer conferencing system called ICoSy, which supports both person-to-person electronic mail and person-to-group computer conferences. Each project team had a separate conference. In the Computer+Phone condition, students were allowed to use the computer conference and to telephone each other. In the Face-to-Face condition, the participants could conduct meetings, telephone conversations, and exchange documents, but were not allowed to use the computer conference.

Dependent Variables

Time Series Data. Each day, students recorded the type of work they had done. Based on a factor analysis, we classified these activities as planning (e.g., Planned how to complete the assignment; Planned who would do what), writing (e.g., Did new writing on project documents), or revising (e.g., Revised another's writing; Evaluated initial drafts). Students also evaluated the progress of the group, the difficulty of coordinating the work, the fairness of the division of labor, the quality of the procedures they were using to communicate, and their feelings about other group members. They also reported how many "communication occasions" they had had with other group members that day, and provided detailed information (e.g., time of day, type of contact, duration, topics discussed, enjoyableness, productivity) about a selected communication.

Retrospective Data. After each of the two projects, students completed questionnaires containing items that described features of (1) the group's work procedures and performance, (2) their own experiences during the project, and (3) the interpersonal dynamics of the group. After completing both projects, students compared face-to-face communication to the other modalities used in the experiment in terms of their usefulness for work and social activities.

Process Data. To obtain a record of the students' work procedures, we retrieved the computer conference files created by the groups in the Computer conditions, and asked students in the Face-to-Face conditions to tape record their scheduled meetings. Because of space constraints, only general descriptions of these data are presented in this report.

Performance Data. Each group's final report was scored by three people. The effective reliability was .77, a satisfactory level of inter-rater agreement.

Analysis

The goal of this report is to determine if the limited interactivity and bandwidth of computer-mediated communication influences groups' ability to perform sustained intellectual team work, and whether these effects depend on the groups' tasks and phases. In the analyses that follow, groups are the unit of analysis. The time series measures were created by finding the mean values within each group for each day of the project. Dependent measures were analyzed using a 3 (Communication Modality) X 2 (Task Divisibility) X 15 (Days) analysis of variance, with days as a within group factor.

The data analysis focuses on the main effects of the communication condition and project type, and on how these manipulations interact with time. Communication Modality x Time interactions are taken as evidence that the effects of computer-mediated communication depend on a project's phase. For most analyses, the Computer Only and Computer+Phone groups are combined, and then contrasted with the Face-to-Face condition. For example, as will be seen below, a Communication Modality x Linear interaction typically reveals that differences between the computer mediated and Face-to-Face groups increase over time[1]. Similarly, the Communication Modality X Quadratic interaction typically shows that these differences are greatest during the middle of the project, when groups are most actively working, and a Communication Modality X Cubic interaction suggests that these differences are greatest when groups are planning and revising. In general the differential effects reflect interactions between communication modality and time-based task variation.

RESULTS

Effects of Experimental Manipulations and Within-Project Variations

Table 1 shows the distribution of communication channels used across the Communication Modality experimental conditions. These results clearly indicate that the Communication Modality manipulation affected participants' use of communication channels appropriately. Table 1 also reveals a small proportion of face-to-face meetings in the Computer Only and Computer+Phone conditions, an indication that some students violated the terms of their experimental conditions. Interestingly, virtually no one in the Face-to-Face condition cheated by using computer communication. However, the number of violations is small; even if we assume some underreporting, the Communication Modality manipulation appears to have been successful. Moreover, whatever violations occurred should have worked to reduce the difference between communication conditions. Thus, the analyses that follow constitute a conservative test of the effects of Communication Modality on intellectual teamwork.

Both natural phases of work activity and the Task Divisibility experimental manipulation were intended to vary divisibility of work tasks. The experimental manipulation of divisibility, however, was apparently unsuccessful; it did not affect any of the behavioral or subjective measures we collected. Thus, we collapse across this variable in the analyses that follow.

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[1] Below we term this the Face-to-Face vs. Computer X Linear interaction.

Communication modality used	Communication Modality Condition		
	Face-to-Face	Computer+Phone	Computer Only
Scheduled face-to-face meetings	64.7%	2.3%	1.1%
Unscheduled face-to-face meetings	23.1%	2.3%	1.1%
Phone calls	12.1%	40.6%	0%
Computer messages	.1%	54.3%	97.9%
Total	1650	875	763

Note: Entries are column percentages (i.e., 100 x number of focal communications using a medium/column total). Column totals are the number of focal communications per communication condition (i.e., approximately the number of projects x number of respondents x number of days per project). Approximately twice as many respondents were assigned to the Face-to-Face condition as to either of the two Computer-Mediated conditions.

Table 1. Use of Communication Channels within Communication Conditions

The other source of differences in projects is within-project variation arising from the differences in component tasks. Based on prior research [Krau88], we assumed that project planning and revising each other's work were substantially more integrative than creating original text. This assumption is corroborated by several internal analyses. The Pearson correlations between involvement in planning, writing, and revision and two measures of communication for each group were computed and combined across groups using the Fisher Z transform. On days in which groups did more planning, a larger proportion of the group was involved in communication (mean r = .17) and they communicated for longer time periods (mean r = .42). Similarly, on days in which groups did more revising a larger proportion of the group was involved in communication (mean r = .29) and they communicated for longer time periods (mean r = .52). The association of writing with the proportion of the group communicating and with the duration of communication were substantially and reliably lower (mean r = .09 and .27 respectively).

Phases of the Project

A typical group spent several days exhorting its members to start working on the project, and then began to develop project outlines. Groups used one of two styles to converge on a common plan. In the first, each group member wrote a separate outline and these outlines were merged after discussion among the group members; in the second, one person drafted an outline which other group members revised and elaborated. After ratifying their common vision in the outline, they typically assigned responsibilities for individual writing assignments. When these assignments were completed, students in the Computer-Mediated groups would post their work in the conference, typically along with apologies for their "draftiness" and invite feedback from other members of the group. In the Face-to-Face conditions, the students reassembled at an agreed-upon

time, passed their drafts around and began to talk over points of content, style, tone, organization, and formatting. For one project, assembly sometimes consisted only of stapling together the separate pieces; more often, one group member was given the responsibility of assembling project elements and printing out a final copy.

This phase structure is corroborated by the quantitative data collected as part of the daily time-use measures. As shown in Figure 1, the average proportion of group members who reported that they spent time on activities associated with planning, writing, and revising varied systematically over the two-week life-span of the projects.

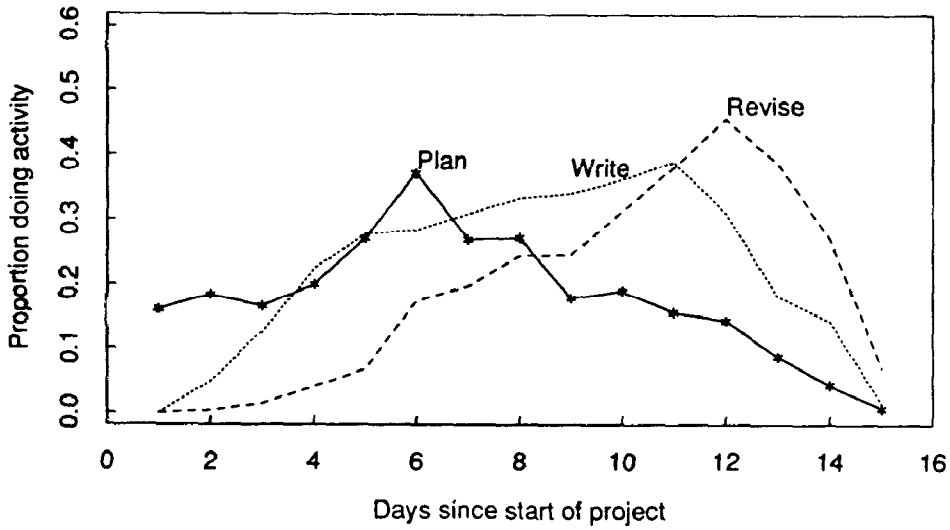

Figure 1. Phases of Activity

Collapsing across communication conditions, we see that most groups did very little on the first few days of the project. When they started working, planning peaked sharply on day 6 and fell off to its starting level by day 8, original writing gradually rose from day 5 to a peak on day 11 and then sharply declined, and revising sharply peaked on day 12, three days before the project was due.

However, this pattern of activities did not unfold at the same rate across communication conditions. For instance, although the Communication Modality manipulation did not lead to different amounts of planning overall, the proportion of people reporting that they were involved in planning their work peaked earlier and dropped more sharply in the Face-to-Face condition than in the two Computer-Mediated conditions (See Figure 2.). ($F(1,74) = 12.0$, $p < .001$ for the linear component of the interaction and $F(1,74) = 7.2$, $p < .01$ for the quadratic component). The contrasts between the Computer Only and Computer+Phone conditions were not significant. This pattern suggests that planning was accomplished earlier and more thoroughly in the Face-to-Face condition than in the Computer-Mediated groups.

Similar patterns of results were obtained for both writing and revising. The proportion of group members reporting these activities peaked earlier in groups that were allowed to meet face-to-face than in those whose communication was restricted.

Amount of work and communication. As we shall see below, groups using computers for communication had many problems in coordinating their work and making others understand what they were referring to. The problems were especially severe when students were commenting on each other's work. These difficulties apparently made it necessary for the Computer-Mediated groups to work longer to finish their projects and

to communicate more. This greater effort was required especially at the end of the projects, during the revision phase.

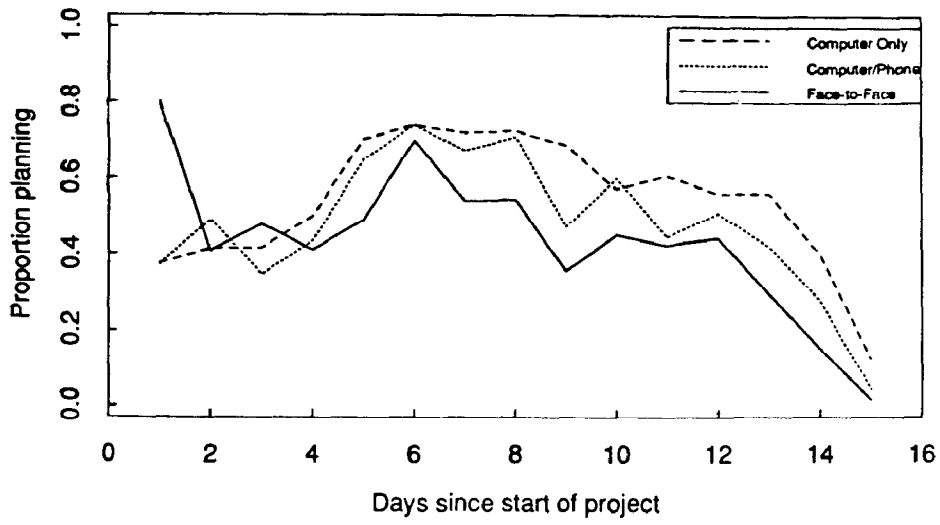

Figure 2. Proportion of Group Members Involved in Planning

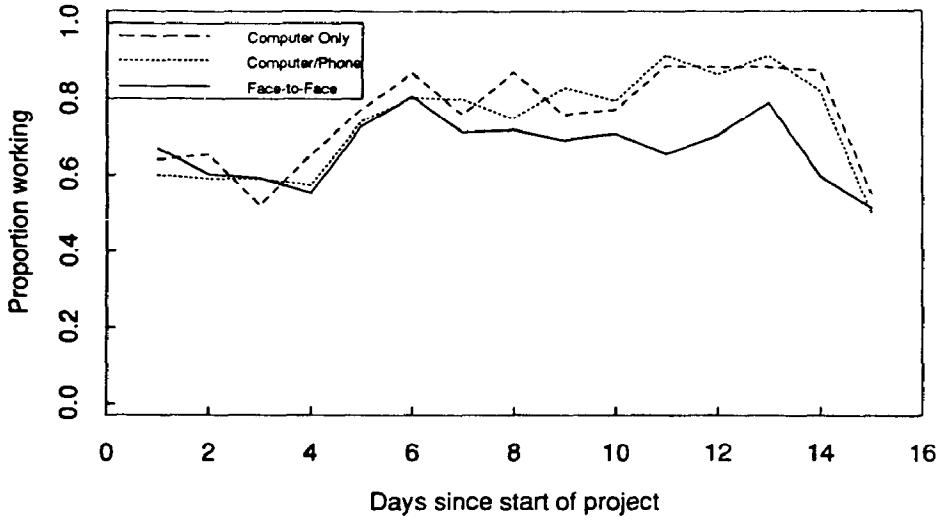

Figure 3. Proportion of Group Members Who Worked on the Project

Figure 3 indicates shows the proportion of students claiming to have done any substantive work on the project on a given day. Students in the two Computer-Mediated conditions worked on more days to get their projects completed ($F(1,74) = 8.38$, $p < 01$). Moreover, this gap increased over time and was especially apparent during the second week of the project. (For the Face-to-Face vs. Computer X Linear interaction, $F(1,74) = 7.44$, $p < .01$).

The increased work by students students in the computer mediated conditions is partially explained by the difficulty of asynchronous, noninteractive conversation. When students could talk directly rather than write and post messages, their communication was more efficient. Students who could only hold discussions by computer spent more time communicating than did students who could hold discussions

either face-to-face or by phone (For the contrast comparing the two voice conditions to the Computer Only condition $F(1,74) = 10.0$, $p < .01$). Time spent in communication is the product of the number of communication occasions reported for a day and the length of the focal conversation, averaged over group members. In the second week of the project, students in the Computer Only condition were spending more than twice as much time per day communicating (107 minutes), as did students in the two voice conditions (Face-to-Face = 55 minutes and Computer+Phone = 61 minutes).

The relationship between Communication Modality and time spent communicating depended on the phase of the project. As shown in Figure 4, the difference in communication between those in the Face-to-Face condition and those in the Computer-Mediated groups increased over time and was especially intense during the revision phase of the project (for the Face-to-Face vs. Computer X Linear interaction, $F(1,74) = 5.3$, $p < .01$). The two Computer-Mediated conditions did not differ from each other in their changes over time.

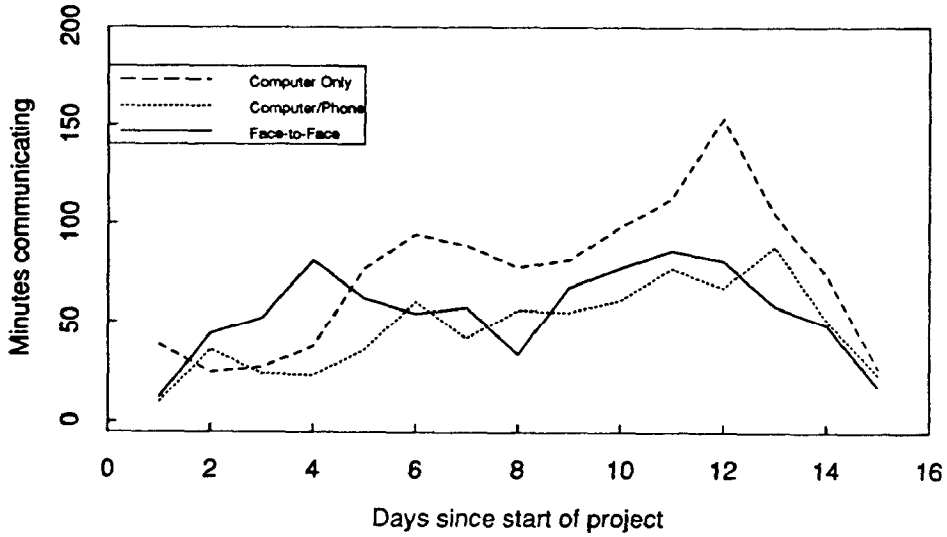

Figure 4. Amount of Time Spent Communicating

Evaluations of Work Process

Although it is possible to interpret these differences in effort and communication time as a reflection of differences in commitment to the project or the group or to greater enjoyment of the process, the data presented in this section suggest that students in the Computer-Mediated groups worked longer because their communication task was more difficult. Students' reports of their experiences suggest that the Computer-Mediated groups had a harder time coordinating their work (For the Face-to-Face vs. Computer contrast ($F(1,74) = 81.44$, $P < .001$). Within the Computer conditions, students who could talk to each other had a marginally easier time coordinating than did those who were restricted to computer communication ($F(1,74) = 3.8$, $p < .06$).

The greater difficulty students had in the two Computer groups varied with project phase. In the Face-to-Face groups, coordination difficulties dropped off early and declined throughout the project. In contrast, students in the Computer-Mediated groups reported that difficulties in coordinating their work increased as they became more deeply involved in the project, and did not diminish until they were nearly finished (For the Face-to-Face vs. Computer X Linear interaction $F(1,74) = 7.8$ $p < .01$; for the quadratic component of the interaction $F(1,74) = 14.8$, $p < .01$). Figure 5 shows this pattern of results.

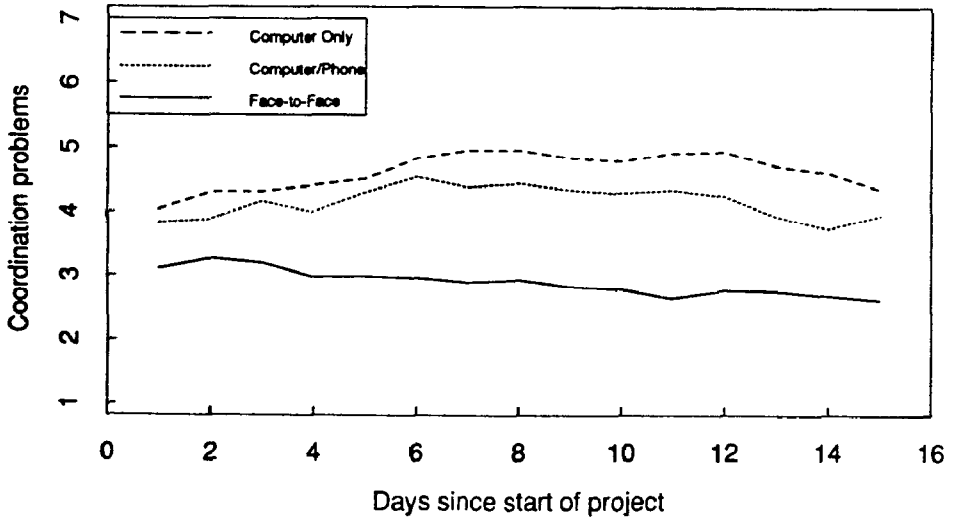

Figure 5. Difficulty in Coordination

The computer files show that coordination problems arise for several different reasons, because of ambiguity in the referent of communication and simply because not being co-present introduces delay in the exchange of information. In many cases, students asked questions and had to wait hours, or even days, for an answer. In the Face-to-Face condition, the same kind of ask-and-answer sequences were completed much more rapidly. The files also reveal examples of problems arising because restricted modalities tend to encourage pairwise communications. When an individual comments and another individual responds, the third group member may be left out of the loop. Finally, being unable to speak directly to one's work partner and know immediately that the partner knows he or she has been spoken to and know that the partner has understood---the mutual knowledge problem---introduces confusion and anxiety about what's going on. The files contain many messages in which the author seemed to be trying desperately to evoke a response of any kind from a silent group member.

Association with work activities. Underlying the preceding time-based analyses is the assumption that the phases of a project proceed relatively uniformly and linearly for most groups (i.e., most groups first plan, then write, and then revise, and that the steps in this sequence occur at the same time across most groups). However, this assumption is only an approximation of reality. A more direct test of the assumption that computer-mediated communication is especially difficult when planning and revising a document would involve assessing differences in the strength of the association between the activities a group is performing and the group's difficulty in coordinating their work across days. To carry out this analysis, we computed the regression of planning, writing, and revising on difficulties in coordination for each group, with an N of 15 days.[2] The standardized beta-weights were entered as dependent variables in a multivariate analysis of variance in which the Face-to-Face vs. Computer contrast was the independent variable.[3]

This analysis shows that across all conditions groups report more difficulty in coordination on days when they are planning (Mean $\beta_{Planning} = .15$), but not when they are writing or revising (Mean $\beta_{Writing} = .01$; Mean $\beta_{Revising} = -.01$). Second, the

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[2] Coordination = Constant + β_1*Planning + β_2*Writng + β3*Revising

[3] $\beta_{Planning} + \beta_{Writng} + \beta_{Revising}$ = Constant + β_1Face-to-face

association of these tasks with coordination problems was greater in the Computer conditions than in the Face-to-Face condition ($F(1,75) = 19.6$, $p < .001$). That is, on average, the more the students in Computer-Mediated groups planned, wrote, or revised, the more coordination problems they had, but no such association between activity and coordination difficulty was observed in the Face-to-Face groups. On an individual task basis, the interaction was significant for revision ($F(1,74) = 5.99$, $p < .02$), and marginally significant for writing ($F(1,74) = 2.81$, $p < .10$) and for planning ($F(1,74) = 2.28$, $p < .11$). Third, and contrary to our expectations, the advantage that the Face-to-Face group had over the Computer-Mediated groups as they performed more tasks did not differ across tasks (Fs comparing writing to planning and writing to revision < 1).

These coordination problems were readily apparent to the research participants. In addition to the specific problems noted earlier, the conference files contain many expressions of general frustration. The annoyance apparent in these comments is reflected in the quantitative data as well. For example, we created a measure of the quality of meetings that combined students' reports on the productivity and enjoyment of focal communication occasions; by this measure, face-to-face communications were both more productive and enjoyable than were computer-mediated communication ($F(1,74) = 20.5$, $p < .001$). Within the Computer groups, having a phone connection made communication occasions more productive and enjoyable ($F(1,74) = 8.9$, $p < .01$). Also, on the retrospective questionnaire, students in the Computer+Phone condition saw completing the project as significantly more difficult than those in the Computer Only condition, who, in turn, saw it as significantly more difficult than those in the Face-to-Face condition..

In rating the utility of the three media for various tasks and activities, students saw computer conferencing as particularly disadvantageous for getting started on a new project, and as about the same as face-to-face communication for exchanging and refining interim versions of work on the project. A similar set of ratings comparing the utility of the telephone to face-to-face communication revealed that the telephone was regarded as somewhat less useful than face-to-face communication for starting projects, and as substantially less useful for working on interim versions of a project.

Project Performance

Despite the difficulties that students in the Computer-Mediated conditions experienced in carrying out their work, their scores were not affected by project divisibility, nor by communication condition. But, even though groups assigned to the Computer-Mediated conditions were as able to produce good papers as those assigned to the Face-to-Face condition, the difficulties they encountered in carrying out their work seemed to affect their satisfaction with it. Students' perceptions of the quality of their work increased over time across all communication conditions, but, on the average, their judgments of the quality of their work were less favorable in the Computer-Mediated communication conditions than in the Face-to-Face condition ($F(1,74) = 6.7$, $p < .01$).

Social Effects

The daily questionnaire asked students whether they had talked to others in their group about non-project related school work or about non-school related topics. Students in the Face-to-Face groups had more of these social communications than did students in the Computer groups ($F(1,75) = 24.8$, $p < .001$). Unlike many of the outcomes directly related to producing a project report, this difference in social communication was not affected by phases in the project and remained constant over the course of the two-week project. Surprisingly, students in the Computer+Phone condition didn't have significantly more social conversations than those in the Computer Only condition ($F(1,74) = 2.2$, $p = .14$).

Students' affective reactions to their groups paralleled their social experiences. A scale measuring attachment to the group revealed that students in Computer-Mediated groups were less positive toward the other members of their group than those in Face-to-Face groups ($F(1,74) = 10.6$, $p < .01$). Again, this difference remained constant across the duration of the project. The two Computer groups did not differ from each other.

A scale measuring student perceptions that they and other members of their group were contributing fairly to the joint project also showed that students in the Face-to-Face group rated the work process as more fair than did those in the two Computer groups ($F(1,74) = 9.7$, $p < .01$). Moreover, this difference in perceptions of fairness was largest in the middle portions of the project, presumably because compared to other phases of the project, individual work efforts during the writing phase were less visible and that this problem was heightened by computer-mediated communication in which other project members tend to disappear (for the Face-to-Face vs. Computer X Quadratic interaction, $F(1,74) = 14.8$, $p < .001$).

Social relationships surrounding the project itself seemed to be strained by channelling all communication through the computer or computer-plus-telephone combination. Still, despite these frustrations, the computer conference supported social interaction on a more distributed, albeit less intense scale. Throughout the class in which this experiment was conducted, students used the computer conference extensively for social purposes. They exchanged hundreds of personal and social mail messages with other students outside their project teams, and, over the course of the semester, the 117 members of the class posted more than 2500 messages on computer bulletin boards devoted to topics such as sports, outdoor recreation, politics, school gossip, and the like. The utility of the computer conference as a community forum was confirmed by the post-project questionnaire, on which students judged that the computer system was superior to telephone and face-to-face communication for keeping up with school gossip.

DISCUSSION

This research grew out of both theoretical and practical concerns: an interest in the communication processes required to carry out a significant piece of collaborative intellectual work and questions about how computer-mediated communication might affect the execution of such a project. Computer-mediated communication intervenes in work procedures typically carried out via more familiar media in two ways: it expands group members' access to each other by enabling them to communicate without being co-present, but it also restricts the range of their interaction by imposing delay and narrowing bandwidth. We expected that computer-mediated communication would interfere with intellectual teamwork because it inhibits interactivity, creates uncertainties about the motivations and activities of others, discourages elaborated comments, annotation, and discussion, and prevents the joint and simultaneous viewing and discussion of documents. We expected this failure to support rich communication to be especially damaging to collaboration during the most integrated phases of a project.

For the most part, the results confirm these expectations. In general, the Computer-Mediated groups had to work harder and communicate for longer periods of time and had greater difficulties in coordinating their work than groups who met face-to-face. In addition, students in these groups were less satisfied with their work products, were less committed to their work partners, and felt less intellectual benefit from working with others than did students who met face-to-face. Furthermore, they reported that launching a new project on the basis of computer-mediated communication was more difficult than in face-to-face meetings, and they reported increases in coordination difficulties and in the amount of time spent communicating as the project neared its end. Finally, it is important to note that the limitations of the computer conferencing system were only partially mitigated by the addition of the telephone. In fact, the

pairwise communication necessitated by the telephone in some circumstances seemed to add to, rather than reduce, the communication and coordination problems introduced by being restricted to an asynchronous communication modality.

On the other hand, despite the difficulties just described, students in the Computer-Mediated groups were able to complete their work and to produce reports that matched the quality of those produced more traditionally. The computer-mediated communication allowed students to communicate around the clock and to keep in touch with a wide network of information and gossip, and they acknowledged that computer-mediated communication is a satisfactory means of handing off independently completed interim products. Clearly this technology could be valuable in conditions where the work couldn't otherwise be done (e.g., in distributed workgroups), even though the costs of working exclusively through computer-mediated communication are high.

Of course, one might argue that the students in the study had years of experience in formal and informal meetings, but most of them were newcomers to electronic conferences. But the structure of the experiment makes it unlikely that lack of expertise can entirely account for our findings. The two class projects involved in our experiment were several weeks apart. During this interval, many students used the computer conference regularly for pairwise communication by electronic mail and to post notices meant to entertain the professor and other members of the class. If the results were an artifact of expertise, this experience should surely have led to some difference in the pattern of results obtained on the two projects. Yet, although the results showed changes in the effects of technology over time *within* a project, they showed no effects of time *between* projects. Moreover, the within-project interactions typically showed that the effects of computer-mediated communication worsened over time.

Although the negative main effects of computer-mediated communication were robust, the assertion that computer-mediated communication was especially poor at supporting more integrated tasks was supported less consistently. A number of production-related measures showed Communication Modality X Time interactions consistent with the phase hypothesis, yet a more direct test failed to show that planning and revision were especially hard-hit by computer communication. In addition, the Task Divisibility manipulation had no effect.

Despite these contradictions, one should not conclude that task divisibility and interdependence are irrelevant to the procedural and evaluative outcomes we have described. Rather, it is more likely that the manipulations and measures used in the present study didn't cleanly capture the concepts. Although the framework used here breaks collaborative writing into phases, the phases are not homogeneous. The activities of planning, writing, and revision are likely to co-mingle and to be recursive. Groups might plan, write, and revise an outline, and within the outline, plan, write, and revise the introductory argument. Operationalizations that treat the full project as the unit of analysis, as the Project Type manipulation did, or measures that only permit respondents to characterize their work at a general level may be too gross or insensitive to tease apart activities. This line of argument suggests the need for more controlled research that better assesses the component tasks performed in intellectual teamwork and the usefulness of various technologies for them. That is, rather than arguing for contingency theory at the level of the project, work group or organizational level [Daft86; Rice89; Tush78;Tush79]), one needs to develop a contingency theory at a more molecular level of analysis. Intellectual progress is likely to depend on matching detailed features of tasks with detailed attributes of the communication modalities [cf Zmud90].

Practically, the results of this study suggest some of the limits as well as the benefits of computer-mediated communication systems. As recent news reports show [Kola90], these systems permit speedy collaboration across barriers of time and distance.

However, the results of this study, as well as prior research (Finh90; Kraut, Galegher, & Egido, Under Review), indicate that complex collaborative work of the sort we have described here involves a continuing need for face-to-face meetings. Electronic groups have a more difficult time initiating and planning their work and form weaker bonds for member support than do Face-to-Face groups. This pattern suggests that computer-mediated communication will be more valuable for coordinating already existing collaborative projects than for starting new ones.

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